

The Decreasing-Term Anachronism

Quantifying the structural over-insurance embedded in Irish mortgage protection — and a framework for re-designing the product around the borrower's outstanding capital.

COMBINED EDITION

Working paper · Annex A (Stochastic-rate simulation) · Annex B (Diagnostics and workbook)

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Combined Edition

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About this edition

This combined edition consolidates the MWP-2026-03 working paper with its two supporting annexes into a single document. The paper presents the central argument and analysis; the annexes provide the technical evidence and audit trail.

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This paper is intended for industry, regulatory, and academic discussion. It is not legal, tax, or financial advice. The analysis is conducted in good faith and from a pro-industry stance: the objective is to support the long-run sustainability of the Irish mortgage-protection market, not to criticise specific providers.

The Decreasing-Term Anachronism

Schedule Mismatch in Irish Mortgage Protection and Three Modernisation Candidates

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The Decreasing-Term Anachronism

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Abstract

The standard Irish mortgage-protection product is a decreasing-term assurance whose sum-assured schedule is fixed at policy inception to a notional 6% amortisation curve. The schedule is contractual — set on the day the policy issues — and it does not adjust when the underlying mortgage subsequently behaves differently. This paper asks a constructive question: in a contemporary Irish mortgage environment of low actual rates, short fixed-rate periods and routine principal events, what would a robust schedule design look like, and what would it cost the manufacturer to deliver? We approach the question by identifying three failure modes of the legacy product — a *design* failure (the schedule mechanic itself), a *distribution* failure documented elsewhere in this series (the bank-channel premium), and a *capital* question (whether modernisation prices fairly under the Solvency II Standard Formula). We then quantify the design failure at the household level and across the principal-dwelling-house stock, evaluate three modernisation candidates already in commercial use in comparable markets (re-rated annuity-falling, event-stepped, balance-linked), and compute the Solvency II capital implications under the Standard Formula. The representative borrower is a 35-year-old non-smoking male with a 30-year, €322,000 mortgage at 4% against a 6% notional schedule. In steady state the household carries a mean over-insurance of €14,332 across the term, peaking at €22,292 in month 223. On a deterministic full-stock basis the aggregate annual premium dead-weight is approximately €12.34m; on a duration-weighted decomposition of the Bank of Ireland Asset-Covered-Securities pool — used as a published-evidence proxy for the in-force PDH cohort distribution — the more conservative central estimate is approximately €4.07m per year. A stochastic extension on the EIOPA EUR risk-free term structure at 30 April 2026, 50,000 paths over 360 months, seed 20260529, with bootstrap-Irish rate dynamics, produces a household over-insurance figure of approximately €26 per household per year (median, 5–95% interval €6–€44), against which three parametric Vasicek calibrations (C1 / C2 / C3) plus a C1 + MS2 spread-switching sensitivity bracket the headline between €14 and €24 per household per year. Under the four common Irish-mortgage disturbances — fixed-rate roll-off, top-up advance, term extension, lump-sum overpayment — the schedule remains unmoved and the policy can fall structurally below the outstanding balance, with peak under-insurance of approximately €80,000 on a five-year term extension. We acknowledge, candidly, that the over-insurance gap also functions as a *prudential cushion*: at year five under a +200 bps upward rate spike, the cushion absorbs the resulting balance trajectory without ever leaving the policy under-cover, even as the mean cushion shrinks by approximately two-thirds. Two of the three modernisation candidates — the event-stepped (M2) and balance-linked (M3) designs — substantially close both the steady-state and the disturbance gaps. The third (M1, re-rated at issue) is a partial response: it closes the steady-state gap but trades it for a disturbance under-insurance gap. The Solvency II Standard Formula mortality capital position is design-by-design: at baseline (DO) and in three of four disturbance scenarios, M1, M2 and M3 each *reduce* SCR_mort relative to the legacy product; in the term-extension disturbance specifically, M2

raises SCR_{mort} by approximately 27% relative to a legacy schedule that has, in that scenario, structurally collapsed below the outstanding balance. We compute the break-even expense loading per policy per year required to fund M1, M2 and M3 against the loss of premium income on the closed over-insurance gap and find it modest: approximately €10.61 per policy per year for M1, €13.01 for M2 and €11.87 for M3, equivalently approximately 2.7%, 3.3% and 3.0% of base premium respectively, against an implicit premium loading of approximately €1.2336 per €1,000 sum-assured per year (equivalently, approximately €397 per policy per year on the representative profile). The recommendation is that Irish life offices evaluate M2 as the proportionate near-term commercial response and treat M3 as the longer-run product-architecture target, within the existing product taxonomy and the European Insurance Distribution Directive's Product Oversight and Governance regime.

Keywords: mortgage protection insurance; decreasing-term assurance; product design; sum at risk; prudential cushion; Solvency II; Standard Formula; mortality stress; bancassurance; Ireland; Consumer Credit Act 1995; EIOPA; risk-free rate; Vasicek; product oversight and governance; protection gap.

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1. Introduction

Mortgage protection assurance is the life-insurance product most widely held by Irish households, because it is embedded in the statutory architecture of the residential mortgage. Section 126 of the Consumer Credit Act 1995 obliges a mortgage lender to ensure that a life-assurance policy is in place on a housing loan, subject to a small set of carve-outs, and the standard market response is a thirty-year decreasing-term assurance whose initial sum assured matches the loan and whose subsequent sum-assured schedule is calculated, at policy inception, on a notional amortisation curve.¹ The notional curve in near-universal Irish use is a six-per-cent amortisation. That convention is long-standing — confirmed at the level of primary policy schedules and key-features documents of the five principal Irish life offices.² It is the contractual basis on which the cover schedule is drawn, and it is independent of the interest rate the borrower actually pays on the mortgage.

This paper asks a constructive, pro-industry question. The legacy product has worked in its present form for decades; it does what its contractual specification says it should do; and the insurers who sell it have priced it on an actuarially honest basis under the contractual schedule. In a contemporary Irish mortgage environment, however — actual rates materially below the notional, short fixed-rate periods, routine principal events on a thirty-year horizon — *what would a robust schedule design look like, and what would it cost the manufacturer to deliver?* We treat this not as a regulatory critique but as a product-modernisation question: a design conversation that an Irish life office, an actuarial pricing function, or a manufacturer's product-oversight committee could constructively engage with under the existing supervisory framework.

The question is timely on several counts. The Irish mortgage book against which the legacy schedule was originally calibrated bore little resemblance to today's. Through the last three decades of the twentieth century the dominant Irish mortgage was variable-rate, on nominal mortgage rates that ran well into double digits for much of the period, with principal events confined largely to redemption or default; the six-per-cent notional schedule sat *below* prevailing rates and the resulting schedule tracked the actual amortising balance more closely than it does today. The contemporary Irish book is structurally different. The Central Bank of Ireland reports a weighted-average new-business PDH rate of three point five two per cent at end-March 2026³, with approximately ninety per cent of new agreements on fixed-rate terms of one to ten years that systematically roll off within a thirty-year policy term.⁴ Top-up advances are a routine Banking and Payments Federation Ireland category⁵; term extensions and arrears restructurings are an established Central Bank forbearance instrument⁶; and lump-sum overpayments occur within published lender contractual caps.⁷ Each of these disturbances changes the outstanding balance $B(t)$ but leaves the contractual schedule $S(t)$ unmoved. The European Insurance Distribution Directive's product-oversight-and-governance regime (Article 25) imposes an ongoing-monitoring obligation on manufacturers to confirm that the product continues to meet target-market needs⁸; on its face, that obligation invites the very modernisation conversation we attempt here.

We are explicit about what this paper is *not*. It is not an argument that the legacy product is in breach of section 126 — the schedule is contractually clear and the premium is actuarially honest under it. It is not an argument that insurers acting on the legacy schedule have acted in bad faith. It is not a regulatory call for action on the schedule mechanic — none of the matters discussed below requires a new regulatory mandate; they sit within the existing Insurance Distribution Directive, the existing Consumer Protection Code, and the existing Solvency II Standard Formula. It is not, finally, an argument for indiscriminate policy replacement: existing cover remains valid cover, and the modernisation argument is squarely about new business and the prospective book.

The paper proceeds as follows. Section 2 sets the institutional context: the statutory architecture, the shape of the Irish principal-dwelling-house mortgage book, and the origin of the six-per-cent notional convention. Section 3 reframes the legacy product as exhibiting three independent but cumulatively-incident failure modes — a *design* failure (the schedule mechanic, the focus of this paper), a *distribution* failure (the bank-channel premium documented in *The Bank Premium*), and a *capital* question (whether modernisation prices fairly under the Standard Formula) — and reviews the international and academic evidence bearing on each. Section 4 specifies the data: the representative borrower, the three-layer mortality stack, the discount basis, the Solvency II capital basis, and the disturbance prevalence calibrations. Section 5 sets out the methodology: the deterministic schedule-balance-gap framework, the four disturbance scenarios, the three modernisation candidates, the household-level and aggregate harm constructions, the present-value layer, and the stochastic extension on the EIOPA risk-free term structure. Section 6 reports the results: household-level over-insurance under steady-state and disturbance, modernisation outcomes, the Solvency II mortality charge by design and scenario, a +200 basis-point rate-spike stress test on the legacy cushion, two aggregate constructions (deterministic

single-vintage and duration-weighted full-stock), the coverage-gap (HARM B) aggregate, and the stochastic-rate headline. Section 7 discusses the mechanisms: why the schedule mechanic generates the two-sided mismatch, why M1 alone is insufficient, why M2 closes events without explicit balance linkage, why M3 requires reconciliation infrastructure, how the over-insurance gap functions as a prudential cushion, and how to read the capital signature of modernisation as a system-level (rather than insurer-level) outcome. Section 8 presents a spectrum of responses calibrated to operational and commercial constraints, computes the break-even expense loading required to fund M1, M2 and M3, and reframes the capital question as one of optionality rather than regulatory imposition. Section 9 records the limitations of the analysis transparently. Section 10 concludes.

The principal findings are these. The representative Irish mortgage-protection policyholder — male, age thirty-five, non-smoker, three hundred and twenty-two thousand euro initial sum assured, thirty-year term, six-per-cent notional schedule against an actual four-per-cent mortgage rate — carries a mean over-insurance of fourteen thousand three hundred and thirty-two euro across the policy term and pays a small but non-trivial dead-weight premium on that excess cover for thirty years. The aggregate annual dead-weight across the Irish principal-dwelling-house stock, computed deterministically at the four-per-cent actual rate, is approximately twelve point three four million euro on a single-vintage uniform-cohort basis; the more conservative duration-weighted decomposition, anchored on the publicly disclosed Bank of Ireland Asset-Covered-Securities mortgage pool as a proxy for the in-force cohort distribution, gives approximately four point zero seven million euro per year. On a stochastic basis, calibrated to the EIOPA EUR risk-free term structure at thirtieth April 2026 with bootstrap-Irish rate dynamics over fifty thousand paths, the headline household harm is approximately twenty-five point nine four euro per household per year (median, five-to-ninety-five-per-cent interval six point zero seven to forty-four point three five euro). Three parametric Vasicek calibrations (C1 / C2 / C3) plus a C1 + MS2 spread-switching sensitivity bracket the bootstrap-Irish headline between thirteen point seven six and twenty-three point six zero euro per household per year, confirming that the headline is not an artefact of the rate-model choice. Under the under-insurance disturbances, the largest single-policy exposures are eighty thousand four hundred and fifty euro of peak under-cover on a five-year term extension and thirty-eight thousand three hundred and sixty-three euro of peak under-cover on a fifty-thousand-euro top-up advance. We acknowledge that the steady-state over-insurance also functions as a prudential cushion: under a two-hundred-basis-point upward rate spike at policy year five, the mean cushion shrinks by approximately two-thirds but the policy never falls under-cover. Two of the three modernisation candidates — the event-stepped (M2) and balance-linked (M3) designs — close both the steady-state and the disturbance gaps. The Solvency II mortality capital implication is mixed by design and scenario: at baseline and in three of four disturbance scenarios, modernisation reduces SCR_mort; in the term-extension scenario specifically, the M2 charge is approximately twenty-seven per cent above legacy, reflecting the restoration of cover that the legacy schedule has, in that scenario, allowed to collapse. The break-even expense loading required to fund M1 (approximately ten point six one euro per policy per year), M2 (approximately thirteen point zero one euro) and M3 (approximately eleven point eight seven euro) is modest against the implicit premium loading of approximately one point two three four euro per thousand euro sum-assured per year — approximately two point seven, three point three and three point zero per cent of base premium respectively.

2. Institutional setting

2.1 The statutory obligation

Mortgage protection assurance is required, on Irish housing loans, by section 126 of the Consumer Credit Act 1995. The substantive obligation runs to the lender, not the borrower. The operative wording of section 126(1) is, verbatim: "a mortgage lender shall arrange, through an insurer or an insurance intermediary, a life assurance policy providing, in the event of the death of a borrower before a housing loan made by the mortgage lender has been repaid, for payment of a sum equal to the amount of the principal estimated by the mortgage lender to be outstanding in the year in which the death occurs on the basis that payments have been made by the borrower in accordance with the mortgage, such sum to be employed in repayment of the principal".¹ Subsection 126(2) provides for a small set of carve-outs — the property is not the borrower's principal residence, the borrower is over fifty at approval, the borrower belongs to a class for which cover is unobtainable except at a significantly higher premium, or the borrower has otherwise arranged sufficient life assurance — and subsection 126(5) expressly provides that excess proceeds, over the outstanding mortgage at the date of death, are payable to the surviving borrower or the deceased borrower's estate rather than retained by the lender.⁹

Two features of the statutory language matter for this paper. First, the obligation is framed in terms of "the amount of the principal estimated by the mortgage lender to be outstanding in the year in which the death occurs on the basis that payments have been made by the borrower **in accordance with the mortgage**". The reference point is the *actual* mortgage and the *actual* outstanding principal — not a notional amortisation curve drawn at inception against a market-convention rate. The legislative intent is balance-tracking against the loan as it stands, on the contractual terms of that loan. Second, the Consumer Protection Code obliges the lender to ensure that mortgage protection is in place at drawdown, but the Competition and Consumer Protection Commission has confirmed and re-confirmed that the borrower is not obliged to take the policy offered by the lender: the borrower may purchase from the lender, from an insurance company directly, or through an intermediary.¹⁰ The decreasing-term schedule is therefore a market convention, not a statutory requirement: section 126 demands that the death benefit cover the outstanding principal, but it does not prescribe the mathematical mechanic by which the sum assured tracks the principal across the policy term. We also note explicitly — and return to the point in Section 8.6 — that the statutory provision for excess proceeds to flow to the estate means that a steady-state over-insurance position is not, in welfare terms, simply dead-weight on the household; a portion of it is a transfer that benefits the deceased borrower's estate on the insured event. We treat that estate-benefit acknowledgement transparently and do not net it into the headline harm.

2.2 The Irish principal-dwelling-house book

At end-June 2025, the Central Bank of Ireland reported 698,335 private residential mortgage accounts secured on principal dwelling houses, with an aggregate outstanding balance of approximately one hundred and six billion euro.¹¹ The Central Statistics Office's *Household Finance and Consumption Survey 2023* reported that thirty per cent of Irish households held a mortgage on their main residence, with a median outstanding balance of one hundred and seventeen thousand nine hundred euro.¹² The Banking and Payments Federation Ireland publishes the quarterly mortgage drawdowns report; the Q4 2025 release records average first-time-buyer PDH drawdown value of approximately three hundred and twenty-two thousand euro and an average first-time-buyer age of thirty-five.⁵ Those two numbers are the representative-borrower anchor used in this paper.

The composition of the new-business book is important for the disturbance analysis in Section 5. The Central Bank's monthly *Retail Interest Rates* release shows that roughly ninety per cent of new mortgage

agreements in recent quarters have been on fixed-rate terms³, and the Governor's blog has confirmed that approximately one in ten PDH mortgages sees a fixed-rate period expire each year.⁴ Irish fixed-rate periods are short by international comparison — typically one to ten years against a thirty-year amortisation — so a single mortgage almost certainly transits multiple rate regimes within a single policy term. The BPF1 top-up category is a separate, well-defined line in the quarterly drawdowns release: the Q4 2025 release records three thousand two hundred and eighty top-up drawdowns nationally.⁵ The Central Bank's mortgage arrears statistics, and Deputy Governor Sibley's July 2021 statement, document that over ninety-five thousand PDH accounts — approximately thirteen per cent of the book — were assessed at that time as facing a shortfall at end of term, with term extension a routine forbearance instrument.⁶ Lender published terms and conditions show overpayment caps that range from five thousand euro per year (Allied Irish Banks) to ten per cent of the normal monthly repayment or €65 — whichever is greater — without breakage fee on fixed-rate accounts at Bank of Ireland (variable-rate accounts have no cap) to twenty per cent per year at ICS Mortgages and certain other lenders.⁷

These are not edge cases. Each of the four disturbance categories used in Section 5 — fixed-rate roll-off, top-up advance, term extension, lump-sum overpayment — is a regular Irish-mortgage event with a published prevalence in either the Central Bank or BPF1 data series. The decreasing-term schedule, as currently engineered, is unmoved by any of them.

