LONGEVITY AS A REAL OPTION: VALUING FLEXIBILITY IN LIFE-CYCLE FINANCIAL DECISIONS

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Increasing longevity fundamentally reshapes individual life-cycle decisions by extending planning horizons while simultaneously amplifying uncertainty related to health, income, and employment trajectories. This paper argues that longevity can be conceptualized as a real option that enhances the value of flexibility in long-term personal and financial decision-making. Building on the real options framework, we interpret key life-cycle choices as sequential decisions under uncertainty with embedded options to wait, expand, switch, or abandon. Longer expected lifespans increase the payoff horizon of these options, thereby raising their economic value and altering optimal timing strategies. We demonstrate how rising longevity intensifies the option value of deferred irreversible commitments, particularly in decisions involving substantial sunk costs and long-term payoffs. Drawing parallels with existing applications of real options in fertility and divorce decisions, we extend the framework to longevity-related investments such as preventive healthcare, lifelong learning, and phased retirement. Our contribution lies in reframing longevity not merely as a demographic or actuarial phenomenon, but as a source of economic flexibility that can be priced using financial option theory. The paper opens new avenues for interdisciplinary research connecting financial economics, health economics, and behavioural life-cycle theory, with policy implications for pension systems, labour markets, and individual financial planning in ageing societies.

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1 Introduction

Modern societies are entering an era of significantly longer lives. Global average life expectancy at birth has more than doubled, rising from about 32 years in 1900 to roughly 73 years by 2023 (Riley, 2005; Zijdeman et al., 2015; HMD, 2025; UN WPP, 2024). As people live longer, they face extended planning horizons for careers, family life, and retirement. These longer lifespans can be a blessing, but they also amplify uncertainties about health, income, and life events throughout the lifespan. Individuals must make crucial life-cycle decisions (when to have children, how long to work, when to retire, etc.) under increased uncertainty and over a longer timeframe than ever before. Longevity gains are already reshaping the economic environment in which life-cycle decisions are made. One implication is an ageing workforce: for example, Allianz projects that around 30% of the global workforce could be aged 50+ by 2050, increasing the salience of mid- and late-career transitions, phased retirement, and retraining (Grimm & Holzhausen, 2023). In parallel, the United Nations expects the number of older persons to rise sharply in the coming decades, reinforcing the policy relevance of how individuals adapt their work and saving trajectories across longer lives (UNFPA, 2024).

Classic life-cycle economics has long incorporated lifespan uncertainty—most famously by modelling mortality risk and its implications for consumption, saving, and insurance demand (Yaari, 1965; Modigliani & Brumberg, 1954; De Nardi et al., 2009). However, many economically consequential life choices are not continuous or frictionless controls, but rather take the form of discrete, sequential commitments involving substantial irreversibility or high adjustment costs.

This is precisely the decision structure emphasized by the real options framework, which models the economic value of flexibility under uncertainty and irreversibility (Dixit & Pindyck, 1994; Trigeorgis, 1996). In such contexts, the option to delay commitment, acquire additional information, or preserve strategic flexibility can be quantified and often justifies deviation from traditional net-present-value (NPV) rules. Foundational research in real options shows that when actions are costly to reverse and payoffs are uncertain, waiting—rather than acting immediately—can hold significant economic value (McDonald & Siegel, 1986). As such, integrating real options into life-cycle decision models provides a richer lens to analyze intertemporal choices under rising longevity and pervasive uncertainty.

Building on this perspective, major life-cycle decisions can be viewed as bundles of embedded options—rights without obligations—to wait, expand, switch, or abandon (Dixit & Pindyck, 1994). Longer lifespans extend the horizon over which these options may be exercised, thereby increasing the economic value of flexibility. Individuals gain more time to observe, adjust, and time irreversible commitments prudently, a mechanism especially relevant under uncertainty and rising longevity.

