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Asymmetric Fertility Elasticities*

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Abstract

This paper develops a theory of fertility choice with loss aversion over consumption. Because children compete with consumption for household resources, loss-averse households cut fertility aggressively to protect living standards when adverse shocks push consumption below reference levels, but respond modestly to positive shocks. Cross-country panel data and quasi-experimental evidence support the model's predictions. A calibrated version attributes a substantial share of China's recent fertility decline to slowing income growth activating loss aversion. The findings suggest that pro-natalist policies are more effective during downturns, temporary subsidies may backfire upon withdrawal, and pro-fertility regimes should target higher fertility under income uncertainty.

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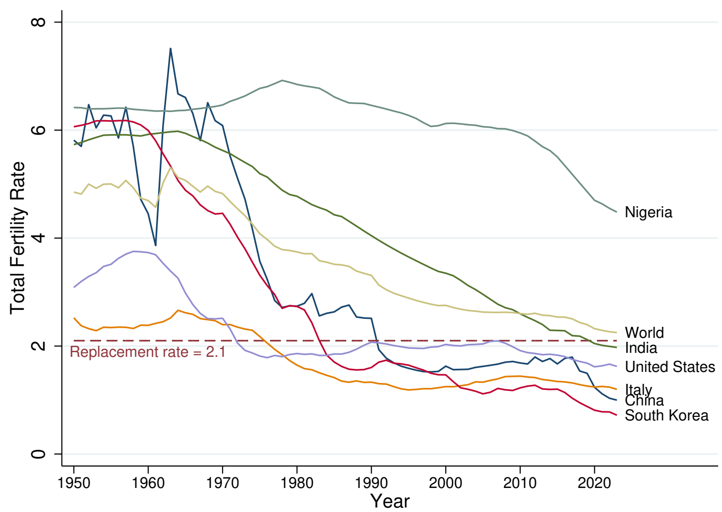
1 Introduction

Fertility rates have fallen below replacement in much of the developed world and are declining rapidly in many developing countries. The sustained downward trend illustrated in Figure 1 raises the specter of an "empty planet" future (Bricker and Ibbitson, 2019), with far-reaching consequences for pension sustainability (Bongaarts, 2004), economic dynamism (Hopenhayn et al., 2022), and long-run growth (Jones, 2022). Understanding the forces that drive fertility decisions—and designing policies that can effectively influence them—has thus become one of the central challenges facing economists and policymakers in the twenty-first century.

Figure 1. Total Fertility Rate Across Countries



Notes: This figure plots the time series of the total fertility rate in several economies using data from the United Nations Population Division.

Current research and policymaking on fertility confront two puzzles that standard economic frameworks struggle to resolve. The first concerns *policy effectiveness*. Recent pronatalist initiatives—including generous parental leave, subsidized childcare, and direct cash transfers—have yielded disappointing results (Sobotka et al., 2019; Gauthier and Gietel-Basten, 2024). This stands in sharp contrast to the perceived success of anti-fertility campaigns over the past half century, which have been credited with substantial reductions in birth rates across the developing world (Zhang, 2017; De Silva and Tenreyro, 2017). Standard economic models, which predict symmetric fertility responses to policies that raise or lower childbearing costs by equivalent amounts, offer no explanation for this pattern.

The second puzzle concerns the *disconnect between fertility and economic fundamentals*. Classical theories predict that fertility should respond systematically to income, the cost of education, housing prices, and labor market conditions. Yet recent fertility changes appear largely uncorrelated with these contemporaneous economic variables (Kearney et al., 2022). The disconnection motivates a search for "hidden" factors—whether cultural, psychological, or institutional—that drive fertility movements beyond what standard models can capture.

This paper develops a unified theoretical framework that helps resolve both puzzles. The central insight is that *loss aversion*—the tendency for losses relative to a reference point to loom larger than equivalent gains—generates asymmetric fertility responses that can account for the differential effectiveness of pro- and anti-fertility policies, the muted response to positive economic shocks, and the amplified response to negative ones. Loss aversion is among the most robust findings in behavioral economics, documented across domains ranging from consumer choice to labor supply to financial decisions (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991; Camerer et al., 2004). The theoretical foundations of reference-dependent preferences have been developed rigorously by Kőszegi and Rabin (2006a, 2007), who provide a portable framework that can be embedded in standard economic models. Yet despite this theoretical machinery, the implications of reference dependence for fertility—a decision with profound consequences for household welfare and aggregate demographics—remain largely unexplored.

The key mechanism is straightforward: children compete with consumption for household resources. When adverse shocks push consumption below households' reference levels, loss aversion amplifies the marginal disutility of consumption shortfalls, inducing aggressive cuts to fertility in order to protect living standards. Positive shocks, by contrast, leave households in the "gain domain" where marginal utility is less sensitive, generating muted fertility responses. This asymmetry arises from the kink in the value function at the reference point—a defining feature of reference-dependent preferences that distinguishes them from expected utility and that has been shown to organize behavior in settings as diverse as insurance demand (Barseghyan et al., 2013), endowment effects (Ericson and Fuster, 2011; Sprenger, 2015), and effort provision (Abeler et al., 2011).

The analysis proceeds in three steps. First, we construct a model of fertility choice in which households exhibit loss aversion over consumption relative to an endogenous reference point. Following Kőszegi and Rabin (2006a), we model the reference point as the household's rational expectation of consumption, which is determined endogenously as part of a personal equilibrium. The household derives utility from both consumption and children, but faces a budget constraint in which fertility expenditures crowd out consumption. This formulation allows us to derive sharp predictions about how fertility responds to anticipated versus unanticipated changes in income and prices—predictions that differ qualitatively from those of standard models and that we take to the data.

In this environment, we establish two main theoretical results. First, fertility responds asymmetrically to changes in the cost of children: increases in costs (which push consumption below reference levels) generate larger fertility reductions than equivalent cost decreases generate fertility increases. Second, there is an analogous asymmetry for income shocks: negative shocks reduce fertility by more than positive shocks raise it. These asymmetries emerge directly from the kink in marginal utility at the reference point and do not require auxiliary assumptions about liquidity constraints, adjustment costs, or heterogeneity.

Extending the model to a dynamic setting, we uncover a *policy rollback effect* with important implications for the design of pro-natalist interventions. When a government introduces a temporary fertility subsidy, households respond by increasing consumption and—if the policy was anticipated—raising their reference points accordingly. When the subsidy is subsequently withdrawn, the elevated reference point persists in the short run, and households find themselves in the loss domain even though economic fundamentals have returned to their pre-policy levels. The result is that fertility and household welfare both fall *below* their pre-policy baselines—a perverse consequence that standard models, which predict immediate reversion to the original equilibrium, cannot generate. The rollback effect illustrates a more general point emphasized by Kőszegi and Rabin (2006a): when reference points are expectations-based, policies that change expectations can have effects that persist beyond the policies themselves.

Second, we marshal four sets of empirical evidence supporting the model's predictions. Using cross-country panel data from the United Nations World Population Policies Database merged with demographic indicators from the World Bank, we document that exposure to anti-fertility policies is associated with statistically significant declines in the total fertility rate, whereas exposure to pro-fertility policies has no detectable effect. Individual-level fertility histories from the World Values Survey confirm this pattern for completed fertility, with the asymmetry persisting after controlling for income, education, and other demographic characteristics.

Quasi-experimental evidence provides sharper identification. González and Trommlerová (2023) study the introduction and unexpected cancellation of Spain's universal baby bonus—a lump-sum payment of €2,500 for each birth, equivalent to over 130 percent of average monthly earnings. Using administrative data on the universe of births, they find that the policy's introduction raised birth rates by approximately 3 percent, but its cancellation reduced them by 5.5 to 6 percent. The negative response to withdrawal was nearly *twice* the magnitude of the positive response to introduction—precisely the rollback pattern our framework predicts. Importantly, the cancellation was largely unanticipated, allowing us to interpret the response as reflecting the kink in preferences rather than anticipation effects.

We complement this evidence with an analysis of Australia's baby bonus, exploiting the timing of policy changes to show that unexpected benefit reductions significantly lowered parental happiness, whereas equivalent increases had much smaller and insignificant effect on well-being.

We also synthesize existing studies documenting asymmetric fertility responses to income and wealth shocks. Chatterjee and Vogl (2018), using Demographic and Health Survey data covering 2.3 million women across 81 developing countries, find that economic recessions are associated with significant fertility declines while periods of rapid growth generate no corresponding increase. Iwata and Naoi (2017), exploiting housing price fluctuations in Japan, document that wealth losses reduce fertility substantially while equivalent gains have negligible effects. These patterns are consistent with reference-dependent preferences but difficult to reconcile with standard models.

We consider three alternative explanations—liquidity constraints, inherent asymmetries in the policy toolkit, and social propagation mechanisms—and show that none can simultaneously account for all four empirical patterns. Liquidity constraints cannot explain the rollback effect, since cash transfers should relax borrowing limits. Policy asymmetries cannot explain why the *same* instrument (Spain's baby bonus) generates asymmetric responses upon introduction and withdrawal. Propagation mechanisms, while potentially amplifying fertility dynamics, do not inherently generate asymmetries without an underlying asymmetric micro-foundation—which reference dependence provides. The distinguishing prediction of our framework—that responses should be asymmetric around a reference point determined by expectations—allows us to discriminate among these alternatives using the quasi-experimental variation in the data.

Third, we calibrate a dynamic version of the model to Chinese data spanning 1984–2023 and use it to assess how much of China's recent fertility decline can be attributed to loss aversion. China provides a compelling laboratory for this exercise. Despite the relaxation of the one-child policy in 2015 and its complete abolition in 2021, fertility has continued to fall, reaching 1.0 children per woman in 2023—among the lowest rates ever recorded for a major economy. Standard models, which would predict a fertility rebound following the removal of binding constraints, cannot account for this pattern. Our framework offers a natural explanation: China experienced extraordinarily rapid income growth for three decades, during which households became accustomed to steadily rising living standards. The subsequent growth slowdown beginning around 2010 generated a sequence of negative income surprises that pushed households into the loss domain, activating the asymmetric response mechanism and accelerating fertility decline.

The calibrated model matches the fertility transition during the rapid-growth era (1984–

2013) and predicts an accelerated decline when growth slows and households enter the loss domain. Counterfactual exercises reveal that loss aversion accounts for a substantial fraction of the predicted fertility decline: removing reference dependence raises projected fertility by approximately 0.25 children per woman over a 25-year horizon. Stochastic simulations further demonstrate that income uncertainty, combined with asymmetric responses, depresses average fertility and raises the probability of ultra-low fertility outcomes even when positive and negative shocks are equally likely.

These findings carry several implications for the design of population policy. First, the *timing* of pro-natalist interventions matters: policies that reduce the cost of children will have larger effects when households perceive themselves as falling short of consumption benchmarks—precisely the conditions under which loss aversion is activated. The same policy implemented during a boom, when households are experiencing positive surprises, will generate smaller responses. Second, *temporary subsidies can backfire*: by raising reference consumption during implementation, their removal is perceived as a loss, generating fertility and welfare declines that may exceed the initial gains. Policymakers should therefore favor permanent or long-duration interventions over temporary programs, and should carefully manage expectations when programs must eventually be phased out. Third, the standard policy objective of *stabilizing fertility at replacement level may be insufficient* when reference dependence exerts persistent downward pressure on births. In environments with substantial income uncertainty, loss-averse households will on average choose lower fertility than certainty-equivalent models predict. Governments may therefore need to target fertility above replacement, or implement complementary policies that reduce income risk, to achieve demographic stability.

More broadly, our analysis suggests that the behavioral revolution in economics—which has transformed our understanding of savings, labor supply, and portfolio choice—has important implications for demography that remain largely unexplored. Reference-dependent preferences provide a tractable and empirically disciplined framework for understanding departures from the standard model (Ericson and Fuster, 2011; O'Donoghue and Sprenger, 2018). If households are loss-averse over consumption, and if fertility decisions are intertwined with consumption choices through the household budget constraint, then the standard neoclassical framework may systematically mispredict fertility responses to economic shocks and policy interventions. The asymmetries documented in this paper are not anomalies to be explained away, but rather signatures of a deeper regularity in human decision-making that deserves a central place in fertility models.

Related Literature

This paper contributes to several strands of the literature on fertility and population economics.

A large empirical literature evaluates fertility policy effectiveness. Studies of anti-fertility interventions include McElroy and Yang (2000), De Silva and Tenreyro (2017), Liu and Raftery (2020), and Yin (2023), while Schultz (2007), Milligan (2005), Laroque and Salanié (2014), and Raute (2019) examine pro-fertility policies. This work generally assesses policies in isolation rather than comparing pro- versus anti-fertility interventions. We contribute by documenting asymmetric policy effectiveness, providing a theoretical explanation rooted in reference-dependent preferences, and presenting quasi-experimental evidence on rollback effects.

Our work connects to the literature on long-run fertility determinants, building on Malthus (1872), Becker (1960), Easterlin (1968), and Galor and Weil (2000). Subsequent research has examined child mortality (Doepke, 2005), maternal morbidity (Albanesi and Olivetti, 2016), child labor (Hazan and Berdugo, 2002; Doepke and Zilibotti, 2005), household technology (Greenwood et al., 2005), family institutions (Gobbi et al., 2026), modernity (Spolaore and Wacziarg, 2022), and social norms (Doepke and Kindermann, 2019; Zhou and Xi, 2025; Nakakuni et al., 2026). Chatterjee and Vogl (2018) document asymmetric fertility responses to business cycles. We complement their findings by providing a theoretical framework and extending the analysis to policy interventions, rollback effects, and subjective well-being.

The most closely related paper is Lutz et al. (2006), who argue that fertility reductions are self-perpetuating, potentially creating a low-fertility trap. Our paper differs in three respects. First, we identify asymmetric elasticities as a distinct channel: the mechanisms in Lutz et al. (2006) operate symmetrically, whereas loss aversion generates different responses to positive and negative shocks. Second, our empirical analysis shows that asymmetric responses exist across countries with both high and low initial fertility, suggesting the mechanism operates throughout the distribution. Third, we emphasize that governments may need to target fertility above replacement to offset downward pressure from reference dependence.

Our theoretical contribution introduces reference-dependent preferences into fertility models, building on foundational work by Kahneman and Tversky (1979) and Tversky and Kahneman (1991). The theoretical framework we employ draws on Kőszegi and Rabin (2006a, 2007), who develop a model of reference-dependent utility in which the reference point is determined by rational expectations. This approach has been applied to explain behavior in labor markets (Crawford and Meng, 2011; Thakral and Tô, 2021), consumer choice (Ericson and Fuster, 2011), and insurance markets (Barseghyan et al., 2013). Recent work has studied identification of reference-dependent preferences from choice data (Sprenger, 2015; Goette et al., 2019) and has explored how such preferences interact with beliefs and information (Bushong et al., 2021). The fertility literature has largely relied on neoclassical frameworks (Barro and Becker, 1989; De La Croix and Doepke, 2003; Carlos Córdoba and Ripoll, 2019).[1] Two exceptions incorporate reference dependence: De Silva and Tenreyro (2020) model disutility from deviating from fertility norms, and Kim et al. (2024) study status externalities in education. These generate level shifts but not asymmetric elasticities. We focus on loss aversion over consumption, which creates a kink in marginal utility and produces asymmetric responses—a qualitative prediction that distinguishes our framework from alternatives and that we test directly.

Our calibration contributes to the literature on fertility in developing economies. By modeling reference points as functions of past growth and expectations, we capture the Easterlin hypothesis (Easterlin, 1968) that aspirations adjust to experience, while providing microfoundations grounded in decision theory. The framework explains why fertility may decline sharply when growth slows: households find themselves in the loss domain, where responses are amplified.

The remainder of the paper is organized as follows. Section 2 develops the theoretical framework and derives the main predictions. Section 3 presents empirical evidence on asymmetric fertility responses and rollback effects. Section 4 calibrates the model and Section 5 reports quantitative results, including counterfactual exercises and stochastic projections. Section 6 discusses robustness and alternative explanations. Section 7 concludes.

2 Theory

This section develops a theory of fertility choice under loss aversion. We begin with a static model that establishes the core mechanism generating asymmetric fertility responses, then extend the analysis to a dynamic setting that captures the persistent effects of policy interventions and the role of expectation formation.

2.1 Static Model

We construct a static model of fertility choice in which a representative household allocates resources between consumption (c) and fertility (n). The household derives utility from two sources. The first is intrinsic utility $u(c, n)$ from consumption and children. The second is gain–loss utility $G(c - r)$ that captures how the household evaluates consumption relative to

[1] Jones et al. (2008), Greenwood et al. (2017), and Doepke et al. (2023) provide surveys.

a reference level r. Deviations of consumption below the reference point generate additional disutility, capturing loss aversion in the spirit of Kahneman et al. (1991).[2]

The model is intentionally parsimonious to isolate the role of reference dependence. As discussed in Section 6, the framework can be extended to incorporate additional choice margins—such as leisure or child quality—without altering the qualitative results. Accordingly, consumption c should be interpreted broadly to encompass not only expenditures on goods but also other resources that compete with fertility in the household's budget.