2.3 The six-per-cent notional convention

The Irish decreasing-term schedule is constructed at policy inception as the amortisation curve of a level-payment loan of the initial sum assured at a notional interest rate, over the policy term. The market standard for that notional rate is six per cent. Formally, for an initial sum assured $S(0)$, term n months, and notional monthly rate $i = 0.06/12$, the contractual schedule at month t is

$$S(t) = S(0) \cdot ((1+i)^n - (1+i)^t) / ((1+i)^n - 1)$$

and the schedule is locked at issue. The premium is computed, on the insurer's pricing basis, against the integral of the mortality-discounted sum at risk across this fixed $S(t)$ curve. Neither the schedule nor the premium adjusts subsequently for the actual mortgage rate, the actual outstanding balance, or any disturbance to the loan.

The six-per-cent figure is a historical artefact. It reflects the long-run average nominal mortgage rate environment under which Irish decreasing-term assurance crystallised as a product class — a period in which Irish mortgage rates of six to fifteen per cent were ordinary, and in which fixing the schedule against a mid-range nominal rate gave a reasonable expected match to the typical loan's actual amortisation profile across a long term. The convention was reasonable when it was set; it is not, by itself, evidence of bad faith on the part of the insurers or the lenders who continue to use it. The six-per-cent convention is confirmed in the current public policy-schedule and key-features documentation of all five principal Irish life offices — Irish Life, Royal London Ireland, Zurich Life Ireland, New Ireland Assurance, and Aviva Life and Pensions Ireland.²

The downstream consequence — and the analytical focus of this paper — is that $S(t)$, the contractual schedule, and $B(t)$, the actual outstanding balance, are now two different objects. In a steady-state Irish mortgage at four per cent actual against a six-per-cent notional, the schedule sits above the balance for almost the entire term, peaking at a divergence of approximately twenty-two thousand euro mid-policy. Under any of the four disturbance categories, the schedule and balance can diverge in the opposite direction, with the schedule falling below the balance and the policy structurally under-insured. The two-sided mismatch — chronic over-insurance, episodic under-insurance — is the central object of analysis in Sections 5 and 6.

3. Three failure modes and the international evidence

This paper sits at the intersection of three independent but cumulatively-incident failure modes of the legacy Irish mortgage-protection product. We discuss them in turn — first naming each, then noting what is *not* claimed about each, and then locating the international and academic evidence that bears on it. The framing is constructive: each failure mode is a candidate for product modernisation rather than for regulatory action, and the modernisation candidates evaluated in Section 5 are already in commercial use in markets comparable to Ireland's.

3.1 The three failure modes

(a) The *design failure* — the *schedule mechanic*. The legacy schedule fixes the sum-assured curve at policy inception, against a notional six-per-cent rate, and holds it fixed across the policy term. As Section 2.3 makes clear, the schedule $S(t)$ and the actual outstanding balance $B(t)$ are now distinct objects: in steady state the schedule sits above the balance (chronic over-insurance), and under principal events the schedule can fall below the balance (episodic under-insurance). The schedule mechanic was a reasonable engineering shortcut in the Irish mortgage environment in which the decreasing-term product class crystallised — a variable-rate book on high nominal rates, with principal events confined largely to redemption or default, and a six-per-cent notional that sat conservatively below prevailing rates and therefore tracked the actual amortising balance closely on average. It is the focus of this paper because, in the contemporary low-rate, short-fixed-period environment, the legacy mechanic generates a systematic two-sided mismatch with the legislative intent of section 126.

(b) The *distribution failure* — the *bank-channel premium*. Documented in *The Bank Premium* (MWP-2026-02), a structural premium attaches to lender-channel mortgage protection in Ireland, with whole-of-market quotation suggesting typical price gaps of twenty to thirty per cent against the cheapest broker-quoted equivalent for an otherwise-identical risk.¹³ This is a distribution-side failure: it arises from tied bancassurance and from the absence of routine consumer comparison at the point of mortgage drawdown. It is independent of the schedule mechanic — the same schedule sold through a broker channel would still exhibit the steady-state and disturbance mismatch — but it compounds the household-level impact. The present paper does not re-litigate that finding; we cite it once and proceed.

(c) The *capital question* — does modernisation price fairly? This is not strictly a failure of the legacy product so much as an open question about modernisation: if Irish life offices are to invest in a modernised schedule (M2 or M3), the Solvency II Standard Formula's mortality capital charge must price modernisation fairly. As Section 6.4 shows, the Standard Formula does price modernisation roughly correctly — at baseline and in three of four disturbance scenarios, modernisation *reduces* SCR_mort; in the term-extension scenario alone it raises the charge by approximately twenty-seven per cent — and that asymmetry is itself diagnostic of the underlying design failure. Section 8.4 returns to the capital question as one of *optionality* for the manufacturer rather than imposition by the supervisor.

For each failure mode the regulatory frame is the existing European supervisory architecture — the Insurance Distribution Directive's product-oversight-and-governance regime (Article 25), the Mortgage Credit Directive's borrower-choice provisions (Article 12), the Solvency II Standard Formula's life-mortality sub-module — and not a new regulatory mandate. The three failure modes can be addressed by three independent technical responses, by different actors, without dependency: schedule

modernisation (this paper), channel-test workflows (per MWP-2026-02), and Standard-Formula-internalised capital optionality (Sections 6.4, 8.4 below).

3.2 European Union — EIOPA and the credit-protection-insurance review

The European Insurance and Occupational Pensions Authority's thematic review of credit-protection insurance, published on 28 September 2022 with a parallel Article 9(3) Warning on 4 October 2022, is the most directly relevant piece of European supervisory work.¹⁴ The review examined 174 insurance undertakings and 145 banks across the European Economic Area, covering data from 2018 to 2020, and concluded that mortgage credit-protection insurance, as then sold via banks, was structurally unprofitable for the consumer: the average claims ratio across the sample was approximately twenty-six per cent of gross written premium, with the remaining seventy-four cents of each euro of premium consumed by insurer costs, distribution commissions, and profit. For single-premium credit-protection products the position was worse — sixty-five per cent of the insurers in the sample reported claims ratios below twenty per cent.

The review identified two structural design problems that bear directly on the schedule-mismatch question. The first is that the dominant distribution mechanic — group policies under which the bank is policyholder and the consumer is an insured life — constrains the insurer's ability to tailor cover to the individual borrower's circumstances. EIOPA stated that "the quality of CPI products might be inadequate and not meet consumer needs given most CPI products are sold as Group Policies where the cover provided is standardised and determined by the bank (the policyholder). In most cases there is little to no tailoring possible to the needs of the consumer."¹⁴ The second is that the standardised group product does not travel with the consumer: "a consumer that purchased a Group Policy may not be able to maintain it in case of remortgaging and would have to purchase a new one." That re-start of cover, at older entry age and potentially higher premium, is itself a manifestation of the schedule-mismatch problem: the implicit balance assumption of the group policy is reset rather than carried forward.

EIOPA issued a public Warning to manufacturers and distributors of credit-protection insurance in parallel with the review, under Article 9(3) of the EIOPA Regulation, calling for fair-value products, for action on conflicts of interest arising from high commissions, and for an end to tied and pressure-sales practices.¹⁵ A follow-up summary of supervisory activities was published in April 2025.¹⁶

The legislative framework that sits behind EIOPA's expectations is twofold. The Mortgage Credit Directive (2014/17/EU) provides the tying-and-bundling architecture: Article 12(1) prohibits pure tying, while Article 12(4) permits creditors to require the borrower to hold an insurance policy provided the borrower is free to choose an alternative insurer offering an equivalent level of guarantee. Recital 25 explicitly preserves the borrower's right to "choose his own insurance provider, provided that his insurance policy has an equivalent level of guarantee as the insurance policy proposed or offered by the creditor".¹⁷ The Insurance Distribution Directive (2016/97) provides the demands-and-needs and product-oversight architecture. Article 20 requires that any insurance product proposed to a customer be consistent with that customer's demands and needs, assessed prior to the contract. Article 25 establishes the product-oversight-and-governance (POG) regime, requiring manufacturers and intermediaries to operate a product approval process that specifies an identified target market, assesses the risks to that target market, and monitors on an ongoing basis whether the product continues to meet the target market's needs.⁸

The POG architecture is directly relevant to the schedule-mismatch question. A target-market assessment for an Irish mortgage protection policy must identify the typical borrower; the demands-and-needs assessment must identify the cover requirement; and the ongoing-monitoring obligation must confirm that the product continues to meet that requirement across the policy term. A schedule

that diverges materially and persistently from the outstanding mortgage balance — both above it in steady state and below it under common disturbances — is, on the face of the IDD architecture, a candidate for the manufacturer's own ongoing-monitoring review. The Central Bank of Ireland's domestic implementation of IDD via the Consumer Protection Code, the *Insurance Distribution Regulations 2018*, and the September 2022 *Differential Pricing Review* applies the same architecture in the Irish jurisdiction.¹⁸

3.3 France — ACPR and *assurance emprunteur*

France operates the largest borrower-insurance market in the European Union, with annual premium volume of approximately seven point six billion euro, and the longest record of supervisory scrutiny of the product class. The market has historically been dominated by bancassureurs — banks distributing captive group policies — who held approximately eighty-one per cent of stock in force as of 2024. The *Autorité de contrôle prudentiel et de résolution* has, in successive supervisory exercises, identified the same structural problems EIOPA later flagged at European level: low claims ratios, high commissions, and elevated claim-refusal rates.¹⁹

The ACPR's most detailed published data on mortgage *assurance emprunteur* are from Vice-Président Jean-Paul Faugère's presentation at the *Matinée de la protection de la clientèle* conference on 14 March 2025.²⁰ The analysis covered six banking groups and their alternative-provider counterparts. *Sinistres/ primes* ratios — the French regulatory analogue of the loss ratio — varied substantially: group contracts averaged thirty-nine per cent (range twenty-one to sixty); *contrats défensifs*, alternative products offered by the same lender, averaged twenty-one per cent (range six to forty-seven); and external contracts averaged thirty-two per cent. Claim-refusal rates were elevated, with group contracts averaging a refusal rate of forty-one per cent. The ACPR's stated supervisory position is that an S/P ratio "ne saurait être durablement inférieur à 30% sans appréciation circonstanciée du management" — that a sustained S/P below thirty per cent is presumptively problematic without management explanation.

The French legislative response to bancassurance captivity has been a sequence of laws progressively widening borrower substitution rights: the *Loi Hamon* (2014), the *Amendement Bourquin* (2017), and ultimately the *Loi Lemoine* (Law no. 2022-270, enacted 28 February 2022), which introduced free substitution of *assurance emprunteur* at any time during the mortgage term (not restricted to major life events), and which abolished the medical questionnaire for loan amounts under two hundred thousand euro per insured life and maturing before age sixty.²¹ While the *Loi Lemoine* addresses distribution competition rather than the schedule-mismatch problem directly, it has indirect bearing on the question: it presupposes that a switching borrower can obtain a policy with a genuinely equivalent level of guarantee, which in turn requires that the sum assured at the switch date accurately represents the outstanding capital. In practice, the comparability of declining-benefit schedules across different insurers has proved to be a frequent point of contestation, and the *Association pour la promotion de la concurrence en assurance des emprunteurs* (APCADE) has documented in its 2025 *Baromètre* that thirty-eight per cent of substitution requests still exceed the legal ten-day deadline, with some delays exceeding two months.²² The French data therefore demonstrate both that the schedule mechanic is a recognised pain point in cross-insurer comparison and that legislative correction of distribution captivity does not, on its own, resolve the underlying product-design issue.

3.4 United Kingdom — FCA reviews and the *Term & Health Watch* data

The United Kingdom is the closest comparator to Ireland on language, regulatory architecture, life-office practice, and product taxonomy. The Financial Conduct Authority has not, to date, published a thematic review of decreasing-term mortgage protection as such. The broader regulatory record is, however,

directly relevant. Thematic Review TR19/2 (general-insurance distribution chain, April 2019) found that "significant commission, or other payments, to firms in the distribution chain ... significantly increased the cost of the product to the end user", with the FCA stating that its findings and expectations were "relevant to all GI products" notwithstanding the original travel-and-GAP focus.²³ Thematic Review TR24/2 (product oversight and governance in general insurance and pure protection, August 2024) found, across twenty-eight manufacturers and thirty-nine distributors covering ten product lines including pure protection, that "many firms lacked effective product governance frameworks" and that "many were not fully meeting the requirements under PROD 4".²⁴ The ongoing *Pure Protection Market Study* MS24/1, launched in March 2025 with an interim report published in January 2026, examines term assurance alongside critical illness, income protection and whole-of-life, and identifies "lower claims ratios for some protection products than others" as one of three priority improvement areas.²⁵

The market-structure paper accompanying the study, MS24/1.3 (December 2025), categorises United Kingdom new-business term-assurance premiums into "Mortgage Related Life (Term Assurance)" and "Non-Mortgage Related Life (Term Assurance)" and reports that, in 2024, mortgage-related term contributed one hundred and eighty-eight million pounds in annual new premiums with top-five-firm concentration of eighty-four per cent, compared with three hundred and eighteen million pounds for non-mortgage-related term with seventy-three-per-cent concentration.²⁶ The FCA notes explicitly that decreasing-term assurance is "commonly used in conjunction with mortgage repayments where the cover is designed to decrease in line with the outstanding mortgage balance" — but, importantly, the supervisory work to date does not examine whether the standard fixed-schedule decreasing-term product actually tracks actual outstanding balances. That gap is the gap this paper attempts to characterise quantitatively.

The most granular published dataset on level-versus-decreasing-term mix in the United Kingdom market is the Swiss Re *Term & Health Watch 2025* report, published in May 2025.²⁷ Of one million four hundred and twenty-one thousand five hundred and twelve new term-assurance policies sold in the United Kingdom in 2024 (including those with critical-illness cover): six hundred and forty-four thousand four hundred and seventy-eight (forty-five per cent) were level-term assurance without critical illness; three hundred and seventeen thousand one hundred and forty-nine (twenty-two per cent) were decreasing-term assurance without critical illness; two hundred and sixty-six thousand one hundred and seventy-nine (nineteen per cent) were level-term with critical illness; and one hundred and forty thousand and ninety-seven (ten per cent) were decreasing-term with critical illness. Swiss Re describes decreasing-term assurance as "a proxy for mortgage-related term", and the 2024 data showed decreasing-term without critical illness growing by three point six per cent year-on-year while level-term without critical illness declined by two point one per cent. The frequently-stated industry narrative that the United Kingdom market has moved decisively to level-term cover for mortgage protection is therefore overstated by Swiss Re's data: decreasing-term remains a meaningful share of new mortgage-linked business, accounting for approximately thirty-two per cent of total new term sales by volume in 2024. Level-term's lead is principally in non-mortgage protection. The United Kingdom precedent does not show a wholesale abandonment of decreasing-term; it shows a market in which both designs coexist and in which the comparability of schedules across insurers — and, by extension, the integrity of the schedule mechanic — is an ongoing FCA concern.

3.5 Canada — FCAC retail-banking review

The Financial Consumer Agency of Canada's *Domestic Bank Retail Sales Practices Review*, published 20 March 2018, examined the retail sales practices of Canada's six largest banks, with creditor insurance — including bank-channel mortgage life insurance — identified as one of the four highest-risk product and distribution categories.²⁸ Three of the FCAC's findings are directly relevant to the Irish schedule-

mismatch analysis. First, the FCAC characterised bank creditor insurance as "a 'sold' product rather than a 'bought' product": consumers rarely initiate purchase, and banks rely on staff to cross-sell at the point of mortgage approval, with penetration targets — typically thirty per cent attachment — incentivising sales irrespective of consumer need. Second, the FCAC documented post-claim underwriting as a structural feature of the Canadian bank creditor-insurance product: "at the time of purchase, the underwriting is performed by assessing answers to a handful of broadly worded yes-or-no questions", with the insurer conducting medical assessment only on death-claim submission. If a pre-existing condition or application inaccuracy emerges at that point, the claim can be declined, leaving the estate liable for the outstanding mortgage. Third, the FCAC found that bank mortgage life insurance offered no portability: "in the large majority of cases, consumers can acquire creditor insurance products only from the bank that sold them the credit product", with the result that the borrower could neither switch insurer nor carry cover across a remortgage. While the post-claim-underwriting concern is structurally distinct from the schedule-mismatch concern, the two compound: a borrower whose cover may be declined on a technicality and whose schedule does not match the actual outstanding balance has two reasons to doubt the product's payable value at the moment of claim.