To make this argument empirically tractable, we define two constructs used throughout the paper. We use the term longevity effect to denote an outward shift in the survival profile that increases the expected remaining lifetime at a given age *a* (or, equivalently, raises survival probabilities over future horizons). In empirical work, this can be operationalized as objective remaining life expectancy at age *a*, cohort- or region-level survival improvements, or subjective survival probabilities reported in surveys. We define option lifetime as the time window during which an embedded life-cycle option remains meaningfully exercisable. This window may be bounded by biological constraints (e.g., fertility), institutional constraints (e.g., statutory retirement rules, eligibility ages), market constraints (e.g., contract features such as annuity lock-ins), or by the economically relevant payoff horizon (e.g., remaining working-life expectancy). Our central mechanism is that an increase in the longevity effect extends the payoff horizon and/or the exercisable window, thereby increasing the value of flexibility in sequential decisions under uncertainty and partial irreversibility.

The idea for this paper emerged from the conference call's motivation to connect real options reasoning with demographic and life-cycle choices. While real options methods are well established in investment theory, their demographic and household applications often appear as dispersed "micro-applications," each tied to a specific decision domain. We therefore aim to systematically identify the life-cycle decisions where option-like flexibility is economically meaningful, and to ask what changes when one of the key parameters, the effective time horizon, expands. This framing also complements a broader strand of work that encourages viewing longer lives not only as a fiscal or demographic burden but also as a potential source of social and economic gains (e.g., via healthier aging and extended productive capacity).

Methodologically, the paper is conceptual and synthesizing. We build an integrative framework that connects real options valuation logic to life-cycle economics, demography, and behavioural life-cycle theory. Rather than estimating a fully structural model in this contribution, we provide an organizing map of longevity-relevant life-cycle choices and the associated option types, intended to support subsequent theoretical and empirical studies that can quantify option values and welfare implications in specific contexts.

The remainder of the paper is structured as follows. Section 2 introduces real options as a decision framework and summarizes the option types most relevant for life-cycle choices. Section 3 develops the conceptual longevity-based life-cycle valuation perspective. The chapter also synthesizes the framework, mapping major life-cycle decisions to embedded option types and their key uncertainties and irreversibilities.

2 Real option theory as a decision framework

Real options theory emerged from the economics of investment under uncertainty, where the ability to wait, expand, contract, switch, or abandon projects holds quantifiable value beyond traditional net present value (NPV) logic (Dixit & Pindyck, 1994; Trigeorgis, 1996). A central insight is that when decisions involve sunk costs or partial irreversibility, and when future payoffs are uncertain, the decision-maker effectively holds a portfolio of rights without obligations. The option value of deferral increases with volatility, the scale of irreversibility, and the time flexibility available for optimal timing. This framework provides a dynamic alternative to static valuation approaches, emphasizing strategic flexibility under uncertainty.

Beyond the canonical option to wait (i.e., deferral or timing flexibility), real options theory distinguishes a range of option types that reflect different forms of strategic and operational flexibility under uncertainty. These options represent rights—but not obligations—to act, and become especially valuable when decisions involve irreversibility and informational asymmetries (Trigeorgis, 1996; Csapi, 2018).

Table 1: Typology of Real Options by Flexibility and Strategic Orientation

	Timing Flexibility	Operational Flexibility
Growth-Oriented Real Options	(1) Postponement/Timing Option	(2) Growth Option
Learning-Oriented Real Options	(3) Abandonment Option (4) Staging Option	(5) Pilot Option
Insurance-Oriented Real Options	(6) Switch off/on Option	(7) Option to contract/expand (8) Switching Option (Input/Output/Supplier) (9) Outsourcing Option

Source: own compilation based on Csapi (2018)

A widely used typology classifies real options along two axes: timing flexibility and operational flexibility. Within this structure, growth-oriented options include the right to delay commitment (postponement) or to expand activities if conditions become favourable. Learning-oriented options involve staged investment and abandonment choices that allow for feedback and revision as uncertainty resolves. Finally, insurance-oriented options enable partial reversibility—such as scaling operations up or down, switching inputs or outputs, or suspending and restarting a commitment.