2.1.1 The Household's Problem

The household solves

$$\max_{c,n} \; U(c,n) = u(c,n) + G(c-r) \tag{1}$$

subject to

$$c + \chi \cdot n = I, \tag{2}$$

$$I \geq c \geq 0, \tag{3}$$

where χ represents the cost of a child in consumption units, and I denotes total household income. In the baseline model, we assume that χ is fixed and independent of I. In Section C.1, we demonstrate that all theoretical results continue to hold when the child cost depends on income, provided that it weakly increases with I.

For simplicity of notation, we let $\{c^* = c^*(I,\chi,r),\, n^* = n^*(I,\chi,r)\}$ denote the solution to this problem.

2.1.2 Assumptions on the Utility Function

We impose standard regularity conditions on the intrinsic utility function:

Assumption U1. *The function $u(c,n)$ satisfies: (i) u is continuously differentiable; (ii) $u_c > 0$ and $u_n > 0$; (iii) $u_{cc} < 0$ and $u_{nn} < 0$; (iv) u is strictly concave; and (v) $\lim_{c\to 0} u_c(c,n) = +\infty$ and $\lim_{n\to 0} u_n(c,n) = +\infty$.*

Assumption U1 ensures that both consumption and fertility are desirable, exhibit diminishing marginal utility, and that corner solutions are ruled out by Inada conditions.

[2] As emphasized by Kőszegi and Rabin (2006b), Crawford and Meng (2011), and Thakral and Tô (2021), reference dependence could also apply to other choice variables, such as fertility itself. Under such a formulation, the degree of loss aversion calibrated in Section 4 should be interpreted as reflecting *differential loss aversion* between consumption and fertility.

We then state another assumption central to the existence of asymmetric fertility responses. Let $\tilde{c}^*(\chi, I)$ denote the Marshallian demand for consumption when the household solves the problem with $G(\cdot) \equiv 0$—that is, in the absence of reference dependence.

Assumption U2. *The Marshallian demand satisfies* $\frac{\partial \tilde{c}^*}{\partial \chi} \neq 0$ *and* $\frac{\partial \tilde{c}^*}{\partial I} \neq 0$.

Assumption U2 ensures that optimal consumption responds to changes in the cost of children and to income. Were consumption independent of χ or I, reference dependence would not interact with fertility decisions in a meaningful way, and the asymmetric responses central to our analysis would not arise.

2.1.3 Assumptions on the Gain–Loss Function

We impose the following conditions on the gain–loss function:

Assumption G1. *The function* $G(y)$ *is continuously differentiable for all* y *and twice differentiable for all* $y \neq 0$, *and satisfies that* $G'(y) \geq 0$ *with* G' *is bounded over all bounded sets of* y.

Assumption G2. *The function* G *satisfies* $G''_-(0) < G''_+(0) \leq 0$ *and* $G''(y) \leq 0$ *for all* $y \neq 0$.

Assumption G1 guarantees the existence and uniqueness of an interior solution when gain–loss utility is present. Assumption G2 captures the defining feature of loss aversion: the marginal utility of consumption is more sensitive to losses than to gains around the reference point.[3] Formally, for any $y > 0$, when $G(0)$ is normalized to 0, Assumption G2 results in $G(y) < -G(-y)$ and $G'(y) < G'(-y)$, a definition of loss aversion given by Bernheim et al. (2018). The degree of loss aversion is governed by the curvature gap $\alpha = G''_+(0) - G''_-(0)$.

An example of a function satisfying Assumptions G1 and G2 is

$$G(y) = \begin{cases} 0 & \text{if } y \geq 0, \\ -\frac{\alpha}{2} \cdot y^2 & \text{if } y < 0, \end{cases} \qquad \alpha > 0. \tag{4}$$

Under this specification, consumption at or above the reference point generates no gain–loss utility, while consumption below the reference point generates disutility that is quadratic in the shortfall. The parameter α governs the intensity of loss aversion.

[3] Piecewise-linear specifications of G, featuring a kink at the reference level, represent another common functional form in the literature. We do not adopt this approach because a continuously differentiable G allows us to characterize optimal choices globally using first-order conditions. Since optimal fertility depends on marginal utilities, a kink in G' around the reference level, as implied by Assumption G2, suffices to generate the asymmetric responses central to our analysis.

2.1.4 Existence, Uniqueness, and Characterization

We now establish that the household's problem admits a unique interior solution.

Lemma 1. *Under Assumptions U1, U2, G1, and G2, the household's optimization problem admits a unique interior solution.*

Proof. See Appendix A.1. □

Lemma 1 ensures that the solution is well defined and interior, allowing us to characterize optimal choices using the first-order condition

$$u_c\left(c^*, \frac{I-c^*}{\chi}\right) + G'(c^*-r) - \frac{1}{\chi}u_n\left(c^*, \frac{I-c^*}{\chi}\right) = 0 \tag{5}$$

and the second-order condition

$$u_{cc}\left(c^*, \frac{I-c^*}{\chi}\right) + G''_d(c^*-r) - \frac{2}{\chi}u_{cn}\left(c^*, \frac{I-c^*}{\chi}\right) + \frac{1}{\chi^2}u_{nn}\left(c^*, \frac{I-c^*}{\chi}\right) < 0, \tag{6}$$

which must hold for both $d \in \{+, -\}$. In fact, we show:

$$u_{cc}\left(c^*, \frac{I-c^*}{\chi}\right) - \frac{2}{\chi}u_{cn}\left(c^*, \frac{I-c^*}{\chi}\right) + \frac{1}{\chi^2}u_{nn}\left(c^*, \frac{I-c^*}{\chi}\right) \tag{7}$$

$$= \begin{bmatrix} 1 & -\frac{1}{\chi} \end{bmatrix} \begin{bmatrix} u_{cc} & u_{cn} \\ u_{cn} & u_{nn} \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{\chi} \end{bmatrix}' < 0 \tag{8}$$

by the assumption that u is continuously differentiable and strictly concave.

To close the model, we specify reference formation following Kőszegi and Rabin (2006b). In this static representative-household environment, we impose the consistency condition $r = c^*$, so that the reference level coincides with optimal consumption. This condition reflects the idea that, in a deterministic steady state, households correctly anticipate their own consumption and form reference points accordingly. In the following lemma, we establish the existence of such a consistent reference level.

Lemma 2. *Under Assumptions U1, U2, G1, and G2, there is $r \in (0, I)$ such that $c^*(r) = r$.*

Proof. See Appendix A.1. □

2.1.5 Asymmetric Fertility Responses

We now present two propositions characterizing the asymmetric fertility responses that arise from loss aversion.

Proposition 1 (**Asymmetric Responses to Cost Shocks**). *Under Assumptions U1, U2, G1, and G2, the optimal fertility response to an increase in χ is larger in magnitude than the response to a decrease:*

$$\left.\frac{\partial n^*}{\partial \chi}\right|_+ < \left.\frac{\partial n^*}{\partial \chi}\right|_- \leq 0. \tag{9}$$

Proof. See Appendix A.2. □

Proposition 2 (**Asymmetric Responses to Income Shocks**). *Under Assumptions U1, U2, G1, and G2, the fertility response to a negative income shock exceeds the response to a positive shock:*

$$\left.\frac{\partial n^*}{\partial I}\right|_- > \left.\frac{\partial n^*}{\partial I}\right|_+ . \tag{10}$$

Moreover, fertility is a normal good if $\chi\,(u_{cc} + G'') < u_{cn}$.

Proof. See Appendix A.2. □

The intuition underlying both propositions is straightforward. Any shock that pushes consumption below the reference level activates loss aversion and generates additional marginal disutility. To mitigate this loss, households optimally resist reductions in consumption. Because consumption and fertility compete for resources through the budget constraint, maintaining consumption requires more aggressive cuts to fertility in the loss domain. Conversely, shocks that push consumption above the reference level leave households in the gain domain, where marginal utility is relatively insensitive and fertility responses are muted.

2.1.6 The Asymmetry Gap and Its Dependence on Loss Aversion

As shown in Section 2.1.5, incorporating loss aversion into traditional fertility choice model results in asymmetric fertility responses. We now formalize the relationship between the degree of loss aversion and the magnitude of asymmetric responses.

Definition 1 (**Degree of Loss Aversion**). *The* ***degree of loss aversion*** *is defined as the gap between the one-sided second derivatives of the gain–loss function at zero:*

$$\alpha \equiv G''_+(0) - G''_-(0). \tag{11}$$

Under Assumption G2, we have $G''_-(0) < G''_+(0) \leq 0$, which implies $\alpha > 0$. The limiting case $\alpha = 0$ corresponds to symmetric preferences with no loss aversion, while larger values of α indicate stronger loss aversion. In the example given by equation (4), we have $G''_+(0) = 0$ and $G''_-(0) = -\alpha$, so the parameter α in that specification corresponds exactly to the degree of loss aversion as defined here.

Definition 2 (**Asymmetry Gap**). *For a given degree of loss aversion α, the* ***asymmetry gap in fertility response to cost shocks*** *is defined as*

$$\Delta_\chi(\alpha) \equiv \left| \frac{\partial n^*}{\partial \chi}\bigg|_+ - \frac{\partial n^*}{\partial \chi}\bigg|_- \right| \tag{12}$$

Analogously, the ***asymmetry gap in fertility response to income shocks*** *is defined as*

$$\Delta_I(\alpha) \equiv \left| \frac{\partial n^*}{\partial I}\bigg|_+ - \frac{\partial n^*}{\partial I}\bigg|_- \right| \tag{13}$$

Proposition 3 (**Monotonicity of Asymmetry in Loss Aversion**). *Under Assumptions U1, U2, G1, and G2, holding $G'(0)$ and $G''_+(0) + G''_-(0)$ constant, at the same consistency point $c^* = r$, the asymmetry gaps satisfy:*

(i) $\Delta_\chi(\alpha) > 0$ *and* $\frac{\partial \Delta_\chi}{\partial \alpha} > 0$ *for all* $\alpha > 0$*;*

(ii) $\Delta_I(\alpha) > 0$ *and* $\frac{\partial \Delta_I}{\partial \alpha} > 0$ *for all* $\alpha > 0$*;*

(iii) $\Delta_\chi(0) = \Delta_I(0) = 0$ *when* $\alpha = 0$*.*

Proof. See Appendix A.2. □

Proposition 3 establishes a monotonic relationship between the structural parameter α and the reduced-form moment Δ_I and Δ_χ. To isolate the effect of the degree of loss aversion α, we impose the condition that both $G''_+(0) + G''_-(0)$ and the consistency point remain constant. Maintaining $G'(0)$ fixed is necessary to ensure the consistency point remains unchanged when G varies.

2.2 Dynamic Model

Having established the existence of asymmetric fertility responses in a static setting, we now examine their dynamic implications. We embed the static model from Section 2.1 into a discrete-time framework to study how reference-dependent preferences interact with policy changes and income dynamics over time.

In each period t, a cohort of fertile households takes the economy-wide reference consumption level r_t as given and chooses fertility and consumption to maximize contemporaneous utility. The within-period decision problem is identical to the static problem analyzed above.

2.2.1 Reference Formation

Following Kőszegi and Rabin (2006b), we assume that households form their reference point for consumption as a rational expectation of contemporaneous consumption based on past information. To avoid a recursive definition, we posit that beliefs about future consumption are anchored in the previous period's reference level. This specification reflects the idea that individuals do not fully anticipate how their preferences will adjust to new reference points, owing to cognitive limitations (Loewenstein et al., 2003; Quoidbach et al., 2013). Formally, the reference level evolves according to

$$r_{t+1} = r\big(r_t, \mathbb{E}_t[c_{t+1} \mid r = r_t]\big), \tag{14}$$

where $\mathbb{E}_t[c_{t+1} \mid r = r_t]$ denotes the household's expectation of period-$t+1$ consumption, holding the reference level fixed at r_t. This expectation is the solution to the problem

$$\max_c \; U(c,n) = u(c,n) + G(c - r_t) \quad \text{s.t.} \quad c + \mathbb{E}_t[\chi_{t+1}] \cdot n = \mathbb{E}_t[I_{t+1}], \quad \mathbb{E}_t[I_{t+1}] \geq c \geq 0 \tag{15}$$

We impose the following assumption on the reference-updating function:

Assumption R1. *The function $r(x,y)$ is continuously differentiable with $r_x(x,y) \geq 0$ and $r_y(x,y) > 0$ for any $\{x,y\}$. Moreover, $r(r_0,r_0) = r_0$ for any r_0.*

The first part of Assumption R1 ensures that reference points exhibit persistence and respond positively to expected consumption. Higher past reference levels and higher expected future consumption both raise the current reference point. The second part of Assumption R1 requires the individual not to deviate from a consistent point. In the following proposition, we show that, under additional assumptions, the individual's reference level converges to the consistent level $c^*(r) = r$.

Proposition 4 (Convergence to the Consistent Reference Level). *Suppose the reference updating function $r(x,y)$ satisfies Assumption R1 and $r_x(x,y) + r_y(x,y) \leq 1$ for all (x,y). Then, for any combination of $\{\chi, I\}$ and starting from any initial reference level, the individual's reference level converges to the consistent level $c^*(r) = r$.*

Proof. See Appendix A.2. □

Proposition 4 establishes the consistency between our assumption on the formation of the reference level in the static model and its counterpart in the dynamic model. Two assumptions are central to the proof of Proposition 4. First, the condition $r(r_0,r_0) = r_0$ for any r_0 ensures that the consistent reference level is "stable" in the updating process: once the consistent level is reached, individuals do not deviate from it. Second, the requirement $r_x(x,y) + r_y(x,y) \leq 1$ guarantees that the reference level does not oscillate around the consistent level.

There are two sources of uncertainty affecting the realization of consumption. First, the cost of children χ_t may change unexpectedly due to shifts in family policy; we analyze such policy changes in Section 2.2.2. Second, income I_t fluctuates over time, reflecting both trend growth and cyclical components. Following Boz et al. (2011), we assume households observe total income but cannot perfectly distinguish between permanent and transitory shocks. In Section 5, we demonstrate how asymmetric responses to income shocks under reference dependence generate a negative relationship between growth slowdowns and fertility decline.

2.2.2 The Rollback Effect

We now examine the fertility and welfare consequences of policy implementation followed by subsequent reversal. We show that such an implementation–reversal cycle can lower fertility and utility below their pre-policy levels, even when economic fundamentals return to their original values. We refer to this mechanism as the *policy rollback effect*.

To isolate this effect, we assume income is constant throughout this subsection, setting $I_t = I$ for all t. We also impose the following technical assumptions:

Assumption UG1. *For any* $\{I, \chi', r\}$ *and* $\{I, \chi'', r\}$ *with* $\chi' \neq \chi''$*, the Marshallian demand satisfies* $c^*(I, \chi', r) \neq c^*(I, \chi'', r)$.

Assumption UG1 extends Assumption U2 from marginal changes in χ around the consistent point $c^* = r$ to global, non-marginal changes. If optimal consumption were unresponsive to changes in χ, fertility policies would not affect the reference level, and consequently no rollback effect would arise.

Assumption G3. *The gain–loss function satisfies* $G''_+(0) = 0$ *and* $G''(y) = 0$ *for all* $y > 0$.

Assumption G3 corresponds to a piecewise-linear specification of loss aversion in the gain domain and ensures that a decrease in the reference level does not affect optimal consumption or fertility, as established in Lemma 3. Because policy implementation and reversal can lower the reference level in some cases, this assumption is essential for establishing that the rollback effect weakly reduces fertility.

We now provide a formal definition of the policy process under study.

Definition 3 (Policy Implementation and Reversal)**.** *A* ***fertility policy implementation and reversal process*** $\{\chi', \chi'', T_0, T_1\}$ *with* $\chi' \neq \chi''$ *and* $T_1 > T_0$ *is defined by*

$$\chi_t = \begin{cases} \chi' & \text{if } t < T_0 \text{ or } t \geq T_1, \\ \chi'' & \text{if } T_0 \leq t < T_1. \end{cases}$$

Households do not anticipate changes in χ_t, so that $\mathbb{E}_{t-1}[\chi_t] = \chi_{t-1}$. The process is termed a ***pro-fertility policy implementation and reversal*** *if $\chi'' < \chi'$, and an* ***anti-fertility policy implementation and reversal*** *if $\chi'' > \chi'$.*

Where T_0 is the time of policy implementation, and T_1 is the time of policy reversal. The following lemma characterizes how optimal consumption responds to changes in the reference level.