3.6 United States — the shift to level-term mortgage cover

Decreasing-term mortgage life insurance was a significant individual-life product category in the United States in the 1980s and 1990s, but the dominant market direction over the past two decades has been toward level-term insurance for mortgage protection. The shift reflects a combination of consumer preference (for a policy that can be assigned to any beneficiary, that provides a fixed benefit regardless of remaining mortgage balance, and that is portable across lenders) and insurer commercial preference (for a standardised product amenable to systematic underwriting and reinsurance).²⁹ LIMRA reports that term life insurance represented approximately nineteen per cent of total United States individual life insurance new premium in 2024 (approximately three billion dollars in new annual premium), with market growth of one per cent year-on-year; the published segmentation does not distinguish granularly between level and decreasing schedules, reflecting the market's wholesale movement to level-term in the mortgage-protection use case.³⁰ The practical result is that, in the United States, mortgage-linked life insurance is overwhelmingly purchased today as level-term cover — frequently a fifteen- or thirty-year fixed-benefit policy timed to the mortgage amortisation period — rather than as a decreasing schedule tied to the amortisation curve. The United States precedent therefore demonstrates that the market can resolve the schedule-mismatch problem at the level of product taxonomy by selecting a level benefit; it does not, in itself, vindicate the alternative resolution (a more accurate decreasing schedule) that this paper analyses.

3.7 Reinsurer published positions

The published research output of the major life reinsurers bearing directly on the schedule-mechanic question is limited. The reinsurance sector's public work has tended to address general market trends, mortality data, and distribution innovation rather than the specific design question of decreasing-term schedule accuracy. Two named contributions are worth recording.

RGA has published a case study in its knowledge centre describing an RGAX partnership to build a prototype for integrating protection into a digital mortgage journey.³¹ The case study observes that "selling insurance alongside mortgages in a digital environment is relatively new" and that "the market doesn't have an adequate insurance solution for customers who engage with the mortgage journey digitally." While the focus is on distribution rather than schedule design, the case study amounts to a reinsurer acknowledgement that mortgage-linked protection is structurally inadequate for the digital-origination context — which has direct implications for schedule accuracy, since the digital mortgage

journey typically generates precise amortisation data that could support a schedule-linked product if the product allowed for it. RGA has also published global survey work on life-insurance product-development cycles, reporting that risk products (individual term life without cash value) take on average seven point one months from concept to launch in the EMEA region — shorter than the comparable cycle in the Americas or Asia-Pacific. The relevance for the present paper is that product redesign timescales for term assurance are achievable within normal actuarial and commercial cycles; schedule modernisation is not a multi-year programme.

Swiss Re has confirmed in *sigma* 5/2024 that "the demand for protection products is generally less responsive to changes in interest rates" and that "looking ahead, the demand for risk protection will be driven by cyclical factors such as improving mortgage markets".³² Swiss Re's *Term & Health Watch* series (cited in Section 3.4) provides the most granular published dataset on United Kingdom decreasing-term-versus-level-term market dynamics. Swiss Re has not, to our knowledge, published a *sigma* or research note specifically addressing schedule-mismatch in decreasing-term mortgage protection.

Searches of the published research output of Munich Re, Hannover Re, and SCOR did not identify a research note, *Topics* article, or *Global Risk Center* publication that specifically addresses the product-design question of decreasing-term schedule accuracy or mortgage-balance linkage. Generic term-assurance market commentary exists in those reinsurers' publication streams but does not bear on the specific design question. We record this gap candidly. The schedule-mechanic question is not yet, to our reading, a published reinsurance research topic; the present paper may help to make the case that it should be.

3.8 Academic literature

Peer-reviewed academic work directly on decreasing-term mortgage protection product design is sparse. The literature has concentrated on three adjacent questions: the adverse-selection and value-for-money problems of credit-life markets generally; the consumer-welfare implications of bancassurance distribution; and the aggregate life-insurance mismatch problem at household level.

Colquitt, Fier, Hoyt, and Liebenberg (2012) provide the most directly relevant empirical study, testing for adverse selection in the United States credit-life market.³³ Their result is that adverse selection in credit life arises from the *absence* of underwriting, not from consumers outsmarting insurers. The result is directly pertinent to the Irish mortgage protection market, where bank-sold cover often operates with minimal individual underwriting. The implication is that schedule-linked products offering individual coverage, with full underwriting, may produce both better risk selection and more defensible claims ratios than the standardised group products that EIOPA, the ACPR, the FCAC, and the FCA have all flagged as structurally problematic.

Bernheim, Forni, Gokhale, and Kotlikoff (2003), in their *American Economic Review* study, quantify the mismatch between life-insurance holdings and household financial vulnerabilities using the United States *Health and Retirement Study*.³⁴ While their focus is on aggregate underinsurance rather than decreasing-term schedule mismatch, the analytical framework — comparing the insured sum with the actual financial liability at each age — is directly analogous to the schedule-tracking problem this paper addresses. The schedule-mismatch problem is, in a sense, the same problem on a single-policy time-series basis: the cover should match the liability at each point, and a mechanism that drifts from the liability is a candidate for redesign.

Zhang, Barnard, Jumanca, Francis, and Hussain (2018) examine, in the *British Actuarial Journal*, how regulatory intervention can improve customer outcomes in life products, including through "more stringent regulation targeted at sales practices and remuneration, product design, disclosure and

ongoing monitoring".³⁵ Their framework is applicable directly to the bancassurance distribution of mortgage protection and provides an actuarial–journal citation for the proposition that product design, disclosure, and remuneration are jointly implicated in poor consumer outcomes.

Finkelstein, Einav, and Cullen (2010), in the *Quarterly Journal of Economics*, provide the canonical welfare analysis of insurance–market distortions arising from imperfect pricing.³⁶ Their framework is the standard academic reference for discussions of the welfare cost of non–actuarially–fair pricing in insurance markets — including the pricing of group mortgage credit–protection insurance, where the premium is not risk–differentiated and the schedule may not match the actual liability profile.

The Irish–domestic actuarial literature on decreasing–term mortgage protection is, as far as we are aware, confined to general practice notes and pricing literature rather than published research papers on schedule design. The Society of Actuaries in Ireland's *Irish Insured Lives Mortality Investigation* (2019), used as the population–to–insured–lives layer of the mortality stack in Section 4.2, is the most recent published Irish actuarial work bearing on the pricing of the product class.³⁷

3.9 What the international evidence does and does not establish

The international and academic record, taken together, establishes four propositions that bear on this paper.

First, that the schedule–mismatch problem is a recognised — though under–articulated — feature of the credit–life and mortgage–protection product class across multiple jurisdictions. EIOPA flagged the absence of tailoring at European level; the ACPR has documented the consequences in French claim–ratio data; the FCA has examined adjacent product–oversight questions; the FCAC has identified the post–claim–underwriting variant of the problem in Canada; and the United States market has resolved it by switching product taxonomy.

Second, that the supervisory direction of travel is toward greater accountability for product design under the EU Insurance Distribution Directive Article 25 product–oversight–and–governance regime, the UK FCA PROD 4 sourcebook, and the equivalent Irish Consumer Protection Code architecture. A schedule that diverges materially and persistently from the outstanding mortgage balance is, on the face of these frameworks, a candidate for manufacturer–led monitoring review.

Third, that the modernisation candidates evaluated in Section 5 of this paper are not novel. Re–rated schedules at issue (the M1 design in this paper's notation) are routine commercial practice in the United Kingdom decreasing–term market and have been used by Irish life offices on bespoke commercial–mortgage business. Event–stepped schedules (M2) sit conceptually close to the French *assurance emprunteur* market architecture, where free substitution at any time during the mortgage term is now contractually enabled under the Loi Lemoine. Balance–linked schedules (M3) sit closest to the United States level–term taxonomy and to the European Insurance and Occupational Pensions Authority's product–tailoring expectation; they are technically demanding in implementation but conceptually unremarkable.

Fourth, that no jurisdiction has yet quantified the schedule–mismatch cost at the level of granularity attempted here — neither at the level of the representative household across the policy term, nor at the level of the principal–dwelling–house stock, nor under stochastic rate dynamics. The closest existing quantification is EIOPA's twenty–six–per–cent average claims ratio for credit–protection insurance, which is a value–for–money measure on the premium side. The schedule–mismatch question is a cover–integrity measure on the benefit side. The two are complementary; this paper addresses the second.

4. Data

This section specifies the data used in the deterministic and stochastic modelling that follows. The complete authority trail — every numerical input, its source URL, and the rationale for the calibration — is recorded in the companion document *MWP-03 Assumptions and Sources*, which is the working-paper-equivalent of the model dictionary. We use only first-party authoritative sources: the European Insurance and Occupational Pensions Authority, the Central Bank of Ireland, the Banking and Payments Federation Ireland, the Central Statistics Office, EUR-Lex / Commission Delegated Regulations, the Society of Actuaries in Ireland, the Institute and Faculty of Actuaries / Continuous Mortality Investigation Bureau, first-party Irish life-office policy schedules and key-features documents, and first-party lender Terms and Conditions pages. No commentary site, broker blog, forum, or aggregator source is used in the calibration.

4.1 Representative borrower

The representative borrower is identical to that used in *The Bank Premium* (MWP-2026-02), to permit direct comparability across the series. The parameters are summarised in Table 1.

Table 1 — Representative borrower parameters

Parameter	Value	Source / rationale
Age at issue	35	BPFI Q4 2025 average first-time-buyer age (PDH). ⁵
Gender / smoker status	Male, non-smoker	Industry-standard underwriting; aligned to the CMI TMNOO select table used in Section 4.2.
Sum assured at issue	€322,000	BPFI Q4 2025 average PDH drawdown value (rounded). ⁵
Term	30 years	BPFI standard PDH term band; consistent with MWP-2026-02.
Notional schedule rate	6.0% p.a.	Long-standing contractual convention for Irish decreasing-term assurance; confirmed in all five principal Irish life offices' current public policy-schedule and key-features documentation. ²
Actual mortgage rate (base case)	4.0% p.a.	CBI Retail Interest Rates: weighted-average new PDH rate end-Mar 2026 was 3.52%; 4.0% adopted as a slightly conservative central case. ³ Sensitivities at 3.0%, 3.5%, 4.5% and 5.0% are reported in Section 6.1.
Premium (deterministic)	€33.10 / month	Equivalent to €0.1028 per €1,000 SA per month — industry-standard Irish pricing point for the representative profile. Implicit premium loading approximately €1.234 per €1,000 SA per year.

There are two reconciliation footnotes worth recording. First, the Central Bank's published PDH stock figure used as the macro denominator in this paper — six hundred and ninety-seven thousand nine hundred and sixty-four — differs slightly from the six hundred and ninety-eight thousand three hundred and thirty-five used in *The Switching Gap*. The difference reflects different vintages of the *Residential Mortgage Arrears and Repossessions* dataset and is immaterial to any conclusion in either paper.³⁸ Second, the six-per-cent notional rate is the *contractual* basis on which the cover schedule is computed at policy inception, and is independent of the borrower's actual mortgage interest rate. The two rates are distinct objects; the schedule does not adjust to the actual rate.

4.2 Mortality basis

The assured-lives mortality curve $q_x(t)$ is constructed as a three-layer multiplicative composition: a population base, a population-to-insured-lives adjustment, and a select-period adjustment. Each layer is sourced separately. Table 2 records the construction.

Table 2 – Mortality stack

Layer	Source	Value	Use
1. Population base	CSO <i>Irish Life Tables No. 17, 2015–2017</i> (16 Dec 2020) ³⁹	Male period q_x ages 30–75	Period population mortality, Irish males.
2. Population-to-insured-lives	SAI Demography Committee <i>Irish Insured Lives Mortality Investigation</i> , Feb 2019 ³⁷	Actual / Expected = 0.529 (7,322 actual deaths, ultimate, all durations)	Applied multiplicatively to ILT17 q_x to give insured-lives ultimate q_x .
3. Select factors	CMI Working Paper 12 (2005), table TMN00 (Temporary Assurances, males NS, 5-year select) ⁴⁰	Policy year 0: 0.492 · 1: 0.629 · 2: 0.735 · 3: 0.840 · 4: 0.943 · 5+: 1.000	Applied multiplicatively to the insured-lives ultimate q_x within the five-year select period.

The IILMI Actual/Expected ratio is retained against ILT17 even though it was originally published against ILT16; ILT17 is the immediately subsequent CSO release and the small movement in the underlying population table between the two would shift the factor by far less than the residual uncertainty in the IILMI estimate. The CMI TMN00 table is used in preference to any later CMI table because it is the table built specifically for temporary-assurance experience and remains the canonical Irish-market reference for select-period adjustment on level- and decreasing-term business in the absence of an SAI-published insured-lives select table. Beyond age seventy-five the curve is linearly extrapolated using the local ratio q_x / q_{x-1} ; the representative policy never reaches that range during the thirty-year horizon.

4.3 Discount basis

All present-value computations use the European Insurance and Occupational Pensions Authority's monthly Risk-Free Rate publication, file *EIOPA_RFR_20260430.zip*, reference date thirtieth April 2026 (the second-quarter 2026 reference release), published 6 May 2026, EUR curve, no Volatility Adjustment.⁴¹ The relevant headline curve points are 1-year 2.68 per cent, 10-year 3.00 per cent, 30-year 3.19 per cent, with the Ultimate Forward Rate at 3.30 per cent, the Last Liquid Point at twenty years, the Smith-Wilson α parameter at 0.069243, and the Credit Risk Adjustment at ten basis points. The technical documentation for the curve construction is *EIOPA-BoS-25-471* (October 2025).⁴² The curve is interpolated to monthly maturities for the simulation.

4.4 Capital basis

Capital is computed on the Solvency II Standard Formula, life mortality sub-module, per Commission Delegated Regulation (EU) 2015/35 Article 137: the mortality stress is "an instantaneous permanent increase of 15% in the mortality rates used for the calculation of technical provisions", applied per Article 83's scenario-based methodology and Article 105(3)(a)'s life mortality risk specification.⁴³ For a pure term assurance the premium leg cancels in the SCR difference, so the mortality SCR reduces to

$$\text{SCR}_{\text{mort}} = \max(0, \text{BEL}_{\text{shock}} - \text{BEL}_0) = 0.15 \cdot \text{PV}[q_x(t) \cdot S(t)]$$

where $S(t)$ is the sum at risk. The Cost-of-Capital rate is six point zero per cent under the current Standard Formula and falls to four point seven five per cent from thirtieth January 2027 under Commission Delegated Regulation (EU) 2026/269 of 29 October 2025, published in the Official Journal of the European Union on 18 February 2026 and entering into force on 10 March 2026.⁴⁴ Risk margin is explicitly omitted from the modelling — a standard product-modernisation simplification — because the comparative interest is in BEL and SCR movement between designs, not in the level of the risk margin.

4.5 Disturbance prevalences

Section 5 specifies four disturbance scenarios — fixed-rate roll-off, top-up advance, term extension, lump-sum overpayment. The aggregate harm calculations in Section 6.6 weight the per-household disturbance integrals by published Irish prevalences. Table 3 records the prevalence calibrations.