These categories are summarized in Table 1 and provide a conceptual foundation for understanding real-world decisions in uncertain, dynamic environments. The value of a real option is influenced by several key factors, many of which mirror those in financial option theory. Among these, uncertainty (volatility), irreversibility (sunk costs), and time are especially central (Copeland & Antikarov, 2003; Amram & Kulatilaka, 1999). Crucially, time, defined as the duration over which the option remains exercisable, plays a pivotal role. The longer the time horizon, the greater the potential to wait for favourable information and defer irreversible commitments, thereby enhancing option value (Csapi, 2018). Longer time frames also allow more learning and adjustment, making flexibility more valuable in dynamic environments. Time matters through the option lifetime (T), defined as the length of the decision window over which an option can be optimally exercised. In life-cycle contexts, T is not purely technical: it is shaped by biological, institutional, and contractual boundaries, and it can be proxied by remaining (working-)life expectancy or by policy-defined eligibility windows. Holding uncertainty and irreversibility fixed, a longer T mechanically increases the value of waiting, learning, and staged commitment.

Mini-case A stylized longevity channel in option value (illustrative calibration)

Consider a life-cycle commitment that requires an irreversible cost K (e.g., annuitization, a major retraining program, a preventive-health investment) and yields a stochastic benefit value S. The individual holds an option to commit at the optimally chosen time before an effective expiry T, interpreted here as the option lifetime (the economically relevant window over which committing still matters).

A standard approximation is to value this flexibility as a call option on S with strike K (Black – Scholes, 1973): $C = S_0\, N(d_1) - K\, e^{(-rT)}\, N(d_2)$,
where $d_1 = [\ln(S_0/K) + (r + 0.5\sigma^2)T] / (\sigma\sqrt{T})$ and $d_2 = d_1 - \sigma\sqrt{T}$,
with r the discount rate and σ capturing payoff uncertainty.

Let S0 = 100, K = 100, r = 0.02, σ = 0.25. Then C increases with T:

T = 10 → C ≈ 37.9

T = 20 → C ≈ 53.9

T = 30 → C ≈ 64.8

Thus, extending the effective horizon by 10 years raises the value of flexibility by roughly 11 (from 53.9 to 64.8) under these parameters. This mini-case illustration mirrors: longevity extends the option lifetime and/or payoff horizon, which increases the economic value of waiting, learning, and staged commitment when decisions are uncertain and partially irreversible.

3 Life-cycle decisions as real options

Although most canonical treatments of real options focus on firm-level investment decisions, the logic is highly portable. Kogut and Kulatilaka (2001) emphasize that a real option can be interpreted as an investment in physical or human assets that enables future responsiveness to uncertainty. This interpretation is especially compelling in life-cycle contexts, where many decisions—such as education, fertility timing, occupational specialization, marriage, or retirement—are sequential, information-sensitive, and partially irreversible. In such domains, flexibility and timing are crucial economic levers, and the option to defer or adapt can significantly shape outcomes over the long term.

A wide range of pivotal life-cycle choices can be interpreted as real options, because they are sequential rather than one-shot, subject to learning about future states (health, income, relationship quality, labor-market conditions), and involve partial irreversibility and sunk costs (time, foregone earnings, relationship-specific investments). In such settings, individuals effectively hold option-like rights, whose value increases with uncertainty and with the time available for optimal timing. Within a longevity context, these option features become even more salient. A longer expected life increases the "runway" for learning and adjustment, thereby raising the economic value of prudent timing and staged commitment: individuals can wait longer before exercising irreversible choices, expand only when the state improves, switch paths when comparative advantages evolve, and abandon unfavourable commitments earlier without forfeiting the possibility of building value elsewhere over a longer remaining horizon.

Mapping real-life cycle decisions, like fertility timing, retirement, human capital accumulation onto the framework of Table 1 reveals how rising longevity tends to extend the option horizon, thereby increasing the value of flexibility across these domains. In what follows, we examine each of these real option categories in greater depth, focusing on how longevity enhances their relevance and payoff structure in sequential household and life-cycle contexts.

3.1 Fertility Timing

Childbearing decisions exhibit a real option structure. Prospective parents face uncertainty regarding income, employment security, partnership stability, and long-term health, while the timing of childbirth remains, to some extent, discretionary. In such contexts, the option to wait represents a valuable form of flexibility, allowing individuals to defer an irreversible commitment until uncertainty resolves. Bhaumik and Nugent (2005) formalize this logic by distinguishing two opposing effects: a positive insurance effect, where higher uncertainty incentivizes earlier fertility as a hedge against future instability, and a negative option-value effect, where uncertainty increases the value of delay. Using the natural experiment of German reunification, they find that in an environment with a robust welfare safety net—where the insurance motive is plausibly muted—the option-value effect dominates. Their empirical results show that heightened uncertainty was associated with delayed or foregone fertility.