Lemma 3. *Consider any $\{I, \chi, r'\}$ and $\{I, \chi, r''\}$ with $r' \neq r''$. Then $c^*(I, \chi, r'') - c^*(I, \chi, r') \geq 0$ if $r'' > r'$, and $c^*(I, \chi, r'') - c^*(I, \chi, r') \leq 0$ if $r'' < r'$. Moreover, if $c^*(I, \chi, r') = r'$, then $c^*(I, \chi, r'') - c^*(I, \chi, r') > 0$ when $r'' > r'$, and $c^*(I, \chi, r'') - c^*(I, \chi, r') = 0$ when $r'' < r'$.*

Proof. See Appendix A.1. □

Lemma 3 establishes that optimal consumption is weakly increasing in the reference level. Starting from the consistent point $c^* = r$, any increase in r leads to a strict increase in c^*, whereas any decrease in r leaves c^* unchanged. Since r affects the household's decision only through G, these results follow directly from Assumption G2.

The next lemma characterizes the persistence of the reference level in response to policy changes.

Lemma 4. *Consider any fertility policy implementation and reversal process $\{\chi', \chi'', T_0, T_1\}$. If $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] < \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$, then $r_{T_1} > r_{T_0}$. If $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] > \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$, then $r_{T_1} < r_{T_0}$.*

Proof. See Appendix A.1. □

Lemma 4 establishes that the effect of fertility policies on the reference level is persistent. This result follows from Lemma 3: a rise in the reference level is self-reinforcing, as higher r induces higher c^*, which in turn raises future reference levels.

Proposition 5 (Rollback Effect on Fertility). *Assume income is constant at $I_t = \bar{I}$. Under any fertility policy implementation and reversal process, $n^*_{T_1} \leq n^*_{T_0-1}$. The inequality is strict if $c^*(I, \chi', r_{T_0}) < c^*(I, \chi'', r_{T_0})$.*

Proof. See Appendix A.2. □

The proof proceeds in two steps. First, policy implementation shifts the reference point from r_{T_0} to $r_{T_1} \neq r_{T_0}$, as established by Lemma 4. Second, after the policy is reversed, Lemma 3 implies that fertility decreases when $r_{T_1} > r_{T_0}$ and remains unchanged when $r_{T_1} < r_{T_0}$.

We next examine the welfare consequences of policy implementation and reversal. To sign these effects, we assume that consumption and fertility are complements:

Assumption UG2. *For any* $\{I, \chi', r\}$ *and* $\{I, \chi'', r\}$ *with* $\chi' > \chi''$*, the Marshallian demand satisfies* $c^*(I, \chi', r) < c^*(I, \chi'', r)$*.*

Under Assumption UG2, the implementation of pro-fertility policies raises the reference level, as established by Lemma 4. Since $G'(y) \geq 0$, this leads to lower welfare, consistent with our empirical findings in Section 3.4. By contrast, if consumption and fertility were substitutes, the sign of the welfare effect would reverse.

An example of a utility function satisfying Assumptions UG1 and UG2 is

$$u(c, n) = c + \frac{\beta \cdot (n - \underline{n})^{1-\zeta}}{1 - \zeta}, \qquad \text{with } \zeta > 1. \tag{16}$$

Proposition 6 (**Rollback Effect on Welfare**). *Assume income is constant at* $I_t = \bar{I}$ *and Assumption UG2 holds. Define* U_t^* *as the utility level given* $\{c^*(I, \chi_t, r_t), n^*(I, \chi_t, r_t), r_t\}$*. Under a pro-fertility policy implementation and reversal process,* $U_{T_1}^* < U_{T_0-1}^*$*; under an anti-fertility policy implementation and reversal process,* $U_{T_1}^* > U_{T_0-1}^*$*.*

Proof. See Appendix A.2. □

This result follows directly from $r_{T_1} > r_{T_0}$ under pro-fertility policies and the fact that $\partial U / \partial r < 0$.

Taken together, Propositions 5 and 6 demonstrate that temporary pro-fertility policies can generate persistent negative effects. By raising households' reference consumption levels, such policies elevate expectations that are not immediately reversed when the policy is withdrawn. The result is lower fertility and utility even after economic fundamentals return to their initial values. These predictions are unique to our framework: standard models without reference dependence would predict that fertility and utility immediately return to their original levels once policies are reversed and fundamentals are restored. The rollback effect thus provides a distinctive empirical signature of loss aversion in fertility decisions.

2.3 Summary and Testable Predictions

The theoretical analysis developed in this section yields four main predictions that distinguish our framework from standard models of fertility choice.

The first prediction concerns **asymmetric responses to cost shocks**. Proposition 1 establishes that fertility declines more sharply when the cost of children increases than it rises when costs decrease by an equivalent amount. This asymmetry arises because cost increases push consumption below the reference level, activating loss aversion and inducing households to cut fertility aggressively to protect consumption. Cost decreases, by contrast, move consumption into the gain domain where marginal utility is less sensitive, generating a muted fertility response.

The second prediction concerns **asymmetric responses to income shocks**. Proposition 2 shows that negative income shocks reduce fertility by more than equivalent positive shocks increase it. The mechanism parallels that for cost shocks: income losses threaten consumption relative to the reference point, triggering loss-averse behavior that manifests as disproportionate fertility reductions.

The third prediction concerns the **rollback effect on fertility**. Proposition 5 demonstrates that a pro-fertility policy followed by its reversal leaves fertility below its pre-policy level, even though economic fundamentals have returned to their original values. This occurs because the policy raises the reference consumption level during implementation, and this elevated reference persists after reversal, crowding out fertility in the new steady state.

The fourth prediction concerns the **rollback effect on welfare**. Proposition 6 shows that the same pro-fertility policy cycle reduces household utility below its pre-policy level. The welfare loss arises because households are evaluated against a reference point they can no longer attain, generating persistent disutility from perceived losses.

These predictions are qualitatively distinct from those of standard models. In the absence of reference dependence, fertility responses to cost and income shocks would be symmetric, and temporary policies would have no persistent effects once reversed. The asymmetries and rollback effects identified here therefore provide testable signatures of loss aversion in fertility decisions.

The following section examines empirical evidence on each of these predictions.

3 Empirical Evidence

This section documents four sets of empirical facts that support the theoretical predictions developed in Section 2. We examine asymmetric fertility responses to cost shocks (Section 3.1), asymmetric responses to income shocks (Section 3.2), the rollback effect on fertility (Section 3.3), and the rollback effect on utility (Section 3.4).

3.1 Asymmetric Fertility Responses to Cost Shocks

Proposition 1 predicts that fertility responds more strongly to increases in the cost of children than to equivalent decreases. To assess this prediction, we examine the relationship between fertility outcomes and policy regimes that generate variation in childbearing costs. If fertility exhibits the predicted asymmetry, anti-fertility policies should be associated with larger fertility effects than pro-fertility policies of comparable intensity.

Identifying the causal effects of fertility policies is inherently challenging because policy adoption is endogenous. Countries are unlikely to implement both pro- and anti-fertility policies for the same households at the same time, precluding direct within-country comparisons. Nevertheless, we document that fertility changes associated with anti-fertility policies are substantially larger than those associated with pro-fertility policies, a pattern consistent with Proposition 1. These findings should be interpreted as suggestive rather than definitively causal.

Direct and comparable measures of the monetary costs associated with fertility policies are not consistently available across countries and over time. We therefore rely on policy stances reported in the United Nations World Population Policies Database.[4] The database classifies national fertility policies into four categories—“lower”, “raise”, “maintain” and “no intervention”—for a broad set of countries from 1976 to 2019. We treat “maintain” and “no intervention” as the reference category and estimate the effects of “lower” (anti-fertility) and “raise” (pro-fertility) policy stances.

Period Fertility Rate Specification

We merge the policy data with country-level demographic and socioeconomic variables from the World Bank's World Development Indicators. An advantage of country-level panel data is broad coverage across countries and time, allowing us to study fertility responses in diverse institutional and economic contexts. By using the total fertility rate as the outcome variable, we capture short-run fertility responses to policy changes. We estimate the following two-way fixed-effects specification:

$$\frac{\Delta \text{TFR}_{ct}}{\text{TFR}_{c,t-1}} = \alpha + \beta_1 \text{Policy\_Lower}_{ct} + \beta_2 \text{Policy\_Raise}_{ct} + \gamma_c + \delta_t + \epsilon_{ct}, \tag{17}$$

where c indexes countries and t indexes years. The dependent variable denotes the growth rate of the total fertility rate in country c between years $t-1$ and t. The terms γ_c and δ_t represent country and year fixed effects, respectively. Policy exposure is measured as the fraction of the previous N years during which a given policy stance was in place:

$$\text{Policy\_Lower}_{ct} = \frac{1}{N} \sum_{T=t-N}^{t-1} \mathbb{1}(\text{Policy}_{cT} = \text{Lower}), \tag{18}$$

$$\text{Policy\_Raise}_{ct} = \frac{1}{N} \sum_{T=t-N}^{t-1} \mathbb{1}(\text{Policy}_{cT} = \text{Raise}), \tag{19}$$

[4] Appendix B presents a meta-analysis showing that our findings are robust to alternative measures that proxy for policy intensity.

where Policy_{cT} denotes the fertility policy regime in country c in year T. In the baseline specification, we set $N = 5$. In Section B.2, we show that our results are robust to alternative choices.

Cohort Fertility Rate Specification

We also combine the policy data with repeated cross-sectional fertility histories from the World Values Survey to examine effects on completed fertility. Individual-level data allow us to account for heterogeneity in characteristics such as education and income, enabling richer controls and facilitating discussion of alternative explanations including liquidity constraints. By focusing on completed fertility, this approach captures long-run adjustments that changes in the total fertility rate may miss and ensures that results are not driven solely by shifts in birth timing. The specification is:

$$\text{Children}_{icbt} = \alpha + \beta_1 \text{Policy\_Lower}_{cb} + \beta_2 \text{Policy\_Raise}_{cb} + \eta \text{Age}_i + \gamma_{ct} + \delta_b + \epsilon_{icbt}, \tag{20}$$

where i indexes individuals, c indexes countries, b denotes the individual's birth year, and t is the survey year. The dependent variable Children_{icbt} measures the number of children of respondent i. The term Age_i is age-group fixed effect. The terms γ_{ct} and δ_b represent country-by-survey-year and birth-year fixed effects, respectively. Policy exposure is defined as:

$$\text{Policy\_Lower}_{cb} = \frac{1}{11} \sum_{t \in [b+\text{MAC}_{c,b+18}-5,\, b+\text{MAC}_{c,b+18}+5]} \mathbb{1}(\text{Policy}_{ct} = \text{Lower}), \tag{21}$$

$$\text{Policy\_Raise}_{cb} = \frac{1}{11} \sum_{t \in [b+\text{MAC}_{c,b+18}-5,\, b+\text{MAC}_{c,b+18}+5]} \mathbb{1}(\text{Policy}_{ct} = \text{Raise}), \tag{22}$$

where $\text{MAC}_{c,b+18}$ is country c's mean age at childbearing when individual i reaches age 18, obtained from the World Bank's World Development Indicators[5]. In Section B.2, we show that our results are robust to different choices of MAC. These measures capture exposure to fertility policies within an eleven-year window centered on the cohort-specific mean child-bearing age. Because our focus is on completed fertility, we restrict the sample to women aged 45 and above at the time of the survey.

[5]MAC is only available for a specific years. We conduct nearest neighbor interpolation for each country to construct a balanced panel of MAC.

Results

Table 1 reports the results. Across both empirical strategies, exposure to anti-fertility policies is associated with economically and statistically significant declines in fertility, whereas the effects of pro-fertility policies are small and statistically indistinguishable from zero. These findings indicate a pronounced asymmetry in fertility responses to cost increases versus cost reductions, consistent with Proposition 1. Columns (2) and (4) demonstrate that results remain robust to the inclusion of controls for economic development, educational attainment, obstetric technology, and women's social status.

Table 1. Asymmetric Fertility Effects of Fertility Policies

Dependent Variable	Changes in Total Fertility Rate		Completed Fertility	
	(1)	(2)	(3)	(4)
Exposure to Anti-Fertility Policies	-0.0126***	-0.0062***	-0.6410***	-0.6414***
	(0.0019)	(0.0021)	(0.1824)	(0.1834)
Exposure to Pro-Fertility Policies	0.0017	-0.0005	0.0698	0.2529
	(0.0044)	(0.0036)	(0.2389)	(0.2335)
Baseline Controls	Yes	Yes	Yes	Yes
Endogenous Controls	No	Yes	No	Yes
Observations	6821	6821	59840	59840
R-Squared	0.128	0.171	0.290	0.310

Notes: This table reports the association between fertility policy stances and fertility outcomes. Anti-fertility ("lower") and pro-fertility ("raise") policies are measured as cumulative exposure over the previous five years. Columns (1)–(2) use country-year panel data with country and year fixed effects; the dependent variable is the percentage change in the total fertility rate. Columns (3)–(4) use individual-level data and a cohort-exposure design; the dependent variable is completed fertility. Baseline controls include demographic structure and region-specific trends. Endogenous controls include GDP per capita, educational attainment, obstetric technology, and measures of women's status for columns (1)–(2), and education and income for columns (3)–(4). Standard errors, reported in parentheses, are clustered at the country level for columns (1)–(2), and country-survey year for columns (3)–(4). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

3.2 Asymmetric Fertility Responses to Income Shocks

Proposition 2 predicts that fertility responds more strongly to negative income shocks than to positive ones. This prediction reflects reference-dependent preferences in which losses relative to a benchmark weigh more heavily than equivalent gains. Empirical evidence consistent with this prediction has been documented by Chatterjee and Vogl (2018) and Iwata and Naoi (2017).

Chatterjee and Vogl (2018) examine how fertility responds to business cycle fluctuations using data from the Demographic and Health Surveys, which provide detailed reproductive histories for approximately 2.3 million women across 81 developing countries. They discretize country-level economic growth rates into intervals and estimate fixed-effects models that trace fertility dynamics within each growth bin. Consistent with Proposition 2, they document a pronounced asymmetry: economic recessions are associated with significant declines in fertility, whereas periods of rapid growth generate little or no corresponding increase. This pattern aligns with a loss-aversion interpretation in which households respond strongly when income falls below their reference level but adjust only weakly when income rises above it.

Complementing this cross-country evidence, Iwata and Naoi (2017) study fertility responses to wealth shocks by exploiting fluctuations in housing prices in Japan. Using panel data from the Keio Household Panel Survey (2004–2011), they focus on non-moving homeowners with married women of childbearing age and examine fertility responses to year-to-year changes in self-reported housing values. Allowing the effect of housing wealth to differ depending on whether values increase or decrease relative to the previous year, they find that declines in housing wealth significantly reduce the birth hazard rate, whereas comparable increases generate only small and statistically insignificant effects. This pattern is again consistent with reference dependence: negative deviations from a wealth benchmark trigger substantial fertility adjustments, while positive deviations elicit muted responses.

Taken together, these findings support the prediction that fertility is more sensitive to adverse shocks than to favorable ones, as implied by reference-dependent preferences with loss aversion.

3.3 Rollback Effect on Fertility

Proposition 5 characterizes a distinctive prediction of our framework: the dynamic consequences of a temporary reduction in fertility costs followed by policy reversal. In contrast to standard models with time-separable preferences, our model predicts a rollback effect whereby equilibrium fertility falls below its pre-policy level after the withdrawal of a temporary pro-fertility policy. This overcorrection arises from reference-dependent preferences: once households adjust their consumption expectations upward during the subsidy period, the subsequent withdrawal is perceived as a loss, generating a disproportionately large negative response.

We examine this prediction using evidence from the introduction and unexpected cancellation of Spain's universal child benefit, studied by González and Trommlerová (2023). This setting is particularly compelling because it features clearly defined implementation and reversal dates, allowing clean identification of dynamic responses. In 2007, Spain introduced a nationwide lump-sum "baby bonus" of €2,500 for every child born or adopted from July 1, 2007 onward, equivalent to roughly 130–150 percent of average gross monthly earnings at the time. The policy remained in place for approximately three and a half years and was unexpectedly terminated for births occurring on or after January 1, 2011. Both the implementation and cancellation were announced less than six months before taking effect, limiting the scope for strategic fertility timing.