Table 3 — Disturbance prevalences (Irish-data calibration)

Disturbance	Prevalence	Calibration source
D1 · Fixed-rate roll-off	95%	Approximately 90% of new mortgage agreements are fixed-rate (CBI <i>Retail Interest Rates</i> ³); Irish fixed terms 1–10y so roll-off events within a 30-year policy term are near-universal. The 95% is the share of policies that experience at least one rate-change event, not a measure of disclosure adequacy.
D2 · €50k+ top-up at year 7	13.1%	BPFI Q4 2025: 3,280 top-up drawdowns nationally / CBI PDH 698,000 = 0.470% annual; $1 - (1 - 0.0047)^{30} = 13.1\%$ lifetime. ⁵¹
D3 · Term extension	8%	CBI 2021 statement: 13% of PDH accounts (over 95,000) face end-of-term shortfall; 20% lifetime forbearance history; term extension is one of several forbearance modes. ⁶
D4 · €20k+ lump overpayment	18%	Suppressed by Irish fixed-rate caps: AIB €5k/yr, Bol 10% of normal monthly repayment (or €65) without breakage fee on fixed accounts (variable accounts uncapped), ICS 20%/yr (lender T&Cs). ⁷

The calibration is deliberately conservative on the under-insurance prevalences D2 and D3 — the disturbance frequencies most relevant to the under-insurance harm — and uses the highest-prevalence assumption available for the over-insurance disturbance D1, so that the steady-state results are not understated. The aggregate harm figures in Section 6 are therefore best read as central estimates with conservatism in the direction that understates the under-insurance harm.

4.6 Macro denominator

The Irish PDH stock used to convert household-level harms to aggregate harms is six hundred and ninety-seven thousand nine hundred and sixty-four mortgages — the Central Bank of Ireland's reported figure at the closest available vintage to the valuation date.³⁸ The aggregate over-insurance computations are constructed both at single-vintage-of-drawdown level (one year of new business) and at full-stock level (all current PDH mortgages). The deterministic full-stock aggregate cited in Section 6.6 is computed both on a uniform-cohort multiplier (Section 6.6 single-vintage scaling) and on a duration-weighted decomposition anchored on the Bank of Ireland Asset-Covered-Securities mortgage pool at 30 June 2025 — published banded data with midpoint assumptions, transparently disclosed — as a proxy for the in-force cohort distribution.⁴⁵ The stochastic aggregate cited in Section 6.7 is computed at single-vintage thirty-year present value.

5. Methodology

This section sets out the mechanics of the model. The deterministic core is straightforward: a representative policy is simulated month-by-month for three hundred and sixty months under a fixed contractual schedule against the actual outstanding balance, the gap is integrated, and the integrals are scaled to the principal-dwelling-house stock. Four disturbance scenarios perturb the actual mortgage trajectory. Three modernisation candidates redefine the contractual schedule. A present-value layer recasts all flows on the EIOPA risk-free curve. The stochastic extension, set out in detail in Annex A, replaces the fixed actual rate with a Monte Carlo distribution of plausible rate paths whose dynamics are anchored on the Central Bank of Ireland's *Retail Interest Rates* series for Irish new-business PDH mortgages, with the EIOPA EUR risk-free curve used for discounting only. The complete reproduction code, with seed and configuration, is in the workspace; the key results in Section 6 are reproducible from the locked seed.

5.1 Schedule, balance, gap

The contractual schedule $S(t)$ is, as derived in Section 2.3,

$$S(t) = S(0) \cdot ((1+i)^n - (1+i)^t) / ((1+i)^n - 1)$$

with $S(0) = €322,000$, $n = 360$ months, $i = 0.06/12$ the notional monthly rate. The actual outstanding balance $B(t)$ is computed as the amortisation of the same initial principal at the actual monthly rate $j = r/12$ over the same term:

$$B(t) = S(0) \cdot ((1+j)^n - (1+j)^t) / ((1+j)^n - 1)$$

The base case is j corresponding to four per cent annual; sensitivities are run at three, three-and-a-half, four-and-a-half, and five per cent. The gap function is $G(t) = S(t) - B(t)$, with sign convention: $G > 0$ is over-insurance, $G < 0$ is under-insurance.

The integral metrics for a single representative policy across the policy term are:

- The *mean gap* (€), arithmetic mean of $G(t)$ over $t \in [0, n]$.
- The *peak gap* (€), $\max_t G(t)$, with the month at which it occurs.
- The *mean share* (%), mean of $G(t)/B(t)$ where $B(t) > 0$.
- The *nominal integral* (€·years), $\sum_t G(t) / 12$ across the term, which is the standard cumulative-exposure metric in actuarial product-comparison work.
- The *present-value integral* (€·years), $\sum_t G(t) \cdot v(t) / 12$ where $v(t)$ is the EIOPA discount factor at maturity t .

5.2 Disturbance scenarios and the prudential-cushion role

Four disturbance scenarios are defined, calibrated to the Irish mortgage market events documented in Section 4.5. Each disturbance redefines $B(t)$ from the disturbance month forward; $S(t)$ is unchanged.

- **DO · Baseline.** No disturbance; $B(t)$ follows the standard amortisation at the actual rate.
- **D1 · Fixed-rate roll-off.** At policy year three the actual mortgage rate transits from 3.5 per cent (fixed) to 4.75 per cent (variable). $B(t)$ is re-amortised from year three forward over the remaining twenty-seven years at the new rate. This is an *over-insurance* disturbance — the higher actual rate steepens the amortisation curve, reducing $B(t)$ more slowly and increasing $G(t)$ modestly relative to baseline. Prevalence 95 per cent.

- **D2 · Top-up advance.** At policy year seven the borrower takes a fifty-thousand-euro top-up advance, secured against the same property. $B(t)$ is re-amortised from year seven forward at the prevailing rate over the remaining twenty-three years on the new combined principal. This is an *under-insurance* disturbance: $B(t)$ jumps upward at year seven by fifty thousand euro and remains structurally above $S(t)$ for a long subsequent period. Prevalence 13.1 per cent.
- **D3 · Term extension.** At policy year five the borrower extends the mortgage term from twenty-five years remaining to thirty years remaining (a five-year extension), with $B(t)$ re-amortised over the new longer schedule. This is the *largest single-policy under-insurance disturbance*: the contractual cover schedule continues to amortise toward zero at the original term-end, while the actual balance continues to amortise toward zero at the new, later term-end, with the result that the schedule falls below the balance from approximately year fifteen onward. Prevalence 8 per cent.
- **D4 · Lump-sum overpayment.** At policy year five the borrower makes a twenty-thousand-euro lump-sum overpayment within the lender's contractual cap. $B(t)$ drops by twenty thousand euro at year five and continues to amortise on the original schedule. This is an *over-insurance* disturbance: $B(t)$ sits structurally below the schedule for the remainder of the term. Prevalence 18 per cent.

The prudential-cushion role of steady-state over-insurance. A point of central importance, and one we acknowledge fully: the steady-state over-insurance documented in Section 6.1 also functions as a *prudential cushion* for the household. If actual rates rise sharply mid-term, the balance trajectory steepens upward and the cushion absorbs the move. Section 6.5 quantifies this directly by simulating a two-hundred-basis-point upward rate spike at policy year five — a stress aligned to certain Irish lender practices on variable and tracker portfolios — and shows that the mean cushion shrinks from €14,332 to €5,032 (approximately two-thirds reduction) but the policy never falls under-cover. The cushion is real, it is welfare-relevant, and any candid modernisation argument must price its loss. The break-even calculation in Section 8.2 prices the loss explicitly. Whether the loss is *welfare-positive* — that is, whether the household would rather hold the cushion for the rare upward-spike state or pay a lower premium against a more accurate balance trajectory — is a question of household risk preference that this paper does not attempt to resolve. We record the trade-off transparently.

Higher-order combinations — D2 + D3, D1 + D2 in different years, multiple top-ups across the policy term — are computationally trivial extensions of the same framework but are not modelled in this paper. They would, if anything, amplify the harm estimates.

5.3 Modernisation candidates

Three modernisation candidates for the schedule mechanic are defined.

- **M1 · Re-rated annuity-falling.** The schedule is recomputed at policy inception using the actual mortgage rate, rather than the six-per-cent notional. Formally, $S^{\{M1\}}(t)$ is the same amortisation formula as $S(t)$ but with i replaced by j (the actual rate). The schedule is still a curve fixed at issue. The premium is re-rated accordingly. This is the *minimal* modernisation: it closes the steady-state gap by construction but, because the schedule remains a curve and not a balance, it does not adjust to subsequent disturbances. M1 is the design most easily implemented inside legacy actuarial systems and is in commercial use on the United Kingdom decreasing-term market and on Irish bespoke commercial-mortgage business.
- **M2 · Event-stepped.** The schedule is computed at policy inception against the actual rate (as M1), and the schedule is *re-set* at each contractually-defined event: rate change, top-up, term extension, material lump-sum overpayment. At each event the new schedule is computed by recomputing the amortisation from the event date forward against the new loan parameters. Between events the schedule is fixed. The premium is re-rated at each event. M2 captures the

disturbance cases without requiring continuous balance reconciliation; it is conceptually equivalent to the French *assurance emprunteur* substitution architecture under the Loi Lemoine, in which the borrower can re-substitute cover at any time during the mortgage term.

- **M3 · Balance-linked.** The schedule *is* the outstanding mortgage balance, reconciled to lender data on a periodic basis (annual reconciliation in the base case). Formally $S^{\{M3\}}(t) \equiv B(t)$ at each reconciliation point, with linear interpolation between. The premium is re-rated at each reconciliation. M3 is the conceptually clean design — the policy benefit tracks the legislative intent of section 126 of the Consumer Credit Act 1995 — but it requires reconciliation infrastructure between insurer and lender that does not currently exist at industry scale in Ireland. M3 is closest in spirit to the United States level-term taxonomy in that it makes the policy benefit the actual liability, but it preserves the decreasing-term economics of pricing the cover only against the diminishing sum at risk.

The implementation overhead for M2 and M3 — the engineering, data-exchange, and operational cost of moving Irish insurers' policy-administration systems from a fixed-schedule basis to an event-driven or balance-linked basis — is not modelled in this paper. The capital cost of fixing the schedule, reported in Section 6.4, is quantified; the implementation overhead is acknowledged as an additional, market-level cost that would be incurred once at modernisation and is properly addressed in a separate operational-implementation study. The break-even expense loading calculation in Section 8.2 quantifies the per-policy commercial budget within which any such implementation cost would need to be amortised.

5.4 Aggregate harm constructions — HARM A and HARM B

Two aggregate harms are computed.

HARM A — Premium dead-weight (over-insurance). The premium attached to the excess sum assured $G(t) > 0$ is, in the strict actuarial sense, dead-weight: the household is paying for cover above the outstanding balance, and the insurer is paying claims (in expectation) on a sum at risk that is structurally above the liability. For each rate sensitivity, the mean excess SA across the term is multiplied by the per-euro-SA premium (€0.1028 per €1,000 SA per month) to give a monthly per-household dead-weight, and scaled to annual and thirty-year-cumulative metrics. Aggregate HARM A is computed both at single-vintage level (one year of new business multiplied by the per-household figure) and at full-stock level. The full-stock construction is reported in two parallel decompositions: a uniform-cohort multiplier across the entire PDH denominator, and a duration-weighted decomposition anchored on the Bank of Ireland Asset-Covered-Securities pool at 30 June 2025 — published banded data with midpoint assumptions, transparently disclosed.⁴⁵

HARM B — Coverage gap (under-insurance). The under-insurance integral $\int \max(0, B(t) - S(t)) dt$ is computed per scenario per design, expressed in €-years, and weighted by the disturbance prevalence to give a per-representative-household expected exposure. The aggregate is the per-household figure multiplied by the PDH stock denominator.

5.5 Present-value layer

All nominal €-year integrals are recast on the EIOPA EUR risk-free term structure at thirtieth April 2026, no Volatility Adjustment, to give actuarially-comparable present values. The PV ratio is typically approximately sixty per cent of nominal for front-loaded over-insurance integrals; for under-insurance integrals it depends on when the under-cover occurs and ranges from approximately seventy per cent of nominal where the under-cover concentrates in the middle of the term (the D2 top-up scenario, where the post-event under-cover starts at year seven and is partly cushioned by the still-positive

early-term discount factors) to approximately fifty per cent of nominal where the under-cover is heavily back-loaded (the D3 term-extension scenario, where the under-cover concentrates in the extended tail). The PV layer is the comparable basis for cross-design and cross-scenario comparison and is the basis on which the Solvency II capital impact in Section 6.4 is computed.

5.6 Stochastic extension — EIOPA-anchored rate paths

The deterministic model assumes a single actual mortgage rate for the policy term. The Irish mortgage market is materially more variable than this, both within a single mortgage's fixed-rate transitions (D1) and across the new-business book over the policy horizon. Annex A documents a stochastic extension in which the single actual rate is replaced by a Monte Carlo distribution of plausible rate paths.

The stochastic specification, in summary form: fifty thousand paths, three hundred and sixty months each, seed 20260529, with the EIOPA EUR risk-free curve at thirtieth April 2026 used for discounting only and no Volatility Adjustment applied. The rate-path *anchor* and the *discount basis* are separate constructions. **The bootstrap-Irish primary dynamics** are anchored on the Central Bank of Ireland's *Retail Interest Rates* series for Irish new-business PDH mortgages (last observation 3.50 per cent, March 2026 modal 3.49 per cent): historical monthly rate changes are sampled with replacement and applied to the Irish spot rate to generate the simulated rate path. **The three Vasicek calibration lenses** are driven off the ECB Deposit Facility Rate; their long-run means θ and mean-reversion speeds κ are calibrated to the CBI Irish-rate change distribution. **The discount basis** for all five lenses — bootstrap-Irish, C1, C1+MS2, C2 and C3 — is the EIOPA EUR risk-free curve at thirtieth April 2026, used to translate path-level over-insurance flows to present value. The bootstrap is the headline construction precisely because it is conservative: it admits the full empirical distribution of realised Irish rate changes without imposing a parametric mean-reverting structure that would damp the extreme over-insurance tails.

Three parametric calibration lenses are used as diagnostic comparators, plus one Markov-switching sensitivity. The driver is a **Vasicek short-rate process** of the form $dr = \kappa(\theta - r) dt + \sigma dW$, calibrated to the realised Irish rate-change distribution in three configurations: (i) **C1 · Data-MLE** — maximum-likelihood calibration on the CBI sample, with $\kappa = 0.063$ and the empirical long-run mean θ (denoted C1 — the closest parametric analogue to the bootstrap-Irish headline); (ii) **C2 · Reinsurance convention** — a reinsurance-style convention calibration with $\kappa = 0.20$ and $\theta = 2.50$ per cent (approximately a 3.5-year half-life), reflecting standard reinsurer pricing assumptions on long-run mean reversion in EUR rate space; and (iii) **C3 · Near-RW** — a near-random-walk variant with $\kappa = 0.02$, providing a low-mean-reversion sensitivity on κ . In addition, the Markov-switching sensitivity **C1 + MS2** layers a two-state Hamilton-filter-calibrated regime on the **spread** between the Irish translation and the EIOPA forward curve (not on the driver volatility σ): this is a *spread-switching* specification, which captures empirically observed regime change in the Irish-EUR retail mortgage spread without re-pricing the underlying Vasicek dynamics. The Vasicek process is chosen in preference to the alternative Cox-Ingersoll-Ross specification because the Annex A simulation, as implemented in code, uses the additive Gaussian noise dynamics characteristic of Vasicek and does not impose the square-root volatility scaling characteristic of CIR. The full lens specification — C1 / C1+MS2 / C2 / C3 — and the calibration procedure are documented in the companion Annex A, which is the canonical specification for the stochastic stack.

The floor regime is asymmetric: there is no driver floor on the rate dynamics, and the floor on the Irish translation is zero per cent (no negative-rate translation into the Irish retail mortgage rate). The floor choice was made deliberately conservative on the under-insurance side and is documented in full in Annex A footnote 8.

The output of the stochastic model is, for each modelled lens, a distribution of household-level HARM A figures (€ per household per year) and of thirty-year present-value figures across the PDH stock (€ millions). The headline figures cited in Section 6.8 are the median of the bootstrap-Irish distribution with the fifth and ninety-fifth percentile interval; the three Vasicek calibrations (C1 / C2 / C3) plus the C1 + MS2 spread-switching sensitivity bracket the headline as a robustness check. The *results* pack (bound as Annex A in the combined edition) frames this collection — bootstrap-Irish headline plus the three Vasicek calibrations plus the C1 + MS2 spread-switching sensitivity — as the *five-lens architecture*. The *diagnostics* pack (bound as Annex B) frames the same simulations as *four lenses* (bootstrap plus three Vasicek calibrations), treating Markov-switching as a spread overlay on C1. Both descriptions refer to the same five output series; the difference is taxonomic, not computational.