This finding supports the broader argument that as expected lifespan increases, the temporal horizon for exercising such options lengthens, raising the economic value of postponement. In the fertility domain, this means that individuals with longer planning horizons can rationally delay childbearing to better align with future information—such as improved labor market prospects, partner stability, or health status—without sacrificing the opportunity entirely. The real option to wait becomes more valuable precisely because longevity allows for more flexibility in life-cycle sequencing under uncertainty.

3.2 Retirement timing choices

Retirement and decumulation decisions are prototypical examples of timing problems under uncertainty. The canonical "option value of work" framework conceptualizes continued employment as preserving the right—but not obligation—to retire at a future date, while wages and pension entitlements evolve stochastically (Stock & Wise, 1990). In this model, the value of working an additional year stems not only from accrued benefits but from maintaining flexibility in the face of uncertain future states.

Retirees often treat the decision of when and how much to annuitize their savings as a real option, due to the largely irreversible nature of annuity purchases. Converting a lump sum into a guaranteed lifetime income is typically a one-time, irreversible choice – once wealth is annuitized, it cannot be readily taken back or reallocated. This irreversibility means there is value in waiting to annuitize, similar to holding an option until more information is available. In other words, delaying annuitization preserves financial flexibility and the ability to adapt to new information (such as changes in health status or interest rates. Milevsky and Young (2001) interpret annuitization as an irreversible financial commitment with an embedded real option. Although immediate annuitization may offer actuarially fair value, deferral can be optimal because it preserves exposure to higher expected returns and provides time to learn about investment markets and personal health status. The annuity purchase resembles a real option in that delaying its exercise has measurable value, especially when volatility and uncertainty are high.

3.3 Human capital, career (re)investment, and lifelong learning

Human-capital theory implies that the timing of skill investment depends on the horizon over which returns can be recouped: a longer remaining work life raises incentives to invest in training and education (Ben-Porath, 1967). A longevity-driven extension follows directly: if longer lives translate into longer potential working lives (or longer periods over which skills generate returns), then retraining, reskilling, and career switching can be interpreted as option-like investments whose value rises with the extended payoff horizon. Recent evidence is consistent with this horizon channel. Pension reforms that increase the residual working horizon causally raise training participation among older workers, suggesting that extending the expected work horizon shifts optimal training incentives upward (Brunello & Comi, 2015; Chinetti, 2024; Fürstenau et al., 2023). Empirically, the adult-learning literature further indicates that returns to adult and vocational qualifications exist but vary substantially across routes, populations, and institutional settings—an environment where postponement, staging, and switching strategies become especially decision-relevant (Bratsberg et al., 2020; Blundell et al., 2021; Leuven, 2005). In this paper, we accordingly treat lifelong learning, mid-career retraining, and career transitions as option-like strategies that preserve adaptability to uncertain labour-market and health trajectories.

3.4 Health investment decisions

A longer life span changes the intertemporal calculus of investing in oneself through education and health, because these choices typically require upfront, partly sunk costs (time, tuition, effort) with uncertain future returns. In human-capital models, a longer horizon over which benefits can be realized strengthens incentives to invest and to re-invest later in life (Ben-Porath, 1967). In parallel, health-capital theory treats health and preventive care as investments that produce "healthy time," implying that expected longevity and uncertainty about future health states shape optimal prevention and related expenditures (Grossman, 1972; Muurinen, 1982). This decision environment naturally supports an option-based interpretation.

Individuals may stage investments, scale them up when signals become favourable, or stop further investment when expected returns deteriorate.

On the health front, preventive care can be viewed as a sequence of adjustable investments with uncertain payoffs, where gradual commitment and updating are economically rational. The compression of morbidity hypothesis emphasizes that postponing morbidity relative to longevity can reduce lifetime disability and associated costs, raising the expected returns to prevention (Fries, 1980). Valuation work in health economics further shows that mortality reductions and longevity improvements generate very large welfare gains, underscoring the potentially high payoff to successful prevention over long horizons (Murphy & Topel, 2006). Consistent with a "hedging" mechanism under uncertainty, evidence also indicates that greater subjective uncertainty about longevity is associated with lower probabilities of unhealthy lifestyles, suggesting that uncertainty can shift behaviour toward prevention (Dormont et al., 2018).