To evaluate the effects of the policy's introduction and reversal, González and Trommlerová (2023) use administrative microdata covering the universe of births in Spain from 2000 to 2017 and construct a province-by-month panel of birth rates for women aged 15–44. They estimate the following specification:

$$Y_{pt} = \alpha + \sum_{k=1}^{4} \beta_k T_{kt} + \sum_j \gamma_j (t_p^j) + \delta X_{p,t-9} + \mu_p + \lambda_m + \varepsilon_{pt}, \tag{23}$$

where Y_{pt} denotes either the log number of births per day or the birth rate in province p and month t; T_{kt} are indicators for four post-policy periods capturing the transition into the benefit, the main benefit period, the transition out following the cancellation announcement, and the post-cancellation period; (t_p^j) represents province-specific polynomial time trends; $X_{p,t-9}$ includes lagged male employment and unemployment rates to control for local economic conditions at conception; μ_p denotes province fixed effects; λ_m denotes calendar-month fixed effects; and ε_{pt} is an error term clustered at the province level. The coefficients β_k identify deviations from smooth province-specific fertility trends at policy-relevant dates. The key identifying assumption is that, absent the reform, fertility would have evolved smoothly according to province-specific trends without discrete national shifts precisely at the announcement and implementation dates. This assumption is supported by the smooth evolution of labor market indicators around the cutoffs and by placebo exercises using alternative reform years that do not generate comparable discontinuities.

The results provide striking support for the rollback prediction. Birth rates increased by approximately 3 percent following the introduction of the benefit, yet the cancellation produced a substantially larger decline of roughly 5.5 to 6 percent. The negative response to withdrawal is nearly twice as large as the positive response to introduction, implying not merely asymmetry but an overshooting below the pre-policy trend. This pattern is difficult to reconcile with standard income-effect mechanisms but emerges directly from reference dependence with endogenous benchmarks. In Section B.4, we show that similar rollback patterns arise across a broader set of countries for anti-fertility policies using the country-level dataset developed in Section 3.1.

3.4 Rollback Effect on Utility

Proposition 6 extends the rollback prediction to parental utility. When a temporary fertility subsidy is withdrawn, the model predicts that equilibrium utility falls below its pre-policy level. The mechanism mirrors that for fertility: the temporary policy raises the reference point, and its removal generates a perceived loss that outweighs the initial gain.

We examine this prediction using changes to Australia's baby bonus as a quasi-natural experiment. In July 2004, Australia substantially increased its fertility subsidy: births occurring after July 1, 2004 became eligible for a maternity payment of 3,000 AUD, replacing the previous maternity allowance of 842.64 AUD. In 2007, this payment was rebranded as the baby bonus and gradually increased to 5,000 AUD by 2012. In July 2013, the policy was partially reversed: the baby bonus for second and subsequent children was reduced from 5,000 AUD to 3,000 AUD.

To evaluate the utility effects of these policy changes, we use data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey, a repeated cross-sectional dataset containing detailed information on family structure and subjective well-being. For the 2004 expansion, we employ the HILDA 2004 wave dataset to estimate:

$$\text{Happiness}_i = \alpha + \beta \mathbb{1}(\text{Last\_Birth}_i > \text{July 1}) + \gamma \mathbf{X}_i + \epsilon_i, \tag{24}$$

where i represents individual. $\mathbf{X}_i$ denotes a vector of control variables including age, income, social economic status, household size, children number and state fixed effects, as well as their interaction with an indicator of gender. Happiness_i is self-reported degree of happiness ranging from 0 to 5; $\mathbb{1}(\text{Last\_Birth}_i > \text{July 1})$ is an indicator of having last birth later than July 1 in the survey year. For the 2013 reduction, which applied only to second and subsequent children, we employ the HILDA 2013 wave dataset to estimate:

$$\begin{aligned}\text{Happiness}_i = \alpha + \beta \mathbb{1}(\text{Last\_Birth}_i > \text{July 1}) \times \mathbb{1}(\text{Children\_Number}_i > 1) + \\ \delta \mathbb{1}(\text{Last\_Birth}_i > \text{July 1}) + \gamma \mathbf{X}_i + \epsilon_i.\end{aligned} \tag{25}$$

Where $\mathbb{1}(\text{Children\_Number}_i > 1)$ is an indicator of having more than 1 children at the time of the survey, i.e., being exposed to the baby bonus reduction. We restrict the sample to parents whose most recent birth occurred within the year preceding the survey and compare reported happiness between parents with births just before and just after July 1.[6]

The credibility of this design stems from the limited scope for strategic manipulation.

[6] Although the HILDA Survey does not record the exact date of the most recent birth, it reports each child's age as of July 1 in the survey year, allowing us to infer whether the most recent birth occurred before or after July 1.

The 2004 reform was announced only two months prior to implementation (Gans and Leigh, 2009), while the 2013 reform was announced eight months in advance (Australian Government Treasury, 2012). These short announcement windows make substantial adjustments to fertility decisions unlikely. Consistent with this, Gans and Leigh (2009) document that fewer than 0.5 percent of annual births were shifted in response to the 2004 expansion. We also conduct placebo tests showing that differences in reported happiness around July 1 are absent in years without policy changes, reinforcing the causal interpretation.

Table 2. Effect of the 2004 Baby Bonus Increase on Happiness

Dependent Variable	Happiness (0–5)		
Model	Ordered Probit		
Sample Year	2004	2003	2002
	(1)	(2)	(3)
$\mathbb{1}(\text{Last\_Birth}_i > \text{July } 1)$	0.037	0.273	0.223
	(0.240)	(0.265)	(0.210)
Control Variables	Yes	Yes	Yes
Observations	423	422	422
R^2	0.389	0.323	0.304

Notes: This table reports ordered probit estimates of the effect of the 2004 increase in Australia's baby bonus on parents' self-reported happiness (measured on a 0–5 scale). The explanatory variable of interest is an indicator equal to one if the respondent's most recent birth occurred after July 1 of the sample year. Column (1) uses the policy year 2004, while Columns (2) and (3) report placebo tests using years without policy changes. Control variables include age, education, household income, marital status, employment status, and state fixed effects. Standard errors are reported in parentheses.

Table 3. Effect of the 2013 Baby Bonus Reduction on Happiness

Dependent Variable	Happiness (0–5)		
Model	Ordered Probit		
Sample Year	2013	2012	2011
	(1)	(2)	(3)
$\mathbb{1}(\text{Last\_Birth}_i > \text{July } 1) \times \mathbb{1}(\text{Children\_Number}_i > 1)$	-0.569**	0.029	-0.207
	(0.279)	(0.272)	(0.424)
Control Variables	Yes	Yes	Yes
Observations	656	681	469
R^2	0.192	0.189	0.303

Notes: This table reports ordered probit estimates of the effect of the 2013 reduction in Australia's baby bonus on parents' self-reported happiness (measured on a 0–5 scale). The explanatory variable of interest is an indicator for having a birth after July 1 interacted with an indicator for having more than one child, reflecting eligibility for the reduced benefit. Column (1) uses the policy year 2013, while Columns (2) and (3) report placebo tests using years without policy changes. Control variables are identical to those in Table 2. Standard errors are reported in parentheses. ** $p < 0.05$.

Tables 2 and 3 present the results. Column (1) in each table reports the main estimates, while Columns (2) and (3) provide placebo tests using earlier years without policy changes. The placebo coefficients are small and statistically insignificant, supporting the validity of the research design. Consistent with Proposition 6, the 2013 baby bonus reduction generates a statistically significant decline in reported happiness, whereas the 2004 expansion produces positive but insignificant effect. The utility response mirrors the fertility rollback effect: the negative impact of policy withdrawal exceeds the positive impact of policy introduction, as predicted by reference-dependent preferences.

3.5 Summary

The empirical evidence presented in this section provides consistent support for the four main predictions of the theoretical framework. We document asymmetric fertility responses to both cost shocks and income shocks, with negative shocks generating substantially larger effects than positive shocks of comparable magnitude. We also find evidence for the rollback effect: the withdrawal of Spain's baby bonus reduced fertility by nearly twice the amount that its introduction raised it, and the reduction of Australia's baby bonus lowered parental happiness while its earlier expansion had no detectable effect. These patterns align with Propositions 1, 2, 5, and 6.

The ideal empirical test of asymmetry would expose similar individuals to positive and negative shocks of identical nature and magnitude within the same context. Such symmetric variation is difficult to obtain in observational data: naturally occurring shocks that raise and lower resources typically differ in their source, timing, or the populations they affect. Our empirical strategy addresses this challenge through triangulation. Cross-country analyses exploit variation in both pro-natalist and anti-natalist policy stances, while the quasi-experimental evidence from Spain and Australia captures responses to both policy introductions and withdrawals. The income shock evidence draws on studies of both positive shocks (lottery wins, resource windfalls) and negative shocks (job displacement, benefit reductions). No single analysis delivers the ideal symmetric design, but the convergent pattern across diverse settings, measures, and identification strategies supports the core predictions.

Several limitations merit acknowledgment. The policy stance analyses cannot fully address the endogeneity of policy adoption, though Section B.3 provides evidence against selection on initial conditions driving the results. The quasi-experimental evidence from Spain and Australia offers cleaner identification but pertains to specific contexts. A natural next step would be survey experiments that randomly assign households to scenarios involving symmetric positive and negative income or cost changes and elicit fertility intentions—a design that could achieve the symmetry that observational data cannot. We leave this for future research.

Despite these limitations, the asymmetries documented here are qualitatively robust and quantitatively substantial. Standard models without reference dependence predict symmetric responses to shocks of equal magnitude and no persistent effects of temporary policies—predictions systematically rejected in the data. The following sections develop a quantitative version of the model to assess whether reference-dependent preferences can match not only the qualitative patterns but also the magnitudes observed empirically. Additional robustness checks and supplementary analyses appear in Appendix B.

4 Calibration

This section develops a quantitative version of the model and calibrates it to Chinese data.

China provides a compelling setting for our quantitative analysis for several reasons. First, China's recent fertility decline has surprised demographers and policymakers alike. Despite the relaxation of the one-child policy in 2015 and its complete abolition in 2021, fertility has continued to fall, reaching 1.0 children per woman in 2023—among the lowest rates ever recorded for a major economy. This decline defies the predictions of standard models, which would have anticipated a rebound following the removal of explicit fertility restrictions. Second, the consequences of this demographic transition are profound. As the world's second-largest economy and most populous nation, China's fertility trajectory will shape global labor markets, international trade patterns, pension sustainability, and geopolitical dynamics for decades to come. Third, China's recent economic history offers an ideal laboratory for testing our theory. The country experienced extraordinarily rapid income growth for three decades, during which households became accustomed to steadily rising living standards. The subsequent growth slowdown beginning around 2010 provides precisely the kind of shift from positive to negative income surprises that our model predicts will activate loss aversion and accelerate fertility decline. By calibrating the model to this episode, we can assess whether reference-dependent preferences can quantitatively account for the observed fertility dynamics and, if so, decompose the contributions of standard income effects versus behavioral amplification through loss aversion.

We begin by specifying the functional forms, income process, and information structure, then describe the data and calibration strategy.

4.1 Parametric Assumptions

4.1.1 Preferences

Households solve the optimization problem

$$\max_{c_t, n_t} \; u(c_t, n_t) + G(c_t - r_t) \tag{26}$$

subject to the budget constraint

$$c_t = I_t(1 - \chi \cdot n_t), \tag{27}$$

where c_t denotes consumption, n_t denotes fertility, $\chi \in (0, 1)$ is the fraction of income foregone per child, I_t is household income, and r_t is the reference level of consumption. This specification follows the quantity-quality tradeoff literature in which childbearing requires a time cost that reduces labor income proportionally. As shown in Section C.1, all theoretical results in previous sections hold with this specification of child cost.

We specify the intrinsic utility function as

$$u(c, n) = c + \frac{\beta \cdot (n - \underline{n})^{1-\zeta}}{1 - \zeta}, \qquad \text{with } \zeta > 1, \tag{28}$$

where β governs the level of utility from fertility, ζ governs the price elasticity of fertility, and $\underline{n}$ is a subsistence fertility level that ensures fertility does not converge to zero as income grows without bound.[7]

The gain-loss utility function takes the piecewise-quadratic form

$$G(y) = \begin{cases} 0 & \text{if } y \geq 0, \\ -\dfrac{\alpha}{2} \cdot y^2 & \text{if } y < 0, \end{cases} \tag{29}$$

where $y = c_t - r_t$ measures the deviation of consumption from its reference level. The parameter $\alpha > 0$ governs the degree of loss aversion. When consumption meets or exceeds the reference point, gain-loss utility is zero. When consumption falls short, the household experiences disutility that is quadratic in the magnitude of the shortfall. This specification captures loss aversion while ensuring continuous differentiability at the reference point.

[7] Strictly speaking, the utility function in equation (28) does not satisfy Assumption U1 globally. However, the role of Assumption U1 is to ensure the existence of interior solutions, which we verify numerically for our calibrated parameters.

4.1.2 Income Process and Expectation Formation

Household income evolves stochastically over time. Rather than specifying a full structural model of income dynamics, we adopt a simple adaptive expectations rule that captures extrapolative beliefs. Households in their early twenties expect future income growth to equal the income growth they witnessed during their formative years:

$$\mathbb{E}t[It + 1] = \frac{I_t \cdot I_{t-1}}{I_{t-2}}. \tag{30}$$

This specification implies that households extrapolate recent growth rates into the future. When income has been growing rapidly, households expect continued rapid growth. When growth slows, expectations adjust downward, but only gradually as the slowdown is observed in realized income.

This formulation builds on a large literature documenting that formative experiences exert outsized influence on subsequent beliefs. Malmendier and Nagel (2011) show that individuals who experienced low stock market returns report lower expected future returns and participate less in equity markets. Malmendier and Nagel (2016) find analogous patterns for inflation expectations. Kuchler and Zafar (2019) demonstrate that individuals extrapolate from personal experiences with local conditions when forming expectations about aggregate outcomes. Our specification operationalizes this insight by anchoring expectations in the growth rates households observed during their transition to adulthood. The simplicity of this rule ensures transparency: the gap between expected and realized income depends only on observable income dynamics rather than on estimated latent state variables.

4.1.3 Reference Point Formation

The reference point represents the household's expectation of future consumption. We assume that households are sophisticated: they understand their own preferences and correctly anticipate how they will behave when future income is realized.

The timing within each period is as follows. At the beginning of period t, the household inherits a reference point r_t that was formed in period $t-1$. The household observes realized income I_t and, given the inherited reference point r_t, chooses consumption and fertility to solve

$$\max_{c,n} \; u(c, n) + G(c - r_t) \quad \text{subject to} \quad c = I_t(1 - \chi \cdot n). \tag{31}$$

Let $c^*(I, r)$ and $n^*(I, r)$ denote the policy functions that characterize optimal consumption and fertility as functions of income and the reference point.

After making current-period choices, the household forms the reference point for the next period. This reference point equals expected consumption next period, evaluated at expected income[8]:

$$r_{t+1} = c^* \left(\mathbb{E}_t[I_{t+1}], r_t \right). \tag{32}$$

The household uses its current reference point r_t as the second argument because r_t is what future consumption will be evaluated against when period $t+1$ arrives and the new reference point r_{t+1} takes effect. This specification captures the idea that reference points reflect what households rationally expect to consume, accounting for the influence of loss aversion on future choices.

This formulation generates a recursive structure. The reference point r_{t+1} depends on the current reference point r_t through the policy function, creating persistence in reference points that emerges endogenously from the optimization problem. When expected income rises, the household anticipates higher future consumption and adjusts its reference point upward. This higher reference point then affects the computation of r_{t+2}, and so on.

The specification ensures that realized consumption can fall below the reference point, generating losses. When the household forms r_{t+1} at time t, it uses expected income $\mathbb{E}_t[I_{t+1}]$. But when period $t+1$ arrives, actual income I_{t+1} may differ from this expectation. If I_{t+1} falls short of $\mathbb{E}_t[I_{t+1}]$, realized consumption will typically be less than r_{t+1}, and the household experiences a loss. The probability and magnitude of such losses depend on the accuracy of income forecasts.

4.2 Data

We calibrate the model using data from China spanning 1969–2023. Income is measured as GDP per capita in current US dollars from the World Bank's World Development Indicators. Fertility is measured as the total fertility rate (TFR), also from the World Bank, available from 1984 onward. We adopt the adjustment in Yang et al. (2022) to correct for potential misreporting in the data.

We aggregate the annual data into five-year periods. This aggregation smooths year-to-year fluctuations and aligns with the notion that fertility decisions reflect medium-term economic conditions rather than transitory annual variation. We define eight model periods spanning 1984–2023: 1984–88, 1989–93, 1994–98, 1999–03, 2004–08, 2009–13, 2014–18, and 2019–23. For each period, we compute the arithmetic mean of annual GDP per capita and TFR.