The choice to floor the Irish translation at zero per cent — rather than admit negative Irish retail mortgage rates as the CBI series did briefly during the 2020–2022 period — is the single most material modelling judgement in the stochastic specification. The effect is to mildly shorten the lower tail of HARM A in falling-rate regimes (because zero floor truncates very low actual rates that would otherwise generate the largest schedule-versus-balance gaps). The asymmetric floor — no driver floor, zero on translation — keeps the upper tail intact and is therefore conservative on the headline. The robustness check across the three Vasicek calibrations (C1 / C2 / C3) and the C1 + MS2 spread-switching sensitivity (where the floor effect is small) confirms that the headline is not driven by the floor choice.

6. Results

This section reports the model output. The structure mirrors the methodology: household-level results first (Sections 6.1 to 6.4), the prudential-cushion stress test (6.5), the deterministic aggregate over-insurance results (6.6), the coverage-gap (HARM B) aggregate (6.7), and the stochastic-rate headline last (6.8).

6.1 Household-level — steady-state over-insurance

Under the base-case actual rate of four per cent against the six-per-cent notional schedule, the representative single policy carries the following over-insurance profile across the thirty-year term:

- **Mean excess sum assured:** €14,332.
- **Peak excess sum assured:** €22,292, occurring at month 223 (year 18 and 7 months).
- **Mean share of excess over schedule** (excess relative to the contractual sum assured, i.e. $\text{mean}[(S-B)/S]$): 9.4 per cent.
- **Nominal integral:** 431,154 €-years (cumulative under-the-curve area between schedule and balance).
- **Present-value integral:** 264,636 €-years.

Table 4 reports the over-insurance summary across the rate sensitivities. The sensitivity grid is on 50 basis-point steps, and the resulting central slope is approximately €224,000 of nominal integral per 100 basis points near the four-per-cent centre — materially larger than the headline figures imply if read as a single point.

Table 4 — Module 1, over-insurance under rate sensitivities (single representative policy, 30-year term)

Actual rate	Mean excess SA (€)	Peak excess SA (€)	Mean share excess	Nominal integral (€·yr)	PV integral (€·yr)
3.00 %	21,913	33,845	14.2 %	659,203	404,648
3.50 %	18,093	28,041	11.8 %	544,289	333,905
4.00 %	14,332	22,292	9.4 %	431,154	264,636
4.50 %	10,637	16,605	7.1 %	319,991	196,407
5.00 %	7,013	10,989	4.7 %	210,977	129,500

Two features of Table 4 deserve note. First, the steady-state over-insurance is monotonically decreasing in the actual mortgage rate, as expected: the closer the actual rate to the six-per-cent notional, the smaller the gap. Second, the relationship is approximately linear in the rate spread, with each one-hundred-basis-point change in the actual rate moving the mean excess sum assured by approximately seven thousand four hundred euro near the four-per-cent centre, and moving the nominal integral by approximately €224,000. In the historically low Irish mortgage-rate environment of 2020 to 2022, when new-business PDH rates touched two-and-a-half per cent, the steady-state excess on a freshly drawn policy would have approached the upper sensitivity in Table 4.

6.2 Household-level – disturbance scenarios

The four disturbance scenarios D1 to D4 generate the additional integrals reported in Table 5. The reference column is the under-insurance integral, in €·years, for each design across each scenario.

Table 5 – Under-insurance integral (€·years) by scenario × design (single representative policy)

Scenario	Legacy	M1 (re-rated)	M2 (event-stepped)	M3 (balance-linked)
DO · Baseline	0	0	0	0
D1 · Fixed-rate roll-off (y3)	0	217,223	0	0
D2 · €50k top-up (y7)	280,713	662,427	0	4,107
D3 · Term extension (y5)	651,293	908,824	0	0
D4 · €20k overpayment (y5)	0	0	0	0

The largest single-policy under-insurance exposures are in D3 (term extension, €80,450 peak under-cover) and D2 (top-up advance, €38,363 peak under-cover). Table 5 also reveals the central design finding of this paper: the minimal modernisation, M1, creates a substantial disturbance-side under-insurance liability that does not exist in the legacy product. The M1 schedule is drawn against the actual rate at issue and is therefore tighter than the legacy schedule by approximately the steady-state over-insurance gap. Under any disturbance that increases the actual outstanding balance relative to the original amortisation path – fixed-rate roll-off to a higher rate (D1, €217,223 €·years), top-up advance (D2, €662,427 €·years), or term extension (D3, €908,824 €·years) – M1 falls below the post-disturbance balance and the policy is structurally under-insured for the remainder of the term. The M1 under-insurance integrals in D2 and D3 are materially larger than the corresponding legacy figures (€280,713 and €651,293 respectively), precisely because the tighter M1 curve has less slack to absorb the disturbance. M1 closes the steady-state over-insurance gap fully (Table 6, DO–D3) but trades it for a disturbance under-insurance gap in three of the four disturbance scenarios. The single scenario in

which M1 carries no under-insurance is D4 (lump-sum overpayment), because the overpayment reduces the actual balance below the original schedule rather than above it.

The lesson is straightforward: re-rating the schedule at issue, without an in-life adjustment mechanism, *systematically* trades steady-state over-insurance for disturbance under-insurance. It is not a complete modernisation; on the disturbance side it is in three of four scenarios *worse* than the legacy product. M2 (event-stepped) closes all four disturbance gaps fully, because at each event the schedule is recomputed against the new loan parameters. M3 (balance-linked) closes the disturbance gaps to within rounding (D2 shows a small residual of 4,107 €·years, attributable to the annual reconciliation lag in the base specification; quarterly reconciliation would reduce it further).

6.3 Household-level – modernisation outcomes (over-insurance side)

The over-insurance side is reported in Table 6, again per design, for the base-case 4-per-cent actual rate.

Table 6 – Over-insurance integral (€·years) by scenario × design (single representative policy, 4% actual)

Scenario	Legacy	M1	M2	M3
DO · Baseline	431,154	0	0	26,769
D1 · Fixed-rate roll-off (y3)	327,067	0	0	26,764
D2 · €50k top-up (y7)	49,440	0	0	30,865
D3 · Term extension (y5)	51,795	0	0	26,772
D4 · €20k overpayment (y5)	722,345	291,191	0	26,774

Three observations. First, all three modernisations substantially close the steady-state over-insurance gap (DO): M1 and M2 close it fully by construction; M3 leaves a small residual of approximately €26,770 €·years per year, equivalent to roughly six per cent of the legacy DO figure, attributable to the annual reconciliation lag. The reduction is therefore approximately ninety-four per cent under M3 rather than full closure — a distinction we mark deliberately. Second, under D4 (lump-sum overpayment) M1 carries a residual over-insurance integral of 291,191 €·years, because the M1 schedule remains a curve fixed at the original principal and does not adjust downward when the principal is paid down. M2 and M3, both event-aware, close the D4 over-insurance gap. Third, the residual M3 figures across DO–D4 are tight and stable in the ~€26,770–€30,870 range, with the modest D2 elevation reflecting the annual reconciliation lag straddling the top-up event at year seven.

Taken together, Tables 5 and 6 give the design hierarchy that the rest of this section quantifies in capital and aggregate terms: M2 and M3 are the substantial modernisations; M1 is a partial modernisation that closes the steady-state side at the cost of materially worsening the disturbance side in three of four scenarios.

6.4 Household-level – Solvency II Standard Formula mortality SCR

Table 7 reports SCR_mort and the underlying Best Estimate Liability, by scenario × design, computed on the EIOPA 30-Apr-2026 curve under the Article 137 mortality stress.

Table 7 – Solvency II Standard Formula mortality charge by scenario × design (single representative policy, €)

Scenario	Legacy SCR_mort	M1 SCR_mort	M2 SCR_mort	M3 SCR_mort	Legacy BEL	M1 BEL	M2 BEL	M3 BEL
DO · Baseline	687	624	624	628	4,582	4,159	4,159	4,189
D1 · Fixed-rate roll-off	687	607	641	645	4,582	4,050	4,273	4,303
D2 · €50k top-up	687	624	713	718	4,582	4,159	4,752	4,785
D3 · Term extension	475	437	603	607	3,165	2,915	4,017	4,047
D4 · €20k overpayment	687	624	587	591	4,582	4,159	3,911	3,940

The honest framing is this. **At baseline (DO) and in three of four disturbance scenarios – D1, D2 and D4 – modernisation candidates M1, M2 and M3 each reduce SCR_mort relative to the legacy product.** The reductions range from approximately ten per cent (DO) to fifteen per cent (D4 under M2 and M3). The reason is the same in each case: the modernised schedule tracks the sum at risk more closely than the fixed legacy curve, and a smaller sum at risk attracts a smaller mortality stress under Article 137.

The exception is D3 (term extension). Under D3, the legacy product's SCR falls to €475 *because the cover has collapsed below the outstanding balance*, which is precisely the under-insurance failure documented in Table 5; restoring cover under M2 or M3 raises the SCR back to approximately €603 to €607, a twenty-seven per cent increase relative to the legacy charge under that same disturbance. That twenty-seven per cent is **the price of product integrity in the D3 scenario specifically – not a steady-state capital uplift across the book.** It is the additional capital required to back a cover schedule that actually does what section 126 of the Consumer Credit Act intends a mortgage protection policy to do. In absolute euro terms it is small; in percentage terms it is the visible cost of fixing the schedule mechanic in the one disturbance where the legacy schedule fails most acutely.

Two implications follow. First, the legacy product's lower SCR under D3 is, in this strict sense, *understated* capital: it reflects a sum at risk that the legislative intent of section 126 says should be larger. Second – and this is the systemic frame to which we return in Section 7 – the capital cost of modernisation is concentrated in a specific disturbance scenario rather than uniformly distributed across the book. A manufacturer evaluating modernisation can therefore reason about the D3 uplift as a scenario-specific contingency rather than as a portfolio-wide capital tax.

6.5 Prudential-cushion stress test – Legacy schedule under +200bps at year 5

To quantify the prudential-cushion role of the steady-state over-insurance we run a focused stress test on the **Legacy** product. We hold the 6%-notional decreasing-term schedule unchanged (it is fixed at policy inception by construction – the central feature of the product under analysis) and apply a two-hundred-basis-point upward shock to the borrower's actual mortgage rate at policy year five, stepping the actual rate from the 4% base case to 6% with re-amortisation over the remaining twenty-five years on the balance at end of month sixty. The shock is aligned to certain Irish lender practices on variable and tracker portfolios where mid-term rate movements of this magnitude have been observed historically.

The stress test is run on the Legacy schedule rather than M1 because M1 (re-rated at issue against the actual 4% rate) has zero steady-state over-insurance by construction (Table 6, DO/M1 = 0) and therefore has no prudential cushion to stress. The cushion is a Legacy-product feature; the stress test is therefore the cushion test for the Legacy product specifically.

The headline stress-test results, single representative policy:

- **Monthly payment trajectory:** €1,537.28 (pre-shock, 4% actual) → €1,876.47 (post-shock, 6% actual at year 5) — an increase of approximately twenty-two per cent.
- **Mean cushion across the term:** €14,332 (pre-shock baseline, 4% actual against 6% notional schedule) → €5,032 (post-shock) — a reduction of approximately sixty-five per cent.
- **Peak over-insurance:** €22,292 at month 223 (pre-shock) → €8,394 at month 60 (post-shock).
- **Cushion deficit (under-insurance) under post-shock trajectory:** zero across all 360 months — the cushion never falls below the post-shock balance.

The reading is straightforward. A two-hundred-basis-point upward rate spike at year five — itself a non-trivial stress, and one that lands the borrower's actual rate at the 6%-notional schedule rate — shrinks the prudential cushion by approximately two-thirds but does *not* exhaust it. The household remains over-insured throughout the policy term even under the spike. The post-stress cushion converges toward zero in the late-term tail (because the actual rate now equals the notional rate, so balance and schedule amortise on the same trajectory) but the policy never goes structurally below cover. The cushion exists, it is welfare-relevant, and it does its job in the rare stress state in which the actual balance trajectory steepens. Section 8.6 returns to the welfare implication: the question is whether the cushion is the most efficient way to deliver the rare-stress insurance, or whether a modernised schedule with explicit rate-spike protection would deliver the same household outcome at lower premium. We do not attempt to resolve that question in this paper; we record the trade-off transparently.

6.6 Aggregate — HARM A (premium dead-weight, deterministic)

Table 8 reports HARM A — the premium dead-weight on the excess sum assured — at the per-household level across the rate sensitivities, and at the aggregate level on the four-per-cent base case. We report two parallel aggregate constructions: a single-vintage uniform-cohort multiplier across the entire PDH denominator (the construction used in the predecessor papers in this series) and a duration-weighted decomposition anchored on the Bank of Ireland Asset-Covered-Securities pool at 30 June 2025 — published banded data with midpoint assumptions, transparently disclosed — as a proxy for the in-force cohort distribution.⁴⁵ The duration-weighted decomposition recognises that the in-force book is not uniformly distributed by remaining term, and that older cohorts (with shorter remaining terms and lower outstanding balances) carry materially smaller per-policy over-insurance integrals than freshly drawn policies. The Bol ACS pool, while specific to one lender, is the most granular publicly disclosed Irish mortgage pool dataset available, with reported weighted-average remaining term (WART) of 20.71 years on an aggregate balance of €10.82 billion across 73,622 loans across seven remaining-term buckets — well-suited as a transparent proxy for the system-level cohort distribution.⁴⁶ We note for transparency that the published Bol ACS banding includes a 30–35-year remaining-term bucket (midpoint 32.5 years, 3,875 loans, 5.26 per cent weight). A remaining term beyond thirty years sits outside this paper's thirty-year representative-policy frame; the bucket is faithfully transcribed from the published Bol banding and the duration-weighted aggregate is reported as published. The bucket carries the highest per-loan annual excess of any band in the Bol pool (€15.13/yr) and a 5.26 per cent weight; removing it lowers the duration-weighted headline from €4,065,413 to approximately €3,704,000 — an approximately 8.9 per cent reduction. This is modest but not negligible. We retain the

published banding faithfully and report the headline as published, with the understanding — consistent with the structural caveat in §4.4 and §5.5 — that a remaining term beyond thirty years sits outside this paper's thirty-year representative-policy frame. Readers comparing the duration-weighted central estimate against alternative cohort proxies should treat the published-as-banded figure and the ex-30-35-year figure as a sensitivity range (approximately €3.7m to €4.07m on the Bol ACS proxy).

Table 8 — HARM A: premium dead-weight on excess SA (4% actual base case unless stated)

Metric	Value
Mean excess SA per household (€, 4% base)	14,332
Premium on excess SA, monthly (€)	1.47
Premium on excess SA, annually (€)	17.68
Premium on excess SA, lifetime 30-year cumulative (€)	530.37
Annual aggregate cost per drawdown vintage (€)	819,568
Annual aggregate cost across PDH stock — single-vintage uniform multiplier (€)	12,340,009
Annual aggregate cost across PDH stock — duration-weighted (Bol ACS proxy) (€)	4,065,413
Single-vintage 30-year cumulative aggregate (€)	24,587,026

The duration-weighted aggregate is approximately one-third of the uniform-multiplier construction. Both are valid constructions of "aggregate annual dead-weight"; they answer different questions. The uniform-cohort multiplier asks: *if every PDH mortgage in Ireland were currently at the representative-borrower stage (35 years old, just drawn down, 30 years remaining), what would the aggregate annual dead-weight be?* The duration-weighted construction asks: *given the actual mixed cohort distribution of the in-force book, with WART of about 20.7 years on the published lender proxy, what is the more conservative system-level annual dead-weight today?* The conservative duration-weighted figure of approximately €4.07 million per year is the more defensible central estimate of *today's* system-level annual dead-weight; the €12.34 million figure is the more relevant comparator for a new-business cohort or a forward-looking single-vintage projection. We lead with the duration-weighted figure as the central estimate and report both constructions transparently.

At the level of the individual household, the annual dead-weight is modest in absolute terms — under €20 per year on the four-per-cent base. The aggregate, on either construction, is materially larger than the per-household figure suggests. Section 6.7 reports the stochastic refinement.

6.7 Aggregate — HARM B (coverage gap, deterministic)

Table 9 reports HARM B — the under-insurance exposure aggregated across the disturbance scenarios using the prevalence calibrations from Table 3.

Table 9 — HARM B: coverage gap (under-insurance, system level)

Scenario	Per-HH under-cover (€·yr)	Prevalence	Contribution (€·yr)
D1 · Fixed-rate roll-off	0	95 %	0
D2 · €50k top-up at year 7	280,713	13.1 %	36,773
D3 · Term extension	651,293	8 %	52,103
D4 · €20k overpayment	0	18 %	0
Total per representative household			88,877
Aggregate across PDH stock (€ bn·yr)			62.0

The aggregate HARM B figure of 62 billion €·years is the cumulative under-cover exposure across the entire principal-dwelling-house stock under the legacy product, weighted by Irish-data-calibrated prevalences. The figure is large; it should be: it represents thirty years of compounded under-cover across hundreds of thousands of mortgages under the legacy schedule mechanic. It is fully closed by modernisation candidates M2 and M3 (Table 5).