3.5 Marriage and divorce decisions

Marriage and divorce can be framed as sequential commitments under uncertainty, where entry and exit costs create partial irreversibility and therefore an "option value" of waiting and flexibility. Treating marriage as a long-horizon partnership investment highlights how the expected duration of the relationship amplifies both the gains from a good match and the losses from a bad match. Legal regimes matter because they change the effective irreversibility of marriage: the move from mutual-consent to unilateral/no-fault divorce can be interpreted as introducing a more readily exercisable exit option, reshaping incentives in marriage markets. In a search-and-learning framework, divorce-law liberalization alters marriage rates, selection into marriage, and divorce outcomes because it changes outside options and bargaining positions (Rasul, 2006). Empirically, the US unilateral-divorce reforms are associated with a short-run spike in divorce that largely reverses over time, consistent with a one-time regime shift rather than a permanent level effect (Wolfers, 2006), and they also shift intra-household bargaining and measured family distress (e.g., domestic violence and female suicide), consistent with an expanded exit threat affecting behavior within marriage (Stevenson & Wolfers, 2006). Overall, longer horizons plausibly heighten the salience of both timing (when to commit) and exit flexibility (when to leave), strengthening the relevance of an option-based interpretation of family decisions.

Having introduced the relevant option categories, Table 2 provides a structured synthesis that operationalizes the conceptual framework. It maps core life-cycle decisions onto dominant option types and makes the framework empirically tractable by pairing each mapping with a testable longevity effect and an observable behavioral implication.

Table 2: A Comparative Matrix of Life-Cycle Real Options under Increasing Longevity

Life-Cycle Decision	Option Type	Longevity Effect	Empirical Implications
Fertility Timing	Option to Wait	Extends reproductive planning window, increases value of waiting under uncertainty	Delayed childbearing in high uncertainty contexts
Retirement Timing	Option to Wait / Expand / Switch	Extends work horizon, raises value of deferring or staging retirement	Rising trend of phased retirement, delayed annuitization
Human Capital Investment	Option to Expand / Switch	Lengthens payoff period, increases incentive to retrain or re-enter education	More mid-life reskilling programs, career switches
Health Investment	Option to Expand	Greater healthspan improves returns to preventive investments	Healthier behaviors, demand for wellness programs
Marriage and Divorce	Option to Wait / Abandon	Extended time horizon increases flexibility in relationship decisions	Later-life divorce and remarriage patterns

Source: Authors' own compilation

The Table 2 does not present new empirical findings, but serves a methodological function by offering a structured classification of key life-cycle decisions as real options influenced by increasing longevity. It synthesizes earlier conceptual discussions into a comparative matrix, highlighting how different decision domains exhibit distinct types of embedded optionality in response to longer life horizons.

From an analytical perspective, this framework establishes a common typology through which future empirical studies can be organized and tested. It provides a basis for operationalizing longevity effects on behavior using life-cycle financial data, survey instruments, or simulation models.

On the implication side, the table reinforces the practical relevance of viewing longevity as a generator of economic flexibility. The option-enhancing effects of extended life expectancy manifest in recognisable behavioural patterns: delayed childbearing, staggered retirement, midlife reskilling, and adaptive health behaviours, among others. Recognizing these as outcomes of expanded decision horizons enables more targeted design of retirement systems, adult learning incentives, public health campaigns, and family policy timing mechanisms. By bridging conceptual modeling with real-world implications, this typology strengthens the case for longevity-aware economic planning and supports the broader reframing of aging societies as option-rich environments rather than solely demographic burdens.

3.6 Operationalization and testable hypotheses

Our framework can be tested by linking measurable longevity proxies to observable timing, participation, and switching outcomes in domains where decisions are sequential and partially irreversible. At the individual level, longevity can be proxied by subjective survival probabilities or health expectations; at the cohort/region level, by remaining life expectancy at age *a* or survival improvements over time. Option lifetime (T) can be proxied by remaining working-life expectancy, policy-defined eligibility windows (e.g., retirement ages, pension rules), or contract-defined lock-in horizons (e.g., annuity features). Uncertainty can be proxied by income volatility, job-loss risk, health-risk indicators, or macro uncertainty measures, while irreversibility can be proxied by sunk monetary/time costs or adjustment-cost indices.