To initialize expectations for the first model period (1984–88), we require income data

[8]Note that here we use $c^* \left(\mathbb{E}_t[I_{t+1}], r_t \right)$ instead of $\mathbb{E}_t[c^*(I_{t+1}, r_t)]$ as in Section 2.2. Since c^* is continuous in I_{t+1} by Berge's Maximum Theorem, $c^* \left(\mathbb{E}_t[I_{t+1}], r_t \right)$ can be considered as a first-order approximation to $\mathbb{E}_t[c^*(I_{t+1}, r_t)]$, which greatly simplifies the simulation of the model.

from three preceding periods. We therefore construct three pre-model periods: 1969–73, 1974–78, and 1979–83. These periods provide the lagged income values necessary to compute adaptive expectations for all model periods using the rule $\mathbb{E}_{t-1}[I_t] = I_{t-1} \cdot I_{t-2}/I_{t-3}$.

4.3 Calibration Strategy

The model has five parameters: χ (child cost share), β (fertility utility level), ζ (fertility elasticity), α (loss aversion), and $\underline{n}$ (subsistence fertility). We calibrate these parameters to match the fertility transition observed in China from 1984 to 2013—the six periods preceding the dramatic fertility decline.

The child cost parameter $\chi = 0.15$ implies that each child reduces household consumption by 15 percent of income. This value lies within the range of estimates in the literature on the cost of children in developing countries and captures both direct expenditures and opportunity costs of parental time (De La Croix and Doepke, 2003).

The remaining parameters β, ζ, $\underline{n}$, and α are calibrated jointly to match four targets: the level and trend of fertility during the 1984–2013 period, the elasticity of fertility with respect to a positive cost shock, and the degree of asymmetry in fertility responses to cost shocks implied by experimental evidence on loss aversion. We set $\beta = 250$, $\zeta = 5.0$, $\underline{n} = 0.7$, and $\alpha = 0.0013$.

The elasticity parameter $\zeta = 5.0$ implies that fertility is relatively inelastic with respect to the shadow price of children. This high value is consistent with the modest fertility responses to income changes observed during periods of rapid economic growth.

The loss aversion parameter $\alpha = 0.0013$ is calibrated to generate an asymmetry ratio of approximately 3.0, meaning that fertility responds nearly three times more strongly to cost increases (which push households into the loss domain) than to equivalent cost decreases (which leave households in the gain domain). Figure 2 illustrates how the asymmetry ratio varies with α. Higher values of α generate greater asymmetry, as the quadratic loss penalty amplifies the marginal utility cost of consumption shortfalls.

4.4 Model Fit

Figure 3 compares the model's predicted fertility path to the data for the calibration period 1984–2013. The model captures the broad decline in fertility from approximately 2.4 children per woman in 1984–88 to 1.5 in 2009–13. The model slightly overpredicts fertility in the first period but tracks the subsequent decline reasonably well.

The model generates declining fertility through the substitution effect: as income rises, the opportunity cost of children increases, inducing households to substitute away from fer-

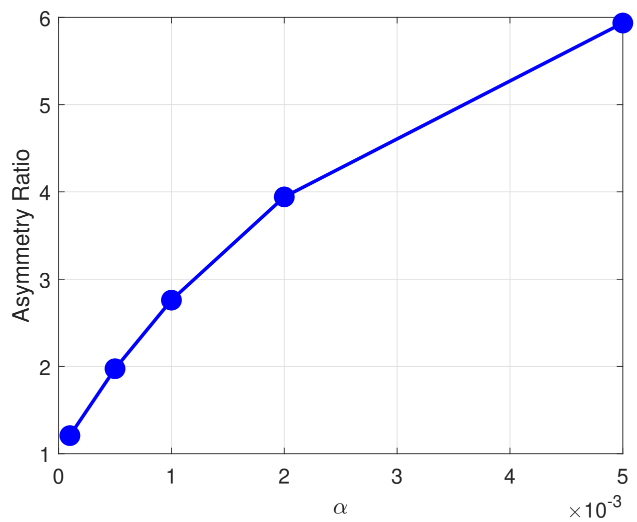


Figure 2. Identification of the Loss Aversion Parameter

Notes: The figure plots the asymmetry ratio—defined as the absolute fertility response to a cost increase divided by the absolute response to an equivalent cost decrease—as a function of the loss aversion parameter α. The asymmetry ratio is computed by perturbing the child cost parameter χ by ± 0.001 around a consistent steady state where the reference point equals consumption. Higher values of α generate greater asymmetry in fertility responses.

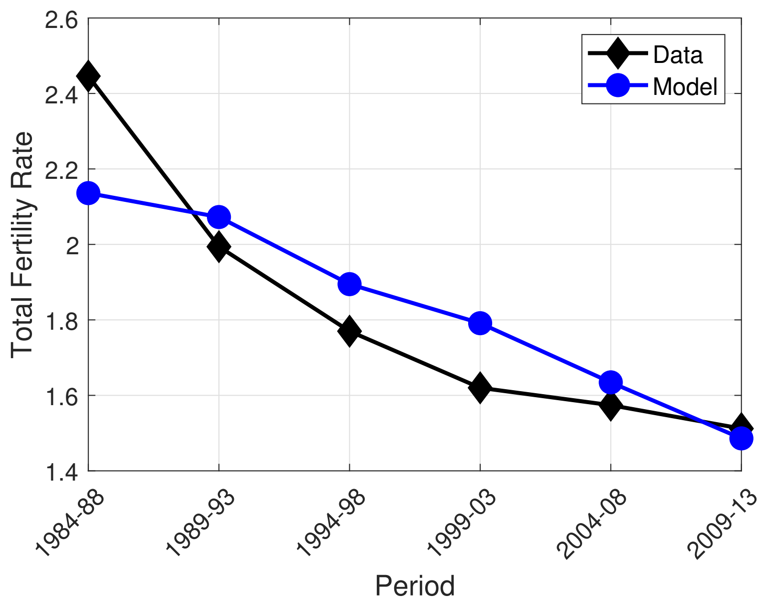


Figure 3. Model Fit: Calibration Period (1984–2013)

Notes: The figure compares observed total fertility rate (TFR) to model predictions for the six calibration periods spanning 1984–2013. The model is calibrated to match the level and trend of fertility during this period. Parameters: $\chi = 0.15$, $\beta = 250$, $\zeta = 5.0$, $\alpha = 0.0013$, $\underline{n} = 0.7$.

tility toward consumption. Although higher income also generates a positive income effect on fertility, the substitution effect dominates under our utility specification. During this period, income consistently exceeded expectations (households experienced positive surprises), so loss aversion plays a limited role. The calibration essentially pins down β and ζ to match the level and slope of fertility during the gain domain.

Table 4 summarizes the calibrated parameter values.

Table 4. Calibrated Parameter Values

Parameter	Description	Value
χ	Child cost (fraction of income)	0.15
β	Fertility utility level	250
ζ	Fertility elasticity	5.0
α	Loss aversion	0.0013
$\underline{n}$	Subsistence fertility	0.7

Notes: Parameters are calibrated to match Chinese fertility data from 1984–2013 and to generate an asymmetry ratio of approximately 3.0 in fertility responses to cost shocks.

5 Quantitative Results

This section presents the quantitative implications of the calibrated model. We examine how the model explains China's recent fertility decline, decompose the contributions of loss aversion and income dynamics through counterfactual exercises, and explore the effects of income uncertainty through stochastic simulations.

5.1 Income Growth Slowdown and the Fertility Decline

The calibrated model generates a striking prediction for the post-2013 period. Figure 4 displays the gap between realized and expected income—computed as the log difference $\log I_t - \log \mathbb{E}_{t-1}[I_t]$—for each five-year period. During 1984–2013, income consistently exceeded expectations: households experienced positive surprises as China's rapid growth outpaced extrapolated forecasts. Beginning in 2014–18, however, this pattern reverses. Income falls short of expectations, and the negative gap widens substantially in 2019–23.

This reversal from the gain domain to the loss domain activates the asymmetric response mechanism central to our framework. When households experience negative income surprises, loss aversion amplifies the fertility decline beyond what standard preferences would predict. Figure 5 compares model predictions to observed fertility for the four most recent periods (2004–2023). The model tracks the data reasonably well through 2004–13 and again from 2019–23, but it predicts a sharp fertility decline in 2014–18 that did not fully materialize in the data. This discrepancy suggests that the actual puzzle is not why fertility began falling in China recently, but rather why the large drop did not occur earlier.

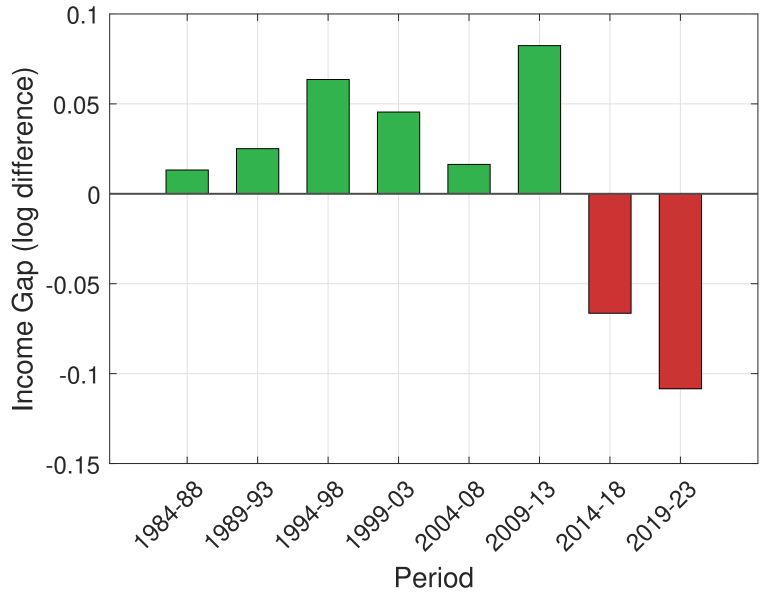


Figure 4. Income Surprises: Gap Between Realized and Expected Income

Notes: The figure displays the log difference between realized income and expected income, $\log I_t - \log \mathbb{E}_{t-1}[I_t]$, for each five-year period. Expected income is computed using the adaptive expectations rule $\mathbb{E}_{t-1}[I_t] = I_{t-1} \cdot I_{t-2}/I_{t-3}$. Green bars indicate positive surprises (gains); red bars indicate negative surprises (losses).

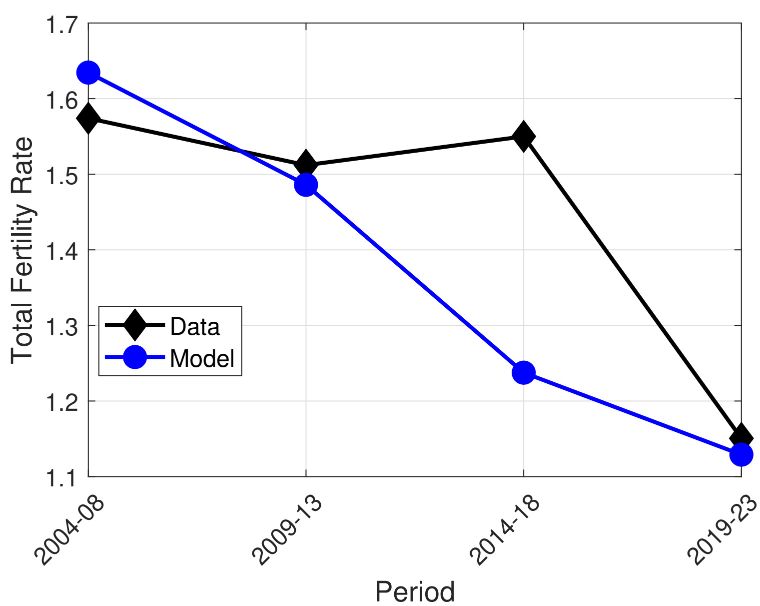


Figure 5. Model Predictions vs. Data: 2004–2023

Notes: The figure compares observed TFR to model predictions for four periods spanning 2004–2023. The model predicts a sharper fertility decline than observed in 2014–18, when income first fell below expectations and households entered the loss domain.

The model's overprediction of the fertility decline in 2014–18 reflects the strong asymmetric response embedded in the calibration. Several factors may account for the gap between model and data. First, the one-child policy and its relaxation in 2015–16 created institutional constraints not captured in the model; the policy relaxation temporarily boosted fertility in ways orthogonal to income dynamics. Second, the model's adaptive expectations may adjust too slowly to the growth slowdown, generating larger negative surprises than households actually perceived.

Despite this quantitative gap, the model's qualitative prediction is notable: loss aversion generates an accelerated fertility decline when growth slows, precisely because households find themselves in the loss domain where behavioral responses are amplified. This mechanism may help explain fertility declines observed across diverse economies following growth slowdowns. South Korea provides a striking example: fertility had stabilized around 1.5 during the high-growth decades of the 1980s and early 1990s, but following the 1997 Asian Financial Crisis and subsequent growth deceleration, it fell precipitously to 1.08 by 2005 and has since dropped below 0.8. Japan exhibits a similar pattern—fertility stabilized near 1.5 during the 1980s boom but resumed its decline after the asset bubble burst in 1991 and the economy entered its "lost decades." Taiwan's fertility likewise declined from around 1.7 in the early 1990s to approximately 1.0 by the 2010s as growth moderated. More recently, the United States and several European countries experienced fertility declines following the Great Recession, with U.S. fertility falling from 2.1 in 2007 to 1.6 by the early 2020s. The common thread across these cases is that households accustomed to rising living standards appear to reduce fertility when those gains slow or reverse—a pattern consistent with reference points shaped by past experience and amplified behavioral responses in the loss domain.

5.2 Counterfactual Analysis: The Role of Loss Aversion

To isolate the contribution of loss aversion to the fertility decline, we solve the model under the counterfactual assumption that $\alpha = 0$. In this scenario, households have standard preferences with no asymmetry between gains and losses. Figure 6 compares fertility paths with and without loss aversion for the four most recent periods.

Without loss aversion, fertility declines more gradually. The gap between the two paths widens over time as households in the baseline model accumulate exposure to negative income surprises. By 2019–23, loss aversion accounts for approximately 0.25 children per woman of the predicted fertility decline—a substantial fraction of the total decline from 2009–13 levels.

This counterfactual isolates the pure behavioral channel. Even holding income realizations constant, the presence of loss aversion generates lower fertility for two reasons: negative surprises trigger larger fertility reductions, and reference points adjust sluggishly, prolonging exposure to the loss domain.

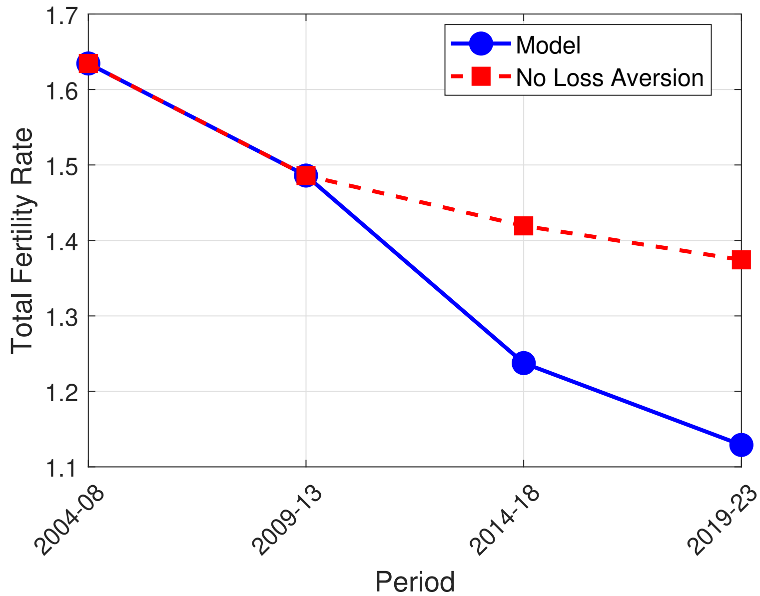


Figure 6. Counterfactual: Model With and Without Loss Aversion

Notes: The figure compares model-predicted fertility under the baseline calibration ($\alpha = 0.0013$) to a counterfactual with no loss aversion ($\alpha = 0$). The difference between the two paths represents the contribution of loss aversion to the fertility decline.

5.3 Counterfactual Analysis: The Role of the Growth Slowdown

A complementary counterfactual asks: what would fertility have been if income growth had continued at its pre-slowdown pace? We construct an alternative income path in which the growth rate from 2009–13 to 2014–18 and subsequent periods equals the peak growth rate observed from 2004–08 to 2009–13. Figure 7 compares fertility under this counterfactual to the baseline.

Under sustained rapid growth, households remain in the gain domain: realized income meets or exceeds expectations. Without negative surprises, loss aversion is not activated, and fertility follows the gradual decline as substitution effects dominate income effects.

Comparing the two counterfactuals reveals that both channels matter. Removing loss aversion (Figure 6) raises fertility while holding income fixed. Removing the growth slowdown (Figure 7) raises fertility by keeping households out of the loss domain. The interaction between these two channels—loss aversion and negative income surprises—generates the sharp fertility decline predicted by the baseline model.