6.8 Stochastic-rate headline

The stochastic extension specified in Section 5.6 and detailed in Annex A produces, on bootstrap-Irish rate dynamics over fifty thousand paths (anchored on the CBI Irish-mortgage-rate spot of 3.50 per cent, discounted on the EIOPA EUR risk-free curve at thirtieth April 2026), the following headline.

Table 10 — Stochastic HARM A, bootstrap-Irish headline with three Vasicek calibration lenses (C1 / C2 / C3) and the C1 + MS2 spread-switching sensitivity (50,000 paths, 360 months each, seed 20260529)

Lens	HARM A median (€/HH/yr)	5th percentile	95th percentile	PDH 30-yr PV median (€m)	Final rate Q50
Bootstrap-Irish (headline)	25.94	6.07	44.35	345	2.77 %
C1 · Data-MLE ($\kappa=0.063$, empirical θ)	23.60	11.36	36.41	313	3.03 %
C1 + MS2 (spread-switching sensitivity)	17.09	5.65	30.66	224	3.80 %
C2 · Reinsurance convention ($\kappa=0.20$, $\theta=2.50$ %)	13.76	8.35	19.48	192	4.52 %
C3 · Near-RW ($\kappa=0.02$)	19.70	4.83	37.74	265	3.61 %

The headline reads as follows. On bootstrap-Irish dynamics — the calibration anchored to the realised distribution of monthly rate changes in the Central Bank's *Retail Interest Rates* series — the median household-level over-insurance harm is approximately twenty-six euro per household per year, with a five-to-ninety-five-per-cent interval of six to forty-four euro. The corresponding thirty-year present value across the Irish PDH stock is three hundred and forty-five million euro with an interval of one hundred to five hundred and eighty-seven million euro.

The three parametric Vasicek calibrations (C1, C2, C3) together with the C1 + MS2 spread-switching sensitivity bracket the bootstrap-Irish headline between thirteen point seven six and twenty-three

point six zero euro per household per year on the central tendency. The headline is therefore not an artefact of the rate-model choice: the stochastic excess-cover exposure ranges, across plausible Vasicek calibrations of the underlying rate process, between roughly fourteen and twenty-four euro per household per year, with thirty-year PV exposures across the PDH stock between one hundred and ninety and three hundred and forty-five million euro.

The deterministic four-per-cent base case in Section 6.6 reported aggregate HARM A across the PDH stock of either twelve point three four million euro per year (uniform-cohort) or four point zero seven million euro per year (duration-weighted), against approximately eighteen point one million euro per year implied by the stochastic median on the uniform-cohort basis (twenty-five point nine four euro per household \times six hundred and ninety-seven thousand nine hundred and sixty-four households). The stochastic headline on the uniform-cohort comparator is therefore approximately forty-seven per cent higher than the deterministic uniform-cohort point estimate. The gap is consistent with the convexity of the over-insurance function in the actual rate: rate paths below the deterministic four-per-cent base contribute disproportionately to the harm integral, and the stochastic median is pulled above the deterministic estimate by the realised lower-tail rate environment of the Irish-mortgage-rate distribution from which the bootstrap is drawn.

The full distributional output, including the fan charts at quarterly milestones and the path-by-path moment summaries, is documented in Annex A.

7. Discussion

This section discusses the mechanisms underlying the results and the design choices implied by them. The aim is to give the reader the analytical handles to interpret the headline figures in Section 6 — to see *why* the schedule mechanic generates the two-sided mismatch, *why* the simplest modernisation is incomplete, *why* the more complete modernisations carry the capital signature they do, and *why* the prudential cushion is welfare-ambiguous rather than uniformly costly to the household.

(i) The six-per-cent notional as an amortisation-shape shortcut. The contractual schedule $S(t)$, as specified in Section 2.3, is the amortisation curve of a level-payment loan against a fixed notional rate. The choice of six per cent is not arbitrary — it tracks the long-run nominal Irish mortgage-rate average over the period in which the decreasing-term product class crystallised — but the choice is also not a balance-tracking choice. It is an *amortisation-shape choice*. The schedule is a curve whose shape resembles the amortisation of a loan; the schedule is not, in any month, the actual outstanding balance. The legislative intent of section 126 of the Consumer Credit Act 1995 is balance-tracking ("a sum equal to the amount of the principal estimated by the mortgage lender to be outstanding"); the schedule mechanic delivers an *approximation* to balance-tracking that depended, for its accuracy, on the actual mortgage rate being close to the notional. In the historic Irish nominal-rate environment that condition was, more or less, met. In the 2020s Irish nominal-rate environment it is not. The schedule mechanic was always an approximation; it has now become a *systematic* approximation, with a known sign (over-insurance in steady state) and a known magnitude (Table 4).

(ii) Two-sided mismatch as the mathematical consequence. The schedule mechanic fixes $S(t)$ at issue and holds it fixed across the policy term. The actual mortgage trajectory $B(t)$ is a stochastic object: it depends on the actual rate (which varies across the term under D1), on principal events (D2, D3, D4), and, in the long run, on the household's financial behaviour. A fixed $S(t)$ is by construction a poor tracker of a stochastic $B(t)$. The over-insurance side (S above B) is the dominant case in steady state, because the notional rate sits above the actual rate. The under-insurance side (S below B) is the

dominant case under disturbance, because principal events move B and leave S unchanged. The two failures are therefore mechanically related: they are the two consequences, with opposite signs, of the same root cause.

(iii) The prudential-cushion role and the welfare-ambiguity it creates. The over-insurance gap is not pure dead-weight from the household's perspective. As Section 6.5's stress test demonstrates, the cushion absorbs upward rate shocks: under a two-hundred-basis-point spike at year five the cushion shrinks by approximately two-thirds but never exhausts. The cushion has therefore three components, conceptually distinct: a *steady-state component* (which is the dead-weight under the central rate scenario), a *rate-state-contingent insurance component* (which is non-zero in rising-rate states and zero in falling-rate states), and an *estate-benefit component* (the surplus on death that statute directs to the surviving borrower or the deceased's estate). The conservative reading is therefore that the *welfare-relevant* dead-weight is smaller than the gross HARM A figure suggests, because some of the gross figure is buying rare-state insurance and some is buying estate benefit. The aggressive reading is that the cushion is an inefficient way to deliver those two services — that rare-state insurance can be delivered by a modernised schedule with explicit rate-spike protection at a fraction of the cost, and that estate benefit is better delivered by an explicit life-cover policy chosen on its own merits. We do not attempt to resolve the trade-off; we record it transparently and observe that the policy and product implications in Section 8 sit within that ambiguity rather than over it.

(iv) Why M1 alone is insufficient. The minimal modernisation M1 re-rates the schedule at issue against the actual rate. By construction, this closes the steady-state gap (Table 6: DO over-insurance is zero under M1). But M1 still draws a curve at issue and holds it fixed. The remaining failure mode is that the M1 schedule is *tighter* than the legacy schedule, because it is calibrated to a lower rate, and that tighter curve has materially less slack to absorb disturbances. Across the three disturbance scenarios in which the actual balance moves away from the at-issue trajectory — D1 (rate roll-off), D2 (top-up at year seven), D3 (term extension) — the under-insurance integral under M1 is therefore materially larger than under the legacy product. Specifically: under D1 the M1 under-insurance integral is 217,223 €·years against zero under the legacy product; under D2 it is 662,427 €·years against 280,713 €·years on the legacy product (because the tighter M1 schedule is further below the post-top-up balance than the looser legacy schedule); and under D3 it is 908,824 €·years against 651,293 €·years on the legacy product. Only under D4 (lump-sum overpayment) is M1 not worse than legacy: there the balance steps down at the overpayment date and M1's tighter curve sits closer to the post-overpayment balance, so the under-insurance integral is zero under both legacy and M1. M1 trades steady-state over-insurance for disturbance under-insurance in three of the four disturbance scenarios. It is not a costless improvement; it is a different — and in three disturbance scenarios materially worse — failure profile.

(v) Why M2 closes events without explicit balance linkage. The event-stepped modernisation M2 re-sets the schedule at each contractually-defined event. The schedule between events is still a curve fixed at the latest event; it is not balance-linked. But because the events themselves are the disturbances — rate change, top-up, term extension, material overpayment — re-setting at each event reconstitutes the schedule on the new loan parameters precisely when those parameters move. The remaining failure mode is the *between-event* trajectory: small movements in the loan (early extra payments below the materiality threshold for re-setting, small in-arrears positions that are subsequently cured) are not captured. The empirical magnitude of these between-event drifts is small in the Irish context, as Table 5 demonstrates: M2's residual disturbance under-insurance integrals are zero across all four scenarios. M2 is, in the Irish market environment, *operationally equivalent* to balance linkage without requiring the data-exchange infrastructure that M3 demands.

(vi) Why M3 requires reconciliation infrastructure. The balance-linked modernisation M3 sets $S(t) \equiv B(t)$ at each reconciliation point. This is the conceptually clean design — the policy benefit is the

outstanding mortgage balance. But it requires the insurer to know $B(t)$ at each reconciliation point, which requires a data-exchange channel between the insurer and the lender. Such channels are routine in some markets — the French *assurance emprunteur* substitution process under the Loi Lemoine assumes them; the United States level-term taxonomy bypasses them by selecting a fixed cover that is independent of the actual balance — but they are not currently established at industry scale in Ireland. The implementation overhead is real, is *not* modelled in this paper (per Section 5.3), and would in any case be incurred once at modernisation. The marginal payoff of M3 over M2, in the Irish market environment, is the residual D2 reconciliation lag and the elimination of the materiality-threshold judgement on event-stepping; whether that marginal payoff justifies the implementation overhead is an operational-economics question that sits outside the scope of this paper.

(vii) Capital signature — system-level versus insurer-level reading. Section 6.4 reports a result that is easy to misread in the abstract: under D3 (term extension), the legacy product's SCR_mort falls to €475, against €603 under M2 or M3. Read at the *insurer* level, this looks like a +27% capital cost of modernisation, and a manufacturer would be entitled to ask whether modernisation is a net-capital-positive trade. Read at the *system* level — the level relevant to the consumer-protection legislative intent of section 126, and to EIOPA's POG ongoing-monitoring expectations under IDD Article 25 — the result reads differently. The legacy SCR_mort under D3 is *low because the cover has collapsed*. The capital figure is a faithful Standard Formula computation against a sum at risk that the schedule has allowed to fall below the outstanding balance; that low figure is therefore an artefact of the underlying under-insurance failure rather than a measure of legacy capital efficiency. The +27% under modernisation is the capital cost of *restoring* the cover the legislative intent of section 126 says should be there. At baseline (DO) and in three of four disturbance scenarios, modernisation reduces SCR_mort. Across the entire scenario set the picture is not "modernisation is more capital-intensive than legacy"; it is "modernisation prices cover correctly across all scenarios, and the legacy product under-prices capital specifically in the disturbance scenario where its cover has failed." The system-level outcome of modernisation is therefore a *redistribution* of capital — slightly lower under most states, materially higher only under D3 — toward the scenarios where the cover is genuinely there.

(viii) How international precedent maps onto the Irish modernisation question. The international evidence in Section 3 distributes across the modernisation candidates analysed in Section 5. The United Kingdom market's level-term shift (Sections 3.4, 3.6) is structurally distinct from any of M1, M2, or M3 — it is a *taxonomic* response (change the product class) rather than a *schedule-mechanic* response (fix the schedule within the existing class). The French Loi Lemoine substitution regime (Section 3.3) is structurally close to M2 — it enables event-stepped re-substitution. The EIOPA POG architecture under IDD Article 25 (Section 3.2) bears on all three modernisations equally — it imposes a target-market and ongoing-monitoring obligation that any of M1, M2, or M3 would discharge better than the legacy schedule. The Canadian FCAC findings on post-claim underwriting (Section 3.5) are orthogonal to the schedule-mechanic question but complementary in concern: a market in which the schedule is wrong and the claim may be declined on a technicality has a layered cover-integrity problem of which the schedule mechanic is one component. The cumulative international read is that the schedule-mechanic question is genuinely the missing piece in the Irish product-design discussion — neither the level-term shift, nor substitution rights, nor product-oversight obligations, nor underwriting-quality reforms address it directly. Modernisation of the schedule mechanic — by M2 in the proportionate case, by M3 in the long-term-target case — is the *additional* intervention that the international evidence does not, on its own, supply.

8. A spectrum of constructive responses

This section sets out the implications of the analysis for product design, disclosure, product oversight, Solvency II treatment, and the interaction with the demand-side and supply-side findings of the two predecessor papers. The framing is deliberately a *spectrum of responses* rather than a single recommendation: different responses sit at different points on the operational, commercial, and capital-cost trade-off curve, and the appropriate response for any given Irish life office will depend on its own legacy-systems estate, its book-mix, its capital position, and its commercial strategy. The intent, as in *The Bank Premium*, is to order the responses by intrusiveness — beginning with what insurers and intermediaries can do within the existing product framework at lowest operational cost, and progressing to the more structural responses that would engage the manufacturer's product-oversight committee under IDD Article 25.

8.1 The response spectrum

We identify five distinct responses, ordered from least to most operationally intrusive. Each sits within the existing legal and supervisory framework; none requires a new regulatory mandate.

Response 1 — Disclosure-only. Provide, alongside the premium quote, a single-page illustration of the schedule against an indicative balance trajectory under the actual rate at issue, with a sensitivity to a rate-roll-off scenario. The data are already in the insurer's pricing system. This is computationally trivial, requires no schedule re-engineering, and substantively addresses the demands-and-needs assessment requirement under IDD Article 20. It does not, on its own, modernise the schedule mechanic; it makes the existing mismatch visible to the consumer at the moment of purchase. Disclosure is not a substitute for product redesign but it is a precondition for an informed market response. The MCD's European Standardised Information Sheet architecture (Article 14) provides a natural template for the disclosure format.¹⁷

Response 2 — M1 re-rate, no event mechanism. Re-rate the schedule at issue against the actual rate. This is the minimal product change: actuarial pricing systems handle it without operational uplift, the product taxonomy is unchanged, and the steady-state over-insurance is closed by construction. Section 6.2 documents the principal trade-off: M1 *creates* or *enlarges* a disturbance under-insurance gap that the legacy product did not exhibit on the same scale, particularly under D1 (rate roll-off), D2 (top-up) and D3 (term extension). For a manufacturer with a heavy bias to administrative simplicity and a low-disturbance book mix, M1 may be acceptable; for the typical Irish book with 13.1-per-cent top-up prevalence and eight-per-cent term-extension prevalence, M1 is a partial response.

Response 3 — M2 event-stepped. Re-rate at issue (as M1) and re-set the schedule at each contractually-defined event. Section 6.2 documents that M2 closes the disturbance gaps fully. The operational uplift over M1 is modest in principle — the actuarial computation at each event is the same as the at-issue computation — but it requires the policy-administration system to recognise the event, capture the new loan parameters, and trigger the recalculation. Most modern Irish life-office administration platforms can support this with engineering effort measured in months rather than years; legacy mainframe environments may require longer. M2 is in this paper the *proportionate* near-term response: it closes both the steady-state and the disturbance gaps, it does not require continuous lender-data exchange, and it sits structurally close to the French *assurance emprunteur* substitution architecture in commercial use across a comparable European market.

Response 4 — M3 balance-linked. Set the schedule equal to the outstanding mortgage balance at each periodic reconciliation. This is the conceptually cleanest design — the policy benefit *is* the actual outstanding balance — and it directly tracks the legislative intent of section 126. It requires industry

data-exchange infrastructure between insurers and lenders that does not currently exist at scale in Ireland and that would need to be built. M3 is in this paper the *longer-run product-architecture target*: a manufacturer that intends to compete on cover-integrity over a five-to-ten-year horizon would invest in the infrastructure now; a manufacturer focused on the next product cycle may legitimately prefer M2 in the interim.

Response 5 — Product taxonomy switch to level-term. Abandon the decreasing-term mechanic entirely and price the mortgage protection cover as level-term. This is the United States resolution (Section 3.6) and is structurally available in Ireland today — Irish life offices already manufacture level-term assurance for the non-mortgage segment. The trade-off is that level-term breaks the decreasing-term economics of pricing against a diminishing sum at risk: the premium for an equivalent term and SA at issue would be materially higher than under any of M1, M2, or M3. Whether the Irish market would accept that premium uplift is a commercial question; the evidence from MWP-2026-02 suggests the market is price-sensitive in the bank channel.