For a given life-cycle domain, a reduced-form specification can be expressed as:
$Outcome\_\{i,t\} = \alpha + \beta\ Longevity\_\{i,t\} + \gamma\ Uncertainty\_\{i,t\} + \delta\ (Longevity\times Uncertainty)\_\{i,t\} + \theta\ Irreversibility\_\{i,t\} + controls + \varepsilon\_\{i,t\}$,

where outcomes include timing (delay/acceleration), staged participation (phased retirement), switching (career changes), or commitment (annuitization, marriage entry/exit).

Hypotheses.

The core predictions are:

H1 Higher expected remaining lifetime increases the value of waiting, leading to later exercise of irreversible options (e.g., delayed annuitization, delayed retirement, delayed fertility), ceteris paribus.

H2 The delay effect of longevity (H1) is stronger when uncertainty is higher ($\delta > 0$).

H3 The longevity-driven option effect is stronger in domains with higher sunk costs or higher adjustment costs.

H4 Greater longevity increases investment in flexibility-enhancing actions such as reskilling and career switching, especially when the remaining work horizon expands through policy reforms.

H5 Greater longevity increases preventive-health investment when prevention yields benefits over long horizons, with stronger effects when expected healthspan rises.

These hypotheses map directly to the decision domains summarized in Table 2 and provide a clear empirical agenda for future work using administrative data, survey panels, or policy reforms as sources of exogenous variation in horizon length.

4 Conclusion

Longevity, once considered purely a demographic or actuarial variable, can fruitfully be viewed as a real option that imbues individuals with greater flexibility in their life-cycle decisions. Longer expected lifespans increase the time horizon and uncertainty of life outcomes, which in turn raises the economic value of strategies that preserve flexibility – such as delaying irreversible decisions and keeping the option to adapt. We saw how this perspective illuminates a range of choices: from fertility and marriage (waiting for the right time or the right partner, with exit options in case of mismatch), to retirement and work (deferring retirement, phasing out of work gradually, or re-entering if needed), to health and education investments (staging and adjusting them as new information arrives). By integrating longevity risk and health uncertainty into a real options valuation framework, we gain a richer understanding of why people make the timing choices they do, and how they can be supported in making optimal decisions. Rather than viewing increased longevity as simply a fiscal challenge (more old people to support) or an actuarial adjustment, it becomes a source of economic value – if individuals and societies are flexible enough to capture it.

This reframing opens several interdisciplinary avenues. In financial economics, it suggests new ways to price and hedge longevity-related risks (for example, valuing the option component of pensions or insurance products that allow adjustments based on lifespan outcomes). In health economics, it underscores the importance of preventive care and health flexibility (treating health capital as something that one can invest in gradually, with options to adjust behaviors). In labor economics and education, it calls for models where human capital accumulation is ongoing and option-driven, not just front-loaded in youth. It also aligns with behavioral life-cycle theory by considering how real people might deviate from purely rational models – sometimes failing to exercise valuable options (like delaying unhealthy consumption) due to biases, which policy could aim to correct.

Overall, treating longevity as a real option highlights policies like adaptive retirement ages, incentives for continued learning, and robust health programs as ways to empower individuals in an aging society. If society adapts creatively – turning longer lives into opportunities for prolonged productivity and fulfillment – then longevity can be "an engine for sustainable, inclusive growth" rather than a crisis. In practical terms, that means moving toward a life-cycle framework that values resilience and optionality: helping people keep their options open as they navigate the uncertainties of a very long life. The payoff is not only individual well-being but also fiscal and economic health, as more people aging well can continue contributing to society. In conclusion, longevity should be seen not merely as a burden to manage, but as a form of capital – an expanded portfolio of years – whose value can be unlocked through flexibility, timely choices, and supportive policy. By pricing and managing this real option wisely, both individuals and societies can better thrive in the era of 100-year lives.

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