These findings extend beyond the Chinese context to inform our understanding of demographic transitions in catching-up economies more broadly. Rapid growth followed by convergence-induced deceleration is a defining feature of successful economic development: Japan, South Korea, and the Southeast Asian tigers all experienced sustained periods of high growth that eventually moderated as their income levels approached the technologi-

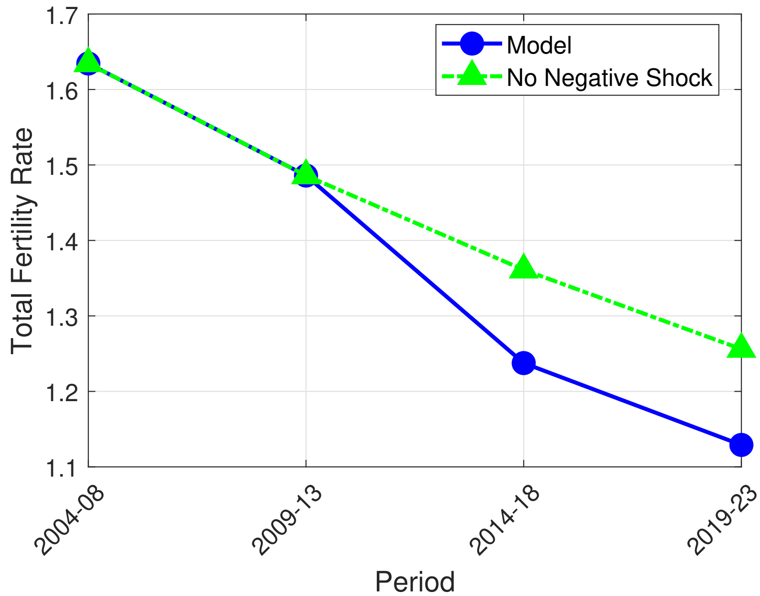


Figure 7. Counterfactual: Model With and Without the Growth Slowdown

Notes: The figure compares baseline model predictions to a counterfactual in which income growth continues at the peak rate observed from 2004–08 to 2009–13. Under this counterfactual, households remain in the gain domain and fertility declines more slowly.

cal frontier. Our framework suggests that this universal pattern of growth slowdowns may generate fertility dynamics that differ systematically from those predicted by standard models. Households in catching-up economies form expectations based on recent high growth rates, and when convergence inevitably slows the pace of income gains, the resulting negative surprises push households into the loss domain where fertility responses are amplified. This mechanism implies that countries currently in the midst of rapid catch-up growth—including much of South and Southeast Asia, as well as parts of Sub-Saharan Africa—may face unexpectedly sharp fertility declines once their growth trajectories begin to moderate.

5.4 Stochastic Simulations: Income Uncertainty and Fertility Dynamics

To examine how loss aversion affects fertility under income uncertainty, we conduct a stochastic simulation exercise. We project the economy forward from the last observed period (2019–23) and compare fertility outcomes with and without loss aversion across many simulated income paths.

5.4.1 Simulation Design

We assume that log income follows a deterministic trend plus stationary AR(1) deviations:

$$\log I_{T+s} = \log I_T + g \cdot s + z_{T+s}, \quad s = 1, 2, \ldots \tag{33}$$

where g is the trend growth rate and z_t is an AR(1) process:

$$z_t = \rho\, z_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim \mathcal{N}(0, \sigma^2). \tag{34}$$

We set the trend growth rate g equal to the observed growth rate between 2014–18 and 2019–23. The persistence parameter $\rho = 0.9$ captures high persistence at the five-year frequency, and $\sigma = 0.10$ generates economically meaningful income uncertainty. The deviation process is initialized at $z_T = 0$.

We simulate 500 independent income paths forward for five periods (25 years). For each path, we solve the household's problem under two scenarios: with loss aversion ($\alpha = 0.0013$) and without loss aversion ($\alpha = 0$). Both scenarios use identical income realizations and the same adaptive expectations rule.

5.4.2 Results

Figure 8 displays mean fertility paths and 90 percent confidence bands for the two scenarios.

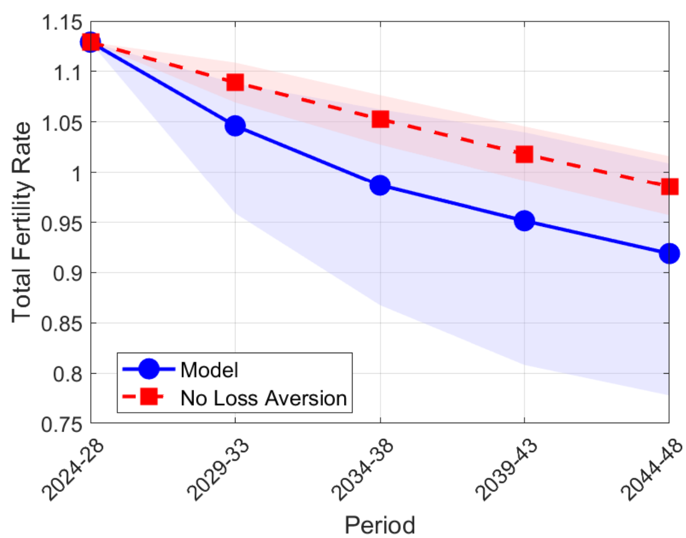


Figure 8. Projected Fertility With and Without Loss Aversion

Notes: The figure displays mean fertility paths and 90 percent confidence bands from 500 stochastic simulations. The blue line and shaded region correspond to the model with loss aversion ($\alpha = 0.0013$); the red line and shaded region correspond to the counterfactual without loss aversion ($\alpha = 0$). Both scenarios use identical simulated income paths.

Several findings emerge from this exercise. First, the model with loss aversion generates systematically lower average fertility across all projection periods. By the terminal period (2044–48), mean fertility is approximately 0.06 children per woman lower with loss aversion than without. This gap emerges because negative income surprises trigger larger fertility reductions than positive surprises trigger fertility increases. Even though positive and negative shocks are equally likely by construction, the asymmetric response implies lower average fertility.

Second, the confidence bands are wider under loss aversion, indicating greater cross-sectional dispersion in fertility outcomes. This increased volatility reflects the amplified response to negative shocks: households that draw unfavorable income realizations reduce fertility sharply, while those with favorable realizations increase fertility only modestly.

5.5 Policy Implications

These results carry several implications for fertility policy in economies experiencing growth slowdowns or heightened income volatility.

The analysis suggests that pro-natalist interventions may be most effective when households are in the loss domain. Policies that reduce the cost of children—such as childcare subsidies, parental leave, or tax credits—will have larger effects when households perceive themselves as falling short of consumption benchmarks. The same policy implemented during a period of rapid growth, when households experience positive surprises, will generate smaller fertility responses. This asymmetry implies that the timing of pro-natalist policies matters: interventions may be most effective during economic downturns.

The analysis also highlights the importance of expectation management. Because reference points depend on expected future consumption, policies that temper expectations during growth slowdowns may reduce the severity of perceived losses. Gradual communication about changing growth prospects, or policies that smooth consumption across cohorts, could reduce the fraction of households operating in the loss domain and thereby mitigate the fertility decline.

The recursive structure of reference point formation implies that prolonged exposure to the loss domain can generate persistent effects. Households that experience negative surprises adjust their reference points downward, but this adjustment is gradual. A sustained growth slowdown may therefore depress fertility for an extended period even after growth eventually recovers, as reference points slowly catch up to the new income trajectory.

Finally, in environments with substantial income uncertainty, loss aversion implies that average fertility will be lower than in a certainty-equivalent model. Policies that reduce income risk—such as unemployment insurance, income stabilization programs, or progressive taxation—may therefore have pro-natalist effects by reducing the frequency and severity of negative income surprises.

6 Robustness and Alternative Explanations

This section evaluates alternative mechanisms that might account for the asymmetric fertility responses documented in Section 3 and discusses the interpretation of our calibrated loss aversion parameter.

6.1 Alternative Explanations

We consider three alternative mechanisms: liquidity constraints, policy asymmetries, and propagation mechanisms. While each has some merit, none can simultaneously account for all empirical patterns.

Liquidity Constraints

When households face borrowing limits, negative income shocks may push them against these constraints, raising marginal utility and amplifying behavioral responses. Chatterjee and Vogl (2018) invoke this mechanism to explain stronger fertility responses to recessions than expansions.

However, two challenges confront this explanation. First, liquidity constraints cannot account for the rollback effects documented by González and Trommlerová (2023): financial transfers should relax such constraints, yet fertility falls below pre-policy levels after their withdrawal. Second, the individual-level results in Table 1 show asymmetric responses even after controlling for income, whereas a liquidity-constraint mechanism would predict the asymmetry to be concentrated among lower-income households. Moreover, in Section B.1, we show that asymmetric responses are in fact stronger among individuals with higher income or education levels, which is inconsistent with the liquidity-constraint explanation.

Policy Asymmetries

Perhaps governments have access to more effective tools when reducing fertility than when raising it. Three considerations limit this explanation. First, fertility responds asymmetrically to implementation and reversal of the *same policy*. González and Trommlerová (2023) find that Spain's baby bonus raised fertility by 3 percent upon introduction but reduced it by nearly 6 percent upon cancellation. Likewise, Tables 2 and 3 show that happiness responds asymmetrically to policy changes of comparable magnitude involving identical instruments. Second, asymmetric responses to income shocks documented by Chatterjee and Vogl (2018) and Iwata and Naoi (2017) arise independently of policy. Third, the fertility policy toolbox is largely *technologically symmetric*: propaganda, financial incentives, and family planning access have all been deployed in both directions historically. If governments systematically choose different instruments depending on direction, an additional theory is required—and reference dependence provides precisely such a theory.

Propagation Mechanisms

Lutz et al. (2006) argue that fertility decline triggers self-reinforcing dynamics through changing norms and peer effects. However, propagation mechanisms do not inherently generate asymmetries—social spillovers can operate in either direction. For propagation to explain the asymmetry, the underlying process must itself be asymmetric, which simply pushes the question back one step. Reference dependence provides a micro-foundation: negative shocks push households into the loss domain where responses are amplified, while positive shocks leave households in the gain domain where responses are muted.

Summary

Table 5 summarizes each explanation's ability to account for the key findings. Loss aversion uniquely accounts for all patterns: asymmetric responses to policies, to income shocks, and rollback effects.

Table 5. Comparison of Alternative Explanations

Empirical Pattern	Liquidity Constraints	Policy Asymmetries	Propagation Mechanisms	Loss Aversion
Policy asymmetry	✓	✓	✗	✓
Income shock asymmetry	✓	✗	✗	✓
Rollback effect	✗	✗	✗	✓

Notes: A checkmark (✓) indicates the explanation is consistent with the pattern; a cross (✗) indicates it is not. Loss aversion is the only explanation consistent with all patterns.

6.2 Additional Choice Margins

The baseline model abstracts from the labor-leisure decision to isolate the core mechanism. This subsection demonstrates that incorporating labor supply does not alter the theoretical predictions. Consider a household that chooses expenditure e, leisure l, and fertility n to maximize

$$\max_{e,l,n} \quad u(c,n) + G(c-r), \tag{35}$$

where living standard c is produced according to

$$c = f(e, l). \tag{36}$$

The budget constraint is

$$e = w \cdot (1 - l - \chi \cdot n), \tag{37}$$

where w denotes productivity and $\chi \cdot n$ represents the time cost of children. The gain–loss function $G(\cdot)$ retains the same specification as in Section 2.1.

This problem admits a two-stage budgeting solution. In the first stage, the household determines the cost-minimizing combination of expenditure and leisure to achieve any target living standard c. In the second stage, the household chooses the optimal living standard c^* by equating its marginal benefit with its marginal cost. Because reference dependence enters only through the living standard c, the second-stage problem is isomorphic to the baseline model.

This separability has two implications. First, all theoretical results from Section 2—including the asymmetric responses to cost and income shocks and the rollback effects—remain valid. Second, the model remains agnostic about how labor supply responds to shocks, delegating these properties to the home production function $f(e, l)$. For instance, adopting the preference specification proposed by Boppart and Krusell (2020), in which income effects dominate substitution effects, generates declining work hours over time while preserving the fertility predictions derived above.

7 Conclusion

This paper introduces reference dependence into the analysis of fertility choice and demonstrates that loss aversion can account for empirical patterns that standard models cannot explain. The theoretical framework generates two main predictions: fertility responds asymmetrically to shocks that raise versus lower the cost of children or household income, and pro-fertility policies can leave both fertility and welfare below their pre-policy levels through a rollback effect on household expectations.

The empirical evidence supports both predictions. Cross-country and individual-level analyses document substantially larger fertility responses to anti-fertility policies than to pro-fertility ones. Quasi-experimental evidence from Spain shows that the withdrawal of a baby bonus reduced fertility by nearly twice the amount that its introduction raised it. Evidence from Australia reveals asymmetric happiness responses to benefit changes of comparable magnitude. These patterns, combined with existing findings on asymmetric responses to income and wealth shocks, are difficult to reconcile with liquidity constraints, policy asymmetries, or propagation mechanisms alone.

The calibrated model matches the Chinese fertility transition during the rapid-growth era and predicts an accelerated decline when growth slows and households enter the loss domain. Counterfactual exercises attribute a substantial fraction of the projected fertility decline to loss aversion, and stochastic simulations demonstrate that income uncertainty depresses average fertility when households respond asymmetrically to shocks.

These findings carry implications for policy design. Pro-natalist interventions may be most effective during periods when households perceive themselves as falling short of consumption benchmarks. Temporary subsidies risk backfiring if their removal is perceived as a loss relative to elevated expectations. The conventional objective of stabilizing fertility at replacement level may be insufficient when reference dependence exerts persistent downward pressure on births. Governments facing loss-averse populations may need to sustain higher fertility targets or design policies that anchor expectations appropriately.

More broadly, this paper takes a first step toward incorporating expectations and behavioral economics into the study of fertility and demographic change. The demographic literature has long recognized that fertility decisions are forward-looking and shaped by economic circumstances, yet the role of reference points, loss aversion, and expectation formation remains largely unexplored. Behavioral economics has transformed our understanding of savings, labor supply, and consumption, but its insights have scarcely been applied to one of the most consequential household decisions. We argue that this integration is overdue: fertility choices are infrequent, high-stakes, and deeply shaped by perceptions of economic security—precisely the conditions under which reference dependence is likely to matter.

This paper provides a theoretical foundation for this research agenda and offers initial empirical support for its core predictions. Much remains to be done. Future work could incorporate heterogeneity in reference formation and loss aversion across demographic groups, which could sharpen policy targeting and help explain divergent fertility trajectories across socioeconomic strata. Direct measurement of fertility-related expectations through surveys or experimental elicitation would allow researchers to test the mechanism more precisely and to design the symmetric shock comparisons that observational data struggle to deliver. The welfare analysis here treats reference points as given features of preferences; an alternative approach might evaluate policies under the assumption that reference dependence reflects a bias to be corrected. Extending the framework to incorporate social interactions in reference formation could illuminate the role of peer effects and social contagion in fertility dynamics.

We view these extensions as natural next steps building on the framework developed here. The central contribution of this paper is to establish that reference dependence offers a coherent and empirically supported explanation for puzzling features of fertility behavior—asymmetric responses, rollback effects, and the persistent downward pressure on births in slowing economies. Understanding these forces is essential for designing effective policy in an era of widespread demographic decline.

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Appendix

A Proofs

This appendix provides detailed proofs for all lemmas and propositions presented in the main text.

A.1 Proofs of Lemmas

Lemma 1. *Under Assumptions U1, U2, G1, and G2, the household's optimization problem admits a unique interior solution.*

Proof. We begin by reformulating the optimization problem as a single-variable problem in consumption:

$$\max_c U\left(c, \frac{I-c}{\chi}\right) = \max_c u\left(c, \frac{I-c}{\chi}\right) + G(c-r) \quad \text{subject to} \quad I \geq c \geq 0. \tag{38}$$

The second derivative of the objective function with respect to c is

$$\frac{\partial^2 U}{\partial c^2} = u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn} + G''(c-r) = \begin{bmatrix} 1 & -\frac{1}{\chi} \end{bmatrix} \begin{bmatrix} u_{cc} & u_{cn} \\ u_{cn} & u_{nn} \end{bmatrix} \begin{bmatrix} 1 \\ -\frac{1}{\chi} \end{bmatrix} + G''(c-r). \tag{39}$$

By Assumption U1, the quadratic form in equation (39) is negative since the Hessian of u is negative definite. Combined with Assumption G2, we obtain $\frac{\partial^2 U}{\partial c^2} < 0$ for $c \neq r$, and both one-sided second derivatives $\left.\frac{\partial^2 U}{\partial c^2}\right|_+$ and $\left.\frac{\partial^2 U}{\partial c^2}\right|_-$ are strictly negative at $c = r$. By Niculescu and Persson (2006), U is strictly concave in c.