The five responses are not mutually exclusive. A reasonable manufacturer-level pathway might be: Response 1 (disclosure) in the next six months at near-zero cost; Response 3 (M2) over a twelve-to-eighteen-month roadmap as the proportionate product redesign; Response 4 (M3) as a longer-term target once industry-scale lender-data infrastructure is in place. The five responses also distribute differently across the three failure modes identified in Section 3.1: Response 1 partially addresses the *design* failure (by making it visible to the consumer), Responses 2 through 4 address the *design* failure directly, and Response 5 dissolves the *design* failure by leaving the product class entirely. None of the responses addresses the *distribution* failure documented in MWP-2026-02; that requires a separate response from the channel-test side.

8.2 Break-even expense loading — what does modernisation cost the manufacturer per policy?

The capital signature of modernisation is reported in Section 6.4: on Standard Formula, modernisation reduces SCR_mort across most scenarios and raises it in D3 specifically. The capital story is not the only commercial-economics story, however. The manufacturer's premium income on a modernised policy is lower than on the legacy policy *by exactly the dead-weight premium on the closed over-insurance gap*. A manufacturer evaluating modernisation must therefore ask: *what expense loading per policy per year would be required to fund the operational uplift of M2 or M3 against the loss of dead-weight premium income?*

We compute the break-even expense loading directly. The implicit premium loading on the representative policy is approximately €1.234 per €1,000 sum-assured per year. Modernisation extinguishes the dead-weight premium across the term: under M2 and M3 the mean excess sum assured is materially smaller than the legacy €14,332. The break-even expense loadings — the per-policy-per-year revenue uplift required to leave the manufacturer indifferent between the legacy and the modernised product on a single-vintage basis — are:

- **Mean over-insurance closed (Legacy → modernised):** Legacy €10,545; M1 €1,941; M2 €0; M3 €920 per policy per year. These are the closed-gap *premium-income reductions* the manufacturer foregoes under each design (the workbook's *mean over-insurance* column, not break-even loadings).
- **Break-even expense loadings — the per-policy-per-year revenue uplift required to leave the manufacturer indifferent between the legacy and the modernised product on a single-vintage basis:**
 - **M1: €10.61 per policy per year.**

- **M2: €13.01 per policy per year.**
- **M3: €11.87 per policy per year.**

The ordering is logically right: M2, which closes the over-insurance gap fully (mean excess €0) and additionally closes all four disturbance-side gaps, carries the *largest* break-even loading because it foregoes the most premium income; M1, which only closes the steady-state side and creates a disturbance liability in three of four scenarios, carries the smallest; M3 sits between, with full disturbance closure offset by the small steady-state residual.

The break-even figures — €10.61 (M1), €13.01 (M2) and €11.87 (M3) per policy per year — are modest against the implicit per-policy premium of approximately three hundred and ninety-seven euro per year on the representative profile (€33.10 monthly). Expressed as a share of base premium they correspond to approximately 2.7 per cent (M1), 3.3 per cent (M2) and 3.0 per cent (M3). The break-even figures are the per-policy commercial budget within which any operational implementation cost would need to be amortised. Whether the operational implementation cost for any specific Irish insurer falls inside that envelope is an insurer-specific question that depends on legacy systems, IT roadmap, and the size of the in-force book over which the implementation cost can be amortised; we do not attempt to estimate it. The point of the calculation is that the modernisation conversation is *not* a conversation about an order-of-magnitude commercial impact. It is a conversation about whether a manufacturer can deliver M2 or M3 within an expense uplift of roughly eleven-to-thirteen euro per policy per year — equivalently, within roughly three per cent of base premium. The share-of-premium framing is invariant to the premium-per-mille assumption: numerator and denominator scale linearly, so the 2.7–3.3 per cent band holds across a wide range of ppm choices (see BreakEvens!B23:E29 sensitivity table).

8.3 Product oversight under IDD Article 25 / Consumer Protection Code

The Insurance Distribution Directive's product-oversight-and-governance regime (Article 25, IDD 2016/97; PROD 4 in the United Kingdom equivalent; the corresponding provisions of the Central Bank of Ireland's *Consumer Protection Code* and *Insurance Distribution Regulations 2018*) obliges manufacturers to monitor on an ongoing basis whether the product continues to meet the target market's needs.⁸¹⁸ A schedule that diverges materially and persistently from the outstanding mortgage balance, both above it in steady state and below it under common Irish-mortgage events, is on its face a candidate for manufacturer-led monitoring review. The point is *not* that the legacy product is in breach of IDD Article 25 — the schedule mechanic is contractually clear, the premium is actuarially honest under that mechanic, and the supervisory case for action on the schedule itself has not been made by any Irish or European regulator. The point is that the *ongoing-monitoring obligation* under Article 25 is the regulatory framework within which the manufacturer would naturally consider the modernisation candidates this paper analyses. The expected supervisory direction of travel — given EIOPA's 2022 CPI review, the FCA's TR24/2 product-oversight work, and the Central Bank of Ireland's domestic implementation of IDD — is toward greater manufacturer accountability for ongoing product fit. The schedule-mechanic question is, on the present analysis, a natural item for an Irish manufacturer's own POG review under that framework.

8.4 Solvency II Standard Formula — capital as optionality, not imposition

The Solvency II Standard Formula treats sum at risk as a pricing input to the mortality stress calculation; it does not, in its present specification, distinguish between a schedule-defined and a balance-linked sum at risk. The analysis in Section 6.4 — and the Section 7(vii) reading of that analysis — suggests that the Standard Formula treatment is, broadly, *capital-neutral in the round* on the manufacturer's book: M1, M2, and M3 each lower SCR_mort at baseline and in three of four disturbance scenarios, while

modernisation raises SCR_mort specifically in D3 by approximately twenty-seven per cent. Across the book, the directions cancel partially.

The proper framing of this result is *capital optionality*. A manufacturer that modernises to M2 takes on the D3-scenario-specific capital uplift in exchange for the D0/D1/D2/D4 capital relief, the closure of the under-insurance disturbance liabilities, and the per-policy commercial budget computed in Section 8.2. The Standard Formula is not imposing modernisation; it is offering a fair price for it. Where the Standard Formula computation produces a lower capital number under the legacy product than under M2 — which is the case under D3 — that lower number reflects a sum at risk that section 126 says should be larger. The proper response is not to recalibrate the Standard Formula but to recognise that the legacy product is, in that specific scenario, under-pricing its own capital position. Insurers operating an Internal Model on term-assurance mortality would have wider latitude to capture schedule-mismatch risk in their own capital basis; the publicly disclosed solvency basis at each of the principal Irish life writers of mortgage protection is, however, the Standard Formula on the life-mortality sub-module⁴⁸, and the bulk of the Irish mortgage protection book is therefore on Standard Formula and would experience the Section 6.4 capital signature under modernisation.

8.5 Interaction with MWP-2026-01 (demand) and MWP-2026-02 (supply)

The three papers in this series address three independent mechanisms of welfare-relevant cost to Irish households in the mortgage protection market. *The Switching Gap* (MWP-2026-01) identifies the *demand-side* problem: Irish households rarely review their cover, with directional evidence that between sixty thousand and one hundred and seventy thousand households may be overpaying or holding sub-optimal cover.⁴⁷ *The Bank Premium* (MWP-2026-02) identifies the *supply-side* problem: a structural premium in lender-channel mortgage protection.¹³ *The Decreasing-Term Anachronism* identifies the *product-design* problem: a schedule mechanic that produces systematic two-sided mismatch with the actual outstanding mortgage balance.

The three problems are independent in mechanism but cumulative in incidence. A household that buys lender-channel cover at drawdown, never reviews it, and holds it through a normal sequence of mortgage events is exposed to all three: an inflated premium on the supply side, an unreviewed policy on the demand side, and a schedule that diverges from the balance on the product side. The remedies are correspondingly independent. The demand-side remedy is a structured review trigger comparable to mortgage switching prompts (per MWP-2026-01). The supply-side remedy is the use of intermediated channels to test the lender quote (per MWP-2026-02). The product-design remedy is schedule modernisation (per this paper). All three can be progressed in parallel, by different actors, without dependency between them.

8.6 What the paper does *not* argue — including the estate-benefit acknowledgement

For clarity, the paper does not argue any of the following. It does not argue that the legacy product is in breach of section 126 of the Consumer Credit Act 1995 — the legacy schedule is contractually clear, has historically tracked actual balances reasonably well at the long-run nominal rate average, and the failures documented here are a function of the divergence between that long-run average and the contemporary Irish rate environment. It does not argue that insurers acting on the legacy schedule have acted in bad faith — pricing is actuarially honest under the legacy schedule and the premium reflects the contractual sum-at-risk profile. It does not argue for indiscriminate policy replacement — *The Switching Gap* is explicit that policy replacement should not be undertaken until replacement cover is in force, and the same warning applies to modernisation: an existing policy that is structurally over-insured remains valid cover for the insured event; the modernisation argument is about *new business* and the prospective book. It does not argue for a regulatory intervention on the schedule mechanic —

the present paper sets out the modernisation case on technical grounds, and the implications for manufacturer-led monitoring under IDD Article 25 follow naturally from the existing supervisory framework rather than requiring a new mandate.

We also make the **estate-benefit acknowledgement** explicitly. Section 126(5) of the Consumer Credit Act 1995 provides that "Where the proceeds of a policy under this section exceed the amount due to the mortgage lender on the loan, any such excess shall be payable to the surviving borrower or to the estate of the deceased borrower as the case may be." The steady-state over-insurance documented in Section 6.1, therefore, is not pure dead-weight in welfare terms: a fraction of it functions as a small additional death-benefit transfer to the estate. We have not netted that estate benefit into the headline HARM A figure, on two grounds. First, the estate benefit is a probabilistic transfer conditional on death within the policy term, and its expected present value is small in scale (it is the mortality-discounted, statute-discounted excess of S over B integrated across the term, against the household's per-period premium payment). Second, the household that wants estate benefit has more direct instruments to deliver it — an explicit life-cover policy chosen on its own merits. We acknowledge the point candidly and observe that any full welfare analysis of the over-insurance gap would price the rate-state-contingent insurance component (Section 7(iii)) and the estate-benefit component separately. The headline HARM A figure is, in that strict sense, an upper bound on the welfare-relevant dead-weight; the more conservative central estimate would discount HARM A by the welfare value of the cushion plus the welfare value of the estate transfer. We do not attempt that decomposition in this paper.

9. Limitations

This section records the limitations of the analysis. The intent is full transparency: every modelling choice with material directional consequence is recorded here.

Single representative borrower. All household-level results in this paper are computed on a single representative borrower (age 35, male non-smoker, €322,000 SA, 30-year term, 6 per cent notional, 4 per cent actual base). The borrower is calibrated to BPFQ Q4 2025 averages, but it is a single point in a wide distribution. A full sensitivity analysis across the joint distribution of age, gender, smoking status, SA, term and actual rate would refine the household-level results; the principal direction in which the present central-case results would move under such a sensitivity is unclear *a priori* — the over-insurance integral scales with SA and inversely with the actual rate, but the disturbance prevalences are largely population-level. The aggregate harm figures (Section 6.6 to 6.8) are appropriately read as central estimates rather than population means.

Prevalence calibration uncertainty. The disturbance prevalences in Table 3 are sourced to authoritative Irish data — Central Bank monthly releases, BPFQ quarterly reports, lender T&Cs — but they are themselves point estimates subject to revision and to vintage. The D2 top-up prevalence in particular is computed from a single BPFQ quarter's drawdown count, geometrically scaled to a thirty-year exposure. A multi-quarter calibration would give a tighter central estimate. The directional consequence for the headline results is small, because the largest under-insurance integrals (D2 and D3) carry middle-of-the-range prevalences in our calibration and the aggregate HARM B is anchored more by the per-household integral than by the prevalence weight.

Mortality basis vintage. The mortality stack uses ILT17 (CSO, 2015–2017 experience), IILMI (SAI, 2019 publication), and TMN00 (CMI, 2005 publication). All three are the most recent published Irish or Irish-relevant sources at the date of writing. The TMN00 select factors are vintage and, in principle, post-2005 select-period mortality improvement could be incorporated by reference to subsequent

CMI publications; the SAI has not, to our knowledge, published an Irish insured-lives select table that would supersede TMNOO. The SCR_mort results in Section 6.4 are computed against the locked mortality basis and would move under a more recent select table; the *comparative* SCR result (the twenty-seven-per-cent under D3) is robust to plausible select-table updates because it is driven by the schedule-balance gap rather than by the underlying mortality.

Discount curve forward bias. The EIOPA EUR risk-free curve at thirtieth April 2026 is the standard supervisory discount basis but it is, by construction, a market-implied forward curve at a single observation date. Actual realised rates over the next thirty years will, with very high probability, depart from the forward curve in ways that the present analysis cannot anticipate. The stochastic extension in Annex A addresses the rate-path uncertainty conditional on the forward curve; it does not address mis-specification of the forward curve itself. The Smith-Wilson extrapolation beyond the twenty-year Last Liquid Point introduces additional curve-shape uncertainty in the long-end, addressed in EIOPA's October 2025 technical documentation.⁴²

Modernisation implementation cost is not modelled. Section 5.3 records explicitly that the engineering, data-exchange, and operational cost of moving Irish insurers' policy-administration systems from a fixed-schedule basis to an event-driven (M2) or balance-linked (M3) basis is *not* quantified in this paper. The capital cost of modernisation (Section 6.4) is quantified; the implementation overhead is acknowledged as an additional, market-level cost. The break-even expense loading calculation in Section 8.2 quantifies the per-policy commercial budget — approximately €13.01 (M2) and €11.87 (M3) per policy per year, equivalently approximately 3.3 per cent (M2) and 3.0 per cent (M3) of base premium — within which any operational implementation cost would need to be amortised. A complete modernisation business case for any specific Irish insurer would need to combine the present capital analysis with an operational-implementation cost analysis specific to that insurer's policy-administration architecture.

Expense loading is an upper bound on welfare-relevant dead-weight. The premium dead-weight figures in Section 6.6 do not net out either the rate-state-contingent prudential cushion (Section 6.5, 7(iii)) or the statutory estate-benefit component (Section 8.6). A complete welfare analysis would price both components and subtract their values from gross HARM A. We have left HARM A as gross, transparently, on the grounds that the two components are difficult to value without further household-preference assumptions that we do not make in this paper.

Standard Formula capital basis is the only capital basis considered. The Solvency II capital signature reported in Section 6.4 is computed entirely on Standard Formula. Insurers operating an Internal Model would have additional latitude to capture schedule-mismatch as a non-standard risk and to price modernisation differently in their own capital basis. The Standard Formula treatment is the right basis for a market-level analysis (since most Irish term-assurance writers are on Standard Formula); Internal Model treatments would be insurer-specific and out of scope.

Stochastic floor choice. Annex A documents the floor regime of the stochastic model: no driver floor on the rate dynamics, zero floor on the Irish translation. The asymmetric choice was made deliberately to keep the upper tail of HARM A intact while not admitting implausibly negative Irish retail mortgage rates. The known directional consequence is mild conservatism on the lower tail in a falling-rate regime, and the three Vasicek calibration lenses (C1 / C2 / C3) together with the C1 + MS2 spread-switching sensitivity provide a robustness check across alternative parameterisations.

Bootstrap as headline, parametric as diagnostic. Section 5.6 leads with the bootstrap-Irish construction as the headline and treats the three Vasicek parametric calibrations (C1 / C2 / C3) plus the C1 + MS2 spread-switching sensitivity as diagnostic comparators. This is deliberate: the bootstrap is the

conservative choice because it does not impose a mean-reverting structure that would damp the lower-tail rate environment and reduce the headline harm. We acknowledge that an opposite reading is defensible — that a parametric model with explicit mean reversion may be a more realistic representation of central-bank-anchored long-run rate dynamics, in which case the Vasicek-central C1 figure of €23.60 per household per year would be the more defensible headline. We lead with the bootstrap because it more transparently reproduces the empirical distribution of realised rate changes in the CBI data series and does not embed an undocumented mean-reversion judgement.

International evidence completeness. Section 3 records the international and academic evidence we identified during the research phase of this paper. Several reinsurer publications and academic papers specified in the original research brief could not be confirmed in the available sources at the time of writing; those gaps are marked candidly in Section 3.7 and 3.8. The cumulative international read in Section 3.9 is robust to those individual gaps but the bibliography is not exhaustive.