Since the optimization problem has a continuous, strictly concave objective function defined over a convex and compact domain, it admits a unique solution by Boyd and Vandenberghe (2004).

It remains to establish that the solution is interior. The first derivative of U with respect to c is

$$\frac{\partial U}{\partial c} = u_c\left(c, \frac{I-c}{\chi}\right) - \frac{1}{\chi}u_n\left(c, \frac{I-c}{\chi}\right) + G'(c-r). \tag{40}$$

By Assumptions U1 and G1, the Inada conditions and boundedness of G' imply $\lim_{c\to 0} \frac{\partial U}{\partial c} = +\infty$ and $\lim_{c\to I} \frac{\partial U}{\partial c} = -\infty$. By the definition of derivatives, there exists $\epsilon_1 > 0$ such that $U(c') > U(0)$ for all $c' \in (0, \epsilon_1]$, and there exists $\epsilon_2 > 0$ such that $U(c') > U(I)$ for all $c' \in [I - \epsilon_2, I)$. Therefore $c^* \notin \{0, I\}$, confirming that the solution is interior. □

Lemma 2. *Under Assumptions U1, U2, G1, and G2, there is $r \in (0, I)$ such that $c^*(r) = r$.*

Proof. We begin by showing that there is $r \in [0, I]$ such that $c^*(r) = r$. By Lemma 1, for any r, there exists a unique optimal consumption level c^*, which we denote as $c^*(r)$. Since the household's maximization problem has a continuous object function and a compact feasible region independent of r, $c^*(r)$ is continuous in r by Berge's Maximum Theorem. By Brouwer's Fixed Point Theorem, there exists $r \in [0, I]$ such that $c^*(r) = r$. Again by Lemma 1, $c^*(r) \in (0, I)$ for any reference level r. Thus, any r such that $c^*(r) = r$ must satisfy $r \in (0, I)$. We conclude that there exists $r \in (0, I)$ such that $c^*(r) = r$. □

Lemma 3. *Consider any $\{I, \chi, r'\}$ and $\{I, \chi, r''\}$ with $r' \neq r''$. Then $c^*(I, \chi, r'') - c^*(I, \chi, r') \geq 0$ if $r'' > r'$, and $c^*(I, \chi, r'') - c^*(I, \chi, r') \leq 0$ if $r'' < r'$. Moreover, if $c^*(I, \chi, r') = r'$, then $c^*(I, \chi, r'') - c^*(I, \chi, r') > 0$ when $r'' > r'$, and $c^*(I, \chi, r'') - c^*(I, \chi, r') = 0$ when $r'' < r'$.*

Proof. Applying the one-sided implicit function theorem to the first-order condition (5) yields

$$\left.\frac{\partial c^*}{\partial r}\right|_{d_1} = \frac{G''_{d_2}}{u_{cc} + G''_{d_2} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}} \geq 0, \tag{41}$$

where the inequality follows from the second-order condition (6) and Assumption G2. Since equation (41) holds for any r, we have $c^*(I, \chi, r'') - c^*(I, \chi, r') \geq 0$ when $r'' > r'$, and $c^*(I, \chi, r'') - c^*(I, \chi, r') \leq 0$ when $r'' < r'$.

The second-order condition (6) implies $d_2 = d_1$. Consequently, by Assumption G2: (i) $\frac{\partial c^*}{\partial r}\big|_+ = 0$ when $c^* = r$, and $\frac{\partial c^*}{\partial r} = 0$ when $c^* > r$; (ii) $\frac{\partial c^*}{\partial r}\big|_- > 0$ when $c^* = r$, and $\frac{\partial c^*}{\partial r} > 0$ when $c^* < r$. Thus, if $c^*(I, \chi, r') = r'$, then $c^*(I, \chi, r'') - c^*(I, \chi, r') > 0$ when $r'' > r'$, and $c^*(I, \chi, r'') - c^*(I, \chi, r') = 0$ when $r'' < r'$. □

Lemma 4. *Consider any fertility policy implementation and reversal process $\{\chi', \chi'', T_0, T_1\}$. If $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] < \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$, then $r_{T_1} > r_{T_0}$. If $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] > \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$, then $r_{T_1} < r_{T_0}$.*

Proof. Consider the case where $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] < \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$. Note that since $r_{T_0-1} = r_{T_0}$, by Assumption R1, the inequality $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] < \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$ implies $r_{T_0} < r_{T_0+1}$. If $T_1 = T_0 + 1$, the proof is complete.

If $T_1 > T_0 + 1$, observe that by Lemma 3, for any t satisfying $T_0 < t < T_1$, if $r_t \geq r_{T_0}$, then $\mathbb{E}_t[c_{t+1} \mid r = r_t] \geq \mathbb{E}_{T_0}[c_{T_0+1} \mid r = r_{T_0}]$. By Assumption R1, this implies $r_{t+1} \geq r_{T_0+1} > r_{T_0}$. By induction, $r_{T_1} > r_{T_0}$.

The proof for the case $\mathbb{E}_{T_0-1}[c_{T_0}|r = r_{T_0-1}] > \mathbb{E}_{T_0}[c_{T_0+1}|r = r_{T_0}]$ follows by an analogous argument. □

A.2 Proofs of Propositions

Proposition 1 (**Asymmetric Responses to Cost Shocks**). *Under Assumptions U1, U2, G1, and G2, the optimal fertility response to an increase in χ is larger in magnitude than the response to a decrease:*

$$\left.\frac{\partial n^*}{\partial \chi}\right|_+ < \left.\frac{\partial n^*}{\partial \chi}\right|_- \leq 0. \tag{42}$$

Proof. By the law of demand, $\left.\frac{\partial n^*}{\partial \chi}\right|_+ \leq 0$ and $\left.\frac{\partial n^*}{\partial \chi}\right|_- \leq 0$. It remains to show that $\left.\frac{\partial n^*}{\partial \chi}\right|_+ \leq \left.\frac{\partial n^*}{\partial \chi}\right|_-$.

We first establish that $\left.\frac{\partial c^*}{\partial \chi}\right|_- < \left.\frac{\partial c^*}{\partial \chi}\right|_+$. Applying the one-sided implicit function theorem to the first-order condition (5) yields

$$\left.\frac{\partial c^*}{\partial \chi}\right|_{d_1} = \frac{-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}}{u_{cc} + G''_{d_2} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}, \tag{43}$$

where $d_1 \in \{+,-\}$ and $d_2 \in \{+,-\}$. At this stage, the signs of $\left.\frac{\partial c^*}{\partial \chi}\right|_+$ and $\left.\frac{\partial c^*}{\partial \chi}\right|_-$ have not yet been determined. Consequently, whether c^* lies above or below r remains ambiguous, and thus the correspondence between d_1 and d_2 is unclear. Since d_2 depends on d_1, we write $d_2 = d_2(d_1)$ to make this dependence explicit.

From the second-order condition (6), we have $u_{cc} + G''_{d_2} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn} < 0$. Therefore, the sign of $\left.\frac{\partial c^*}{\partial \chi}\right|_{d_1}$ depends solely on the sign of the numerator $-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}$. By Assumption U2, we need to consider two cases.

Case 1: Consumption and fertility are complements. Suppose $-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn} > 0$. Then $\left.\frac{\partial c^*}{\partial \chi}\right|_{d_1} < 0$ for $d_1 \in \{+,-\}$. An example is the utility function $u(c,n) = \log(c + \underline{c}) + \beta \cdot \frac{n^{1-\gamma}-1}{1-\gamma}$ from Greenwood et al. (2005). This implies $d_2(-) = +$ and $d_2(+) = -$. Since the denominator is negative, the numerator is positive, and $G''_- < G''_+$ by Assumption G2, we obtain $\left.\frac{\partial c^*}{\partial \chi}\right|_- < \left.\frac{\partial c^*}{\partial \chi}\right|_+$.

Case 2: Consumption and fertility are substitutes. Suppose $-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}$. Then $\left.\frac{\partial c^*}{\partial \chi}\right|_{d_1} > 0$ for $d_1 \in \{+,-\}$. An example is the CES utility function $u(c,n) = (\delta c^\rho + (1-\delta)n^\rho)^{1/\rho}$ with $\rho < 1$ and $0 < \delta < 1$. This implies $d_2(-) = -$ and $d_2(+) = +$. By the same reasoning as in Case 1, we obtain $\left.\frac{\partial c^*}{\partial \chi}\right|_- < \left.\frac{\partial c^*}{\partial \chi}\right|_+$.

The budget constraint $c^* + \chi \cdot n^* = I$ implies $n^* = \frac{I-c^*}{\chi}$. Differentiating with respect to χ yields

$$\left.\frac{\partial n^*}{\partial \chi}\right|_d = \frac{-\chi \cdot \left.\frac{\partial c^*}{\partial \chi}\right|_d - (I - c^*)}{\chi^2}. \tag{44}$$

Therefore

$$\left.\frac{\partial n^*}{\partial \chi}\right|_+ - \left.\frac{\partial n^*}{\partial \chi}\right|_- = \frac{-\left.\frac{\partial c^*}{\partial \chi}\right|_+ + \left.\frac{\partial c^*}{\partial \chi}\right|_-}{\chi}. \tag{45}$$

Under Cases 1 and 2, $\left.\frac{\partial n^*}{\partial \chi}\right|_+ - \left.\frac{\partial n^*}{\partial \chi}\right|_- < 0$.

□

Proposition 2 (**Asymmetric Responses to Income Shocks**). *Under Assumptions U1, U2, G1, and G2, the fertility response to a negative income shock exceeds the response to a positive shock:*

$$\left.\frac{\partial n^*}{\partial I}\right|_- > \left.\frac{\partial n^*}{\partial I}\right|_+ . \tag{46}$$

Moreover, fertility is a normal good if $\chi\left(u_{cc} + G''\right) < u_{cn}$.

Proof. Applying the one-sided implicit function theorem to the first-order condition (5) yields

$$\left.\frac{\partial c^*}{\partial I}\right|_{d_1} = \frac{-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}{u_{cc} + G''_{d_2} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}. \tag{47}$$

Following a similar argument to Proposition 1, we consider two cases.

Case 1: Consumption is an inferior good. Suppose $-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn} > 0$. Then $\left.\frac{\partial c^*}{\partial I}\right|_{d_1} < 0$ for $d_1 \in \{+, -\}$. This implies $d_2(-) = +$ and $d_2(+) = -$. An example is the Cobb–Douglas utility function $u(c, n) = c^\alpha n^{1-\alpha}$ with $0 < \alpha < 1$. Since the denominator is negative, the numerator is positive, and $G''_- < G''_+$, we obtain $\left.\frac{\partial c^*}{\partial I}\right|_- < \left.\frac{\partial c^*}{\partial I}\right|_+$.

Case 2: Consumption is a normal good. Suppose $-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn} < 0$. Then $\left.\frac{\partial c^*}{\partial I}\right|_{d_1} > 0$ for $d_1 \in \{+, -\}$. This implies $d_2(-) = -$ and $d_2(+) = +$. An example is $u(c, n) = \ln(c + a) + \ln(n)$ with $a > 0$ and $I > \chi^2 a$. By the same reasoning, $\left.\frac{\partial c^*}{\partial I}\right|_- < \left.\frac{\partial c^*}{\partial I}\right|_+$.

The budget constraint $c^* + \chi \cdot n^* = I$ implies $n^* = \frac{I - c^*}{\chi}$. Differentiating with respect to I yields

$$\left.\frac{\partial n^*}{\partial I}\right|_d = \frac{1 - \left.\frac{\partial c^*}{\partial I}\right|_d}{\chi}, \tag{48}$$

which is decreasing in $\left.\frac{\partial c^*}{\partial I}\right|_d$. Under Cases 1 and 2, $\left.\frac{\partial n^*}{\partial I}\right|_- > \left.\frac{\partial n^*}{\partial I}\right|_+$.

For the second part of the proposition, note that $\left.\frac{\partial n^*}{\partial I}\right|_+ > 0$ if and only if $\left.\frac{\partial c^*}{\partial I}\right|_+ < 1$. This condition holds trivially under Case 1. Under Case 2, the second-order condition (6) implies that $\left.\frac{\partial c^*}{\partial I}\right|_+ < 1$ is equivalent to $u_{nn} - \chi u_{cn} > \chi^2 u_{cc} - 2\chi u_{cn} + u_{nn} + \chi^2 G''$, or, $\chi\left(u_{cc} + G''\right) < u_{cn}$. Therefore, the stated condition implies $\left.\frac{\partial n^*}{\partial I}\right|_+ > 0$. □

Proposition 3 (**Monotonicity of Asymmetry in Loss Aversion**). *Under Assumptions U1, U2, G1, and G2, holding $G'(0)$ and $G''_+(0) + G''_-(0)$ constant, at the same consistency point $c^* = r$, the asymmetry gaps satisfy:*

(i) $\Delta_\chi(\alpha) > 0$ *and* $\frac{\partial \Delta_\chi}{\partial \alpha} > 0$ *for all* $\alpha > 0$*;*

(ii) $\Delta_I(\alpha) > 0$ *and* $\frac{\partial \Delta_I}{\partial \alpha} > 0$ *for all* $\alpha > 0$*;*

(iii) $\Delta_\chi(0) = \Delta_I(0) = 0$ *when* $\alpha = 0$*.*

Proof. We prove part (i); part (ii) follows by analogous arguments, and part (iii) is immediate from the symmetry of G when $\alpha = 0$.

Applying the one-sided implicit function theorem to the first-order condition (5) yields

$$\left.\frac{\partial c^*}{\partial \chi}\right|_{d_1} = \frac{-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}}{u_{cc} + G''_{d_2} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}, \tag{49}$$

thus,

$$\Delta_\chi(\alpha) = \left| \left.\frac{\partial n^*}{\partial \chi}\right|_+ - \left.\frac{\partial n^*}{\partial \chi}\right|_- \right| \tag{50}$$

$$= \frac{1}{\chi}\left| \frac{\left(-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}\right)(G''_+ - G''_-)}{\left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)^2 + \left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)(G''_- + G''_+) + G''_- G''_+} \right| \tag{51}$$

$$= \frac{1}{\chi}\frac{\left|-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}\right|\alpha}{\left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)^2 + \left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)(G''_- + G''_+) + G''_- G''_+} \tag{52}$$

$$= \frac{1}{\chi}\frac{\left|-\frac{u_n}{\chi^2} + \frac{I-c^*}{\chi^2}u_{cn} - \frac{I-c^*}{\chi^3}u_{nn}\right|\alpha}{\left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)^2 + \left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)(G''_- + G''_+) + \frac{1}{4}(G''_- + G''_+)^2 - \frac{1}{4}\alpha^2} \tag{53}$$

where the third equality follows since $\alpha \geq 0$ and $\left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)^2 + \left(u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right)(G''_- + G''_+) + G''_- G''_+ > 0$; the fourth equality follows from the definition of α. Since (1) both the denominator and numerator are non-negative; (2) the denominator is decreasing in α, while the numerator is increasing in α, we conclude that $\frac{\partial \Delta_\chi}{\partial \alpha} > 0$. By (iii), it follows that $\Delta_\chi > 0$ for any $\alpha > 0$.

□

Proposition 4 (**Convergence to the Consistent Reference Level**)**.** *Suppose the reference updating function* $r(x, y)$ *satisfies Assumption R1 and* $r_x(x, y) + r_y(x, y) \leq 1$ *for all* (x, y)*. Then, for any combination of* $\{\chi, I\}$*, the individual's reference level converges to the unique consistent level* $c^*(r) = r$*.*

Proof. Define $h(x) = r(x, c^*(x))$, where $c^*(x)$ is optimal consumption under reference level x. By Berge's Maxmization Theorem, $c^*(x)$ is continuous in x, which in turn implies $h(x)$'s continuity by $r(x, y)$'s continuity. And by one-sided implicit function theorem:

$$\left| \frac{\partial c^*}{\partial r}\bigg|_{d_1} \right| = \frac{\left|G''_{d_2}\right|}{\left|u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn} + G''_{d_2}\right|} \tag{54}$$

$$= \frac{\left|G''_{d_2}\right|}{\left|u_{cc} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}\right| + \left|G''_{d_2}\right|} \tag{55}$$

$$\in [0, 1) \tag{56}$$

□

where the second equality follows from the second order condition (6) and Assumption G2. Now:

$$|h'(x)_d| = \left| r_x + r_y \frac{\partial c^*}{\partial r}\bigg|_d \right| \tag{57}$$

$$\leq r_x + r_y \left| \frac{\partial c^*}{\partial r}\bigg|_d \right| \tag{58}$$

$$< r_x + r_y \tag{59}$$

$$\leq 1 \tag{60}$$

since $r_x > 0$, $r_y > 0$, $\left| \frac{\partial c^*}{\partial r}\big|_{d_1} \right| \in [0, 1)$ and $r_x + r_y \leq 1$. By Banach Fixed-Point Theorem, individual's reference level eventually converges to the unique fixed point x^* such that $x^* = h(x^*) = r(x^*, c^*(x^*))$, in despite of the initial reference level. Moreover, by Lemma 2 and Assumption R1, there exists x' such that $x' = r(x', c^*(x')) = r(x', x')$, i.e., the consistent point coincides with the unique fixed point.

Proposition 5 (**Rollback Effect on Fertility**). *Assume income is constant at $I_t = \bar{I}$. Under any fertility policy implementation and reversal process, $n^*_{T_1} \leq n^*_{T_0-1}$. The inequality is strict if $c^*(I, \chi', r_{T_0}) < c^*(I, \chi'', r_{T_0})$.*

Proof. By Assumption UG1, $\mathbb{E}_{T_0-1}[\chi_{T_0}] \neq \mathbb{E}_{T_0}[\chi_{T_0+1}]$. By Lemma 4, this implies either $r_{T_1} > r_{T_0}$ or $r_{T_1} < r_{T_0}$. By Lemma 3, $c^*_{T_1} \geq c^*_{T_0-1}$. Since $I_t = \bar{I}$ for all t, this is equivalent to $n^*_{T_1} \leq n^*_{T_0-1}$.

For the second part, note that $\mathbb{E}_{T_0-1}[c_{T_0}] - \mathbb{E}_{T_0}[c_{T_0+1}] = c^*(I, \chi', r_{T_0}) - c^*(I, \chi'', r_{T_0}) < 0$. By Lemma 4, $r_{T_1} > r_{T_0}$. By Lemma 3, $c^*_{T_1} > c^*_{T_0-1}$, which implies $n^*_{T_1} < n^*_{T_0-1}$. □

Proposition 6 (**Rollback Effect on Welfare**). *Assume income is constant at* $I_t = \bar{I}$ *and Assumption UG2 holds. Define* U_t^* *as the utility level given* $\{c^*(I, \chi_t, r_t), n^*(I, \chi_t, r_t), r_t\}$. *Under a pro-fertility policy implementation and reversal process,* $U_{T_1}^* < U_{T_0-1}^*$; *under an anti-fertility policy implementation and reversal process,* $U_{T_1}^* > U_{T_0-1}^*$.

Proof. By Assumption UG2 and Lemma 4, $r_{T_1} > r_{T_0-1}$ under a pro-fertility policy implementation and reversal process, while $r_{T_1} < r_{T_0-1}$ under an anti-fertility policy implementation and reversal process. Since $\frac{\partial U}{\partial r} = -G'(c - r) < 0$, the inequality $r_{T_1} > r_{T_0-1}$ implies $U_{T_1}^* < U_{T_0-1}^*$, and $r_{T_1} < r_{T_0-1}$ implies $U_{T_1}^* > U_{T_0-1}^*$. $\square$

B Additional Empirical Results

This appendix presents additional empirical evidence supporting the model's predictions.

B.1 Heterogeneity in the Effect of Fertility Policies

In this Section, we test the heterogeneity of fertility policy's effect across different demographic groups using the WVS dataset. The specification is as follows:

$$\begin{aligned}\text{Children}_{icbt} = \alpha + \beta_1 \text{Policy\_Lower}_{cb} + \beta_2 \text{Policy\_Lower}_{cb} \times \text{Demographic}_i + \beta_3 \text{Policy\_Raise}_{cb} + \\ \beta_4 \text{Policy\_Raise}_{cb} \times \text{Demographic}_i + \beta_5 \text{Demographic}_i + \eta \text{Age}_i + \gamma_{ct} + \delta_b + \epsilon_{icbt},\end{aligned} \tag{61}$$

where i indexes individuals, c indexes countries, b denotes the individual's birth year, and t is the survey year. The dependent variable Children_{icbt} measures the number of children of respondent i. The term Age_i is age-group fixed effect. The terms γ_{ct} and δ_b represent country-by-survey-year and birth-year fixed effects, respectively. The independent variables of main interest include policy exposure Policy_Lower_{cb} and Policy_Raise_{cb}, as well as their interaction with demographic variables.

Table A1 reports the results. In column 1, we use self-reported income deciles as Demographic_i; in column 2, we use indicators of education level as Demographic_i, with the lower-education group omitted as the reference category. The results indicate that the asymmetry in responses to fertility policies is more pronounced among individuals with higher income or higher levels of education.

B.2 Alternative Policy Time Window

In this section, we show that the empirical results in Section 3.1 are robust to alternative constructions of the policy exposure variables. In Figure A1, we replicate the results in column 1 of Table 1, while varying N from 1 to 10 in the construction of Policy_Lower_{ct} and Policy_Raise_{ct}. Similarly, in Figure A2, we replicate the results in column 3 of Table 1, assuming that MAC is the same across cohorts and varying it between 20 and 30. Across all these specifications, anti-fertility policies are associated with larger changes in fertility rates than pro-fertility policies.

Table A1. Asymmetric Fertility Effects of Fertility Policies-heterogeneity

Dependent Variable	Completed Fertility	
	(1)	(2)
Exposure to Anti-Fertility Policies	0.1760 (0.2777)	-0.5212*** (0.2020)
Exposure to Anti-Fertility Policies #Income	-0.1891*** (0.4401)	
Exposure to Anti-Fertility Policies #Middle Education		-0.2743 (0.2278)
Exposure to Anti-Fertility Policies #Upper Education		-0.6349** (0.2764)
Exposure to Pro-Fertility Policies	0.1359 (0.5546)	-0.1261 (0.4025)
Exposure to Pro-Fertility Policies #Income	-0.0116 (0.0971)	
Exposure to Pro-Fertility Policies #Middle Education		0.5344 (0.4593)
Exposure to Pro-Fertility Policies #Upper Education		0.3273 (0.4635)
Baseline Controls	Yes	Yes
Endogenous Controls	No	No
Observations	59840	59840
R-Squared	0.291	0.310

Notes: This table reports the association between fertility policy stances and completed fertility rate among individuals with different . Anti-fertility ("lower") and pro-fertility ("raise") policies are measured as cumulative exposure over the previous five years. A cohort-exposure design is adopted, with completed fertility rate as dependent variable. Income is measured as self-reported deciles. Baseline controls include country-survey year fixed effect, age fixed effect and birth year fixed effect. Standard errors, reported in parentheses, are clustered at country-survey year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B.3 Selection into Treatment

In this section, we provide evidence that the results in Table 1 are not driven by cross-country differences in initial conditions. Specifically, Table A2 shows that the asymmetric effects of fertility policies persist in countries with different initial fertility rates and levels of economic development. Thus, it is unlikely that selection into treatment according to countries' initial conditions drive our results.

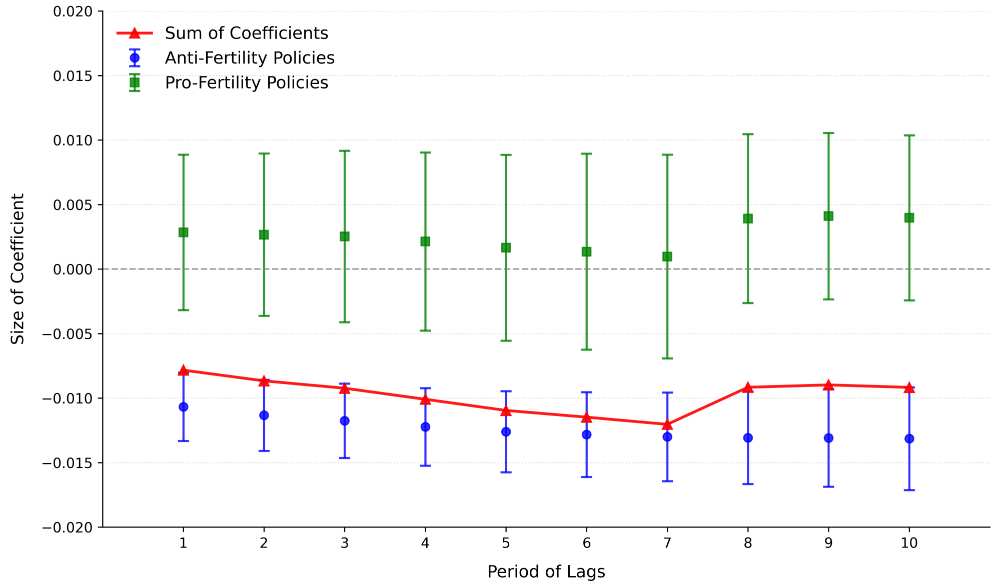

Figure A1. Alternative Measure of Country-Level Policy Exposure

Notes: The figure replicates results in column 1 of Table 1, while varying N from 1 to 10 in the construction of Policy_Lower$_{ct}$ and Policy_Raise$_{ct}$. Point estimates, 95% confidence intervals, and sums of coefficients are plotted in the figure.

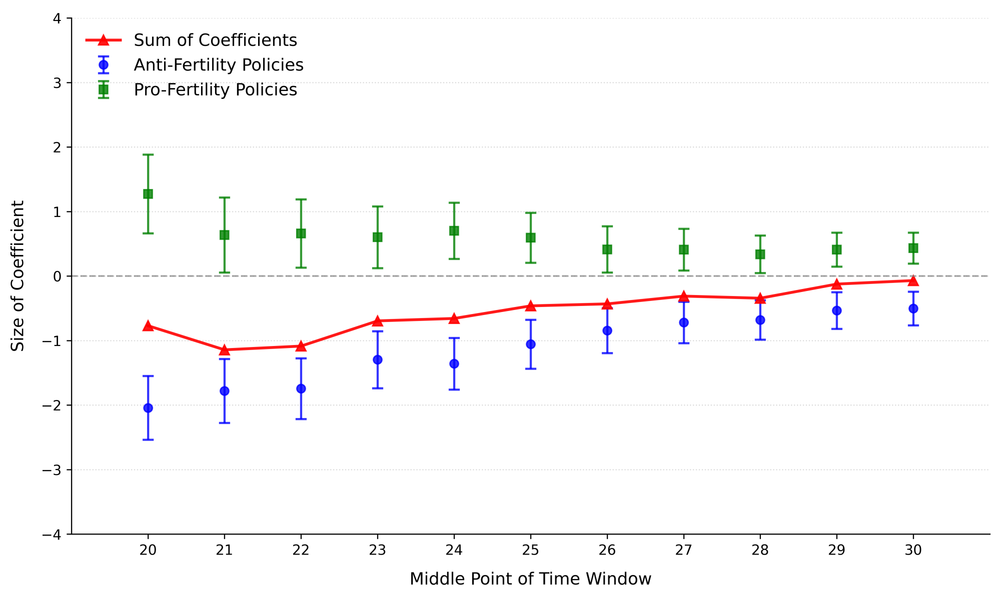

Figure A2. Alternative Measure of Individual-Level Policy Exposure

Notes: The figure replicates results in column 3 of Table 1, assuming that MAC is the same across cohorts and varying it between 20 and 30 in the construction of Policy_Lower$_{ct}$ and Policy_Raise$_{ct}$. Point estimates, 95% confidence intervals, and sums of coefficients are plotted in the figure.

Table A2. Asymmetric Fertility Effects of Fertility Policies within Different Sub-samples

Panel A: Subsample by TFR in 1960				
Dependent Variable	Growth Rate of Total Fertility Rate		Completed Fertility	
Sample	>medium	≤medium	>medium	≤medium
	(1)	(2)	(3)	(4)
Exposure to Anti-Fertility Policies	-0.0077***	-0.0180***	-0.2463	-1.4974***
	(0.0021)	(0.0033)	(0.2451)	(0.4194)
Exposure to Pro-Fertility Policies	0.0002	0.0004	-0.1659	-0.0793
	(0.0057)	(0.0057)	(0.7036)	(0.2535)
Observations	3723	3098	23049	36791
R-Squared	0.321	0.128	0.209	0.227
Panel B: Subsample by GDP per capita in 1960				
Dependent Variable	Growth Rate of Total Fertility Rate		Completed Fertility	
Sample	>medium	≤medium	>medium	≤medium
	(1)	(2)	(3)	(4)
Exposure to Anti-Fertility Policies	-0.0073*	-0.0115***	-1.2150***	-0.3771
	(0.0038)	(0.0025)	(0.3739)	(0.2337)
Exposure to Pro-Fertility Policies	-0.0007	0.0023	-0.1537	0.6838
	(0.0054)	(0.0054)	(0.2637)	(0.5233)
Observations	3637	3184	35106	24734
R-Squared	0.122	0.316	0.240	0.262
Baseline Controls	Yes	Yes	Yes	Yes
Endogenous Controls	No	No	No	No

Notes: This table replicates the result in columns 1 and 3 in Table 1, while uses different sub samples. Panel A divides sub samples into countries with total fertility rate higher than medium in 1960 and lower than medium in 1960; Panel B divides sub samples into countries with GDP per capita higher than medium in 1960 and lower than medium in 1960. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B.4 Additional Evidence on Fertility Rollback Effect

In this section, we extend González and Trommlerová (2023)'s result to a broader set of countries. The empirical strategy is as follows:

$$\frac{\Delta \text{TFR}_{ct}}{\text{TFR}_{c,t-1}} = \alpha + \sum_{i,j \in \{\text{Lower,Raise,No Intervention/Maintain}\}} \beta_{ij} \mathbb{1}(\text{Policy}_{ct-1} = i) \times \mathbb{1}(\text{Policy}_{ct} = j) + \gamma_c + \delta_t + \epsilon_{ct}, \tag{62}$$

where i is the policy stance in country c, year $t-1$, and j is the policy stance in country c, year t. β_{ij} represents the fertility change associated with current policy stance j conditional on previous policy stance i. The result is presented in Table A3. Similar to the results from González and Trommlerová (2023), implementation of a anti-fertility policy significantly reduces fertility rate, while its reversal doesn't result in a corresponding recover in fertility level.

Table A3. Asymmetric Response to Policy Implementation and Reversal

This Period \ Last Period	No Intervention / Maintain	Lower	Raise
No Intervention / Maintain		0.0012	0.0002
		(0.0043)	(0.0053)
Lower	-0.0069***	-0.0111***	-0.0095***
	(0.0024)	(0.0016)	(0.0034)
Raise	0.0013	0.0124***	0.0030
	(0.0045)	(0.0022)	(0.0038)

Notes: This table reports the fertility change associated with different combinations of current and lagged fertility policy stances. We use country-year panel data with country and year fixed effects. Standard errors are reported in parentheses and are clustered at the country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C Additional Theoretical Results

This appendix presents additional theoretical results.

C.1 Income-dependent Child Cost

In this subsection, we show that our theoretical results hold when allowing child cost to be a weakly increasing function of income:

$$\chi = \chi(I) \tag{63}$$

with $\chi(I) > 0$ and $\chi'(I) \geq 0$ for any I. A special case for $\chi(I)$ satisfying these assumptions is that $\chi(I) = \overline{\chi} I$ for some constant $\overline{\chi} > 0$. Clearly, when I is hold constant, whether allowing χ to depend on I doesn't affect our analysis. For the only proposition in which I is not held constant, i.e., Proposition 2, we establish the following result:

Proposition (Asymmetric Responses to Income Shocks with Income-dependent Child Cost). *Under Assumptions of Proposition 2 and income-dependent child cost $\chi(I)$ such that $\chi(I) > 0$ and $\chi'(I) \geq 0$ for any I, the fertility response to a negative income shock exceeds the response to a positive shock:*

$$\left.\frac{\partial n^*}{\partial I}\right|_- > \left.\frac{\partial n^*}{\partial I}\right|_+ . \tag{64}$$

Proof. Note:

$$\left.\frac{\partial n^*}{\partial I}\right|_- - \left.\frac{\partial n^*}{\partial I}\right|_+ \tag{65}$$

$$= \frac{-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}{u_{cc} + G''_{d_2(-)} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}} - \frac{-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}{u_{cc} + G''_{d_2(+)} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}} + \chi'(I)\left(\left.\frac{\partial n^*}{\partial \chi}\right|_- - \left.\frac{\partial n^*}{\partial \chi}\right|_+\right) \tag{66}$$

$$\geq \frac{-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}{u_{cc} + G''_{d_2(-)} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}} - \frac{-\frac{1}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}}{u_{cc} + G''_{d_2(+)} - \frac{2}{\chi}u_{cn} + \frac{1}{\chi^2}u_{nn}} \tag{67}$$

$$> 0 \tag{68}$$

where the first inequality follows from Proposition 1 and the fact that it holds with income-dependent child cost, and the second inequality follows from Proposition 2.

□