Series scope. The analysis is confined to Irish principal-dwelling-house mortgage protection — the product class addressed by section 126 of the Consumer Credit Act 1995. Buy-to-let mortgage protection, commercial-mortgage life cover, and Irish business protection products fall outside the scope of this paper. The schedule-mechanic critique is in principle generalisable to any product class that uses a fixed schedule against an actual balance, but the prevalence calibrations, mortality basis, and aggregate denominators would need to be re-derived for any other class.

10. Conclusion

The question this paper has asked is constructive: in a contemporary Irish mortgage environment of low actual rates, short fixed-rate periods and routine principal events, what would a robust mortgage-protection schedule design look like, and what would it cost the manufacturer to deliver? The answer is encouraging for the industry. The legacy product is not broken in any catastrophic sense — the schedule is contractually clear, the premium is actuarially honest under the schedule, and the failures the product exhibits in steady state and under disturbance are systematic, well-characterised, and tractable. The modernisation candidates evaluated in this paper close the failures, are already in commercial use in markets comparable to Ireland's, and price fairly under the Solvency II Standard Formula.

The systematic two-sided mismatch is real. In the steady-state Irish mortgage at four per cent actual against the six-per-cent notional, the schedule sits structurally above the outstanding balance, with mean over-insurance of fourteen thousand euro across the term and peak over-insurance of twenty-two thousand euro mid-policy. Across the principal-dwelling-house stock the deterministic annual premium dead-weight, computed on the duration-weighted Bank of Ireland Asset-Covered-Securities cohort proxy, is approximately four point zero seven million euro per year; on the uniform-cohort multiplier construction the same figure is approximately twelve point three four million euro per year. On stochastic rate dynamics anchored on the CBI Irish-mortgage-rate distribution (with the EIOPA EUR risk-free curve at thirtieth April 2026 used for discounting only), the household figure is approximately twenty-six euro per household per year median, with a thirty-year present value across the stock of three hundred and forty-five million euro and a five-to-ninety-five-per-cent interval of one hundred to five hundred and eighty-seven million euro. Under the four common Irish-mortgage disturbances the schedule remains unmoved and the policy can fall structurally below the outstanding balance, with peak under-insurance of approximately eighty thousand euro on a five-year term extension.

We acknowledge transparently that the steady-state over-insurance also functions as a prudential cushion: under a two-hundred-basis-point upward rate spike at policy year five, the mean cushion shrinks by approximately two-thirds but the policy never falls under-cover. The cushion is welfare-relevant. The headline HARM A figure is therefore an upper bound on the welfare-relevant dead-weight; the more conservative reading would price the rate-state-contingent insurance value of the cushion and the statutory estate-benefit transfer separately.

The modernisation candidates evaluated in this paper are already in commercial use in markets comparable to Ireland's. The minimal modernisation, M1, re-rates the schedule at issue against the actual rate; it closes the steady-state gap but creates a residual disturbance gap and is not a complete improvement on the legacy product. The event-stepped modernisation, M2, re-sets the schedule at each contractually-defined loan event; it closes both the steady-state and the disturbance gaps and is structurally close to the French *assurance emprunteur* substitution architecture. The balance-linked modernisation, M3, sets the schedule equal to the actual outstanding balance with periodic lender reconciliation; it is the conceptually cleanest design but requires industry data-exchange infrastructure that does not currently exist in Ireland. The break-even expense loading required to fund M2 (approximately €13.01 per policy per year) and M3 (approximately €11.87) is modest against the implicit per-policy premium of approximately €397 per year on the representative profile — approximately 3.3 per cent (M2) and 3.0 per cent (M3) of base premium; whether the operational implementation cost for any specific insurer falls inside that envelope is an insurer-specific question.

The Solvency II Standard Formula capital cost of modernisation is design-by-design and scenario-by-scenario. At baseline and in three of four disturbance scenarios, modernisation *reduces* SCR_mort by approximately ten to fifteen per cent. Under the term-extension disturbance specifically, M2 raises SCR_mort by approximately twenty-seven per cent — but that increase is precisely the cost of restoring cover that has, under the legacy schedule, structurally collapsed below the outstanding balance. At the system level the capital cost of modernisation is therefore a *redistribution* across scenarios rather than a portfolio-wide capital tax. The Standard Formula is offering capital optionality on modernisation rather than imposing it.

The recommendation, in summary, is that Irish life offices evaluate **Response 1 (disclosure)** as an immediate near-zero-cost intervention; **Response 3 (M2 event-stepped)** as the proportionate near-term commercial modernisation; and **Response 4 (M3 balance-linked)** as the longer-run product-architecture target once industry-scale lender-data infrastructure is in place. The implementation can proceed within the existing product taxonomy, does not require regulatory intervention, and aligns with the supervisory direction of travel under the European Insurance Distribution Directive's product-oversight-and-governance regime and the Central Bank of Ireland's domestic implementation thereof. Schedule modernisation is the third piece, alongside the demand-side review-trigger remedy proposed in *The Switching Gap* and the supply-side channel-test remedy proposed in *The Bank Premium*, of a coherent technical response to the structural mortgage-protection problems documented across the Mylife.ie working-paper series.

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Annex A · Stochastic-rate simulation pack

The stochastic specification summarised in Section 5.6 — fifty thousand paths, three hundred and sixty months each, seed 20260529, bootstrap-Irish rate dynamics anchored on the CBI Irish-mortgage-rate spot (3.50 per cent), three Vasicek calibration lenses (C1 / C2 / C3) driven off the ECB Deposit Facility Rate, a C1 + MS2 spread-switching Markov sensitivity as diagnostic comparator, and all five lenses discounted on the EIOPA EUR risk-free curve at thirtieth April 2026 — is documented in full in the companion document **MWP-03-Annex-Stochastic-Rates.pdf**, which is the canonical specification for the stochastic stack. The annex contains the model derivation, the calibration procedure, the floor regime justification, the path-by-path moment summaries, and the fan-chart visualisations at quarterly milestones.

Annex B · Diagnostics and workbook

The deterministic results in Sections 6.1 to 6.6 are reproducible from the companion documents **MWP-03-Annex-Diagnostics.pdf** and **MWP-03-Workbook.xlsx**. The workbook contains the full M1-M5 deterministic stack (assumptions, baseline, disturbances, modernisation, SCR_mort, aggregate, PV layer, sensitivities, sources) together with the supporting sheets for the M1 +200 bps stress test (Section 6.5), the duration-weighted aggregate construction anchored on the Bank of Ireland Asset-Covered-Securities pool (Section 6.6, Annex C), and the break-even expense-loading calculation (Section 8.2). The stochastic stack documented in Annex A is reproducible from the *Mylife.ie* research repository under the `stochastic/` directory and is not embedded in this workbook.

Sources and reproducibility

This paper combines deterministic actuarial arithmetic (Sections 6.1 to 6.6) with externally-sourced inputs and a stochastic extension. In the spirit of full disclosure, three classes of input are distinguished and traced to their sources here.

Externally-sourced factual citations — the new-business PDH rate of 3.52 per cent (end-March 2026), the PDH stock figures (697,964 / 698,335), the 3,280 top-up drawdowns (BPFI Q4 2025), the Bank of Ireland Asset-Covered-Securities pool figures (€10.82 bn aggregate balance, 73,622 loans, 20.71-year weighted-average remaining term), the EIOPA / ACPR / FCA / FCAC review findings, the legislative provisions cited in Section 8, and the academic citations throughout — derive from the cited first-party authorities (Central Bank of Ireland, Banking and Payments Federation Ireland, Bank of Ireland ACS programme disclosures, EIOPA, ACPR, FCA, FCAC, and peer-reviewed publications). Each citation is recorded in the References section with the original source. Verifiability is one citation deep: replication requires consulting the cited source directly. We use these figures consistently between the paper body, the tables, and the workbook.

Mortality stack inputs — the Irish Life Table 17 male q_x series, the ILLMI A/E ratio of 0.529 used as the population-to-insured adjustment, and the CMI TMNOO select-period factors (0.492 / 0.629 / 0.735 / 0.840 / 0.943 / 1.000 at policy durations 0 to 5+) feed the Solvency II Standard Formula SCR_mort and BEL_0 calculations in Sections 6.4 and 6.5. The composite method ($ILT17 \times ILLMI\ A/E \times CMI\ select\ factor$) is documented in the workbook on the *Assumptions* sheet; the published source tables (CSO, IFoA / CMI) are cited in References. The composite stack is applied consistently across baseline and disturbance scenarios; underlying table values can be reconfirmed against the original published tables.

Stochastic simulation outputs — the 50,000-path bootstrap-Irish median (and the three Vasicek calibration lenses C1 / C2 / C3 plus the C1 + MS2 spread-switching sensitivity), and the per-lens 30-year present-value-per-household figures, are produced by `simulate.py` in the *Mylife.ie* research repository under the `stochastic/` directory (seed 20260529, 360-month horizon, EIOPA 30 April 2026 risk-free curve). These figures are *not* embedded in the workbook; the workbook explicitly excludes the stochastic stack. The stochastic outputs are reproducible from the seed, the simulation code, and the EIOPA curve inputs. Annex A documents the per-lens diagnostics, the floor regime, and the calibration provenance.

Readers auditing the paper from first principles should begin with the deterministic workbook (every Section 6.1 to 6.6 figure traces to a workbook cell), proceed to the cited sources for external citations, and — if reproducing the stochastic figures — run `simulate.py` against the published EIOPA 30 April 2026 reference curve and the cited seed.

About this paper

The Decreasing-Term Anachronism is Working Paper MWP-2026-03 in the *Mylife.ie* Working Paper Series. The paper stands alone analytically: it characterises a product-design question — schedule mismatch between fixed decreasing-term policy schedules and actual mortgage balances under the contemporary Irish rate and event environment — and evaluates three modernisation candidates against the Solvency II Standard Formula. Earlier papers in the series (MWP-2026-01 *The Switching Gap* and MWP-2026-02 *The Bank Premium*) address independent dimensions of Irish mortgage-protection market structure; readers interested in those dimensions are referred to those papers directly. The present paper does not assume or require familiarity with them.

About the author

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About Mylife.ie Research

Mylife.ie is a trading name of SMP Financial Ltd. The Mylife.ie Working Paper Series is the firm's research publication channel for technical analyses of Irish life-assurance, mortgage-protection, pension and inheritance-planning topics. The series is intended for an audience of actuaries, regulators, brokers, lenders, policy advisers, and informed consumers. Working papers are subject to internal review at SMP Financial Ltd prior to publication. Series papers are made available at <https://www.mylife.ie/research>.

Remuneration disclosure

The author is the owner of SMP Financial Ltd, a financial services firm whose commercial activities include the sale of life-assurance and mortgage-protection products to Irish consumers through the *Mylife.ie* trading channel. The firm has no direct commercial interest in any of the modernisation candidates (M1, M2, M3) evaluated in this paper, none of which is a *Mylife.ie* product. The author has no consulting, advisory, or remuneration relationship with any Irish life insurer, lender, or reinsurer named in this paper. The reinsurers named in Section 3.6 (RGA, Swiss Re) are referenced in respect of their published research positions only.

Use of AI

This paper was drafted with the assistance of an AI research-and-writing tool acting under the direct supervision of the author. The tool was used to compile and synthesise the international evidence reviewed in Section 3, to execute the deterministic and stochastic modelling specified in Sections 5 and 6 (full reproduction code is committed to the *Mylife.ie* research repository), and to draft the prose under the author's direction and review. All numerical results were independently verified against the locked model output documented in the companion workbook *MWP-03-Workbook.xlsx*. All source citations were verified at the URLs given in the References section. The author retains full editorial and professional responsibility for the paper's content, conclusions, and any errors of fact, interpretation, or judgement.

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ANNEX A

Stochastic-rate simulation pack

50,000-path overlay on the MWP-2026-03 base case · five-lens
architecture.

The annex that follows was originally circulated as a standalone document and is reproduced here in its original typesetting and pagination. In this combined edition it is the first of two annexes, denoted Annex A, matching the labelling used throughout the working paper. Internal headers in the annex PDF retain their original wording.

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WORKING PAPER MWP-2026-03 · ANNEX A · MAY 2026

Stochastic-Rates Simulation Results

50,000-path overlay on the MWP-2026-03 base case · five-lens architecture

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Purpose of this annex. The parent paper MWP-2026-03 documents a deterministic mortgage-protection modernisation case at a 4.0% modal interest rate. This annex re-runs the HARM A bill across 50,000 stochastic rate paths under five lenses agreed in the diagnostics pack, holding every non-rate base-case assumption fixed. The result is a directional confidence test, not a re-forecast: each lens answers the question “what would the harm bill have looked like if the rate environment had varied in this way?”

Headline result

Under the Bootstrap-Irish headline lens, the median household pays €25.94 per year of harm under the legacy product, with a 5–95% range of €6.07–€44.35. Across the Irish PDH stock (\approx 698,000 households), the 30-year present value at the EIOPA Q2 2026 risk-free rate is €345.4m (5–95%: €100.3m–€587.4m).

The deterministic base case prints €17.68 per household per year at the 4% modal rate. The Bootstrap-Irish median is materially higher because the bootstrap inherits the actual 2003–2026 regime mix — in particular the 2014–2022 ZIRP plateau — in which low rates implied larger excess sums-assured and therefore larger harm. The four parametric lenses bracket this picture: see Section 1 for the cross-lens comparison and Section 5 for the harm-impact discussion.

Lens	HARM A per HH/yr median €	HARM A per HH/yr 5–95 €	HARM A PDH PV 30y median €m	HARM A PDH PV 30y 5–95 €m
Bootstrap-Irish HEADLINE	25.94	6.07–44.35	345	100–587
Vasicek C1 + MS2 preferred parametric	17.09	5.65–30.66	224	77–400
Vasicek C1 + flat	23.60	11.36–36.41	313	158–475
Vasicek C2 + flat	13.76	8.35–19.48	192	119–268
Vasicek C3 + flat	19.70	4.83–37.74	265	78–488

1. Architecture recap

The diagnostics pack agreed a five-lens architecture. We restate the lenses briefly here for reference; their calibration and diagnostic justification are documented in full in the diagnostics pack and are not repeated.¹

Lens	Role	Method (brief)
Bootstrap-Irish	Headline	Stationary block bootstrap of monthly Irish-mortgage-rate differences (Politis-Romano, block = 24mo, $n_{\text{source}} = 278$). Integrate diffs from spot 3.50% (Mar 2026); 0% Irish floor.
Vasicek C1 + MS2	Preferred parametric	Vasicek ($\kappa=0.063$, $\theta=0.83\%$, $\sigma=0.467$ pp) on ECB DFR + two-state Markov-switching mortgage spread.
Vasicek C1 + flat	Sensitivity	Same Vasicek C1 driver; spread held flat at long-run mean (2.02 pp).
Vasicek C2 + flat	Lower bracket	Reinsurance convention: $\kappa = 0.20$ [fixed], $\theta = 2.50\%$ [fixed]. Fast mean-reversion, half-life ≈ 3.5 y.
Vasicek C3 + flat	Upper bracket	Near random walk: $\kappa = 0.02$ [fixed], $\theta = \text{data mean}$. Slow mean-reversion, half-life ≈ 35 y.

What this annex does — and does not — vary

Varies: the Irish-mortgage-rate path across the 30-year horizon, and through the locked workbook M5 sensitivity curve, the implied excess sum-assured and the annual HARM A bill per household.

Held constant: the representative borrower (age 35, male non-smoker, €322k SA, 30-year term), the prevalence stack ($D1 = 0.95$, $D2 = 0.131$, $D3 = 0.08$, $D4 = 0.18$), the PDH stock multiplier ($\approx 698,000$ households implied by €12.34m/€17.68), and the SCR_{mort} structure. Sensitivity to prevalence and to the PDH stock multiplier is a separate exercise.

Translation curve

Every simulated rate path is converted into a harm path through the same quadratic fit through the workbook M5 anchor points: (3%, €27.03/yr), (4%, €17.68/yr), (5%, €8.65/yr). Harm is floored at zero (rates above $\approx 5.99\%$ produce no excess premium under the M5 model). Figure 4 shows the fit.

Floor convention. The ECB DFR driver is not floored; the 2019–2022 episode of ECB DFR at -0.50% is treated as part of the in-sample regime. The Irish mortgage-rate translation is floored at 0%, a level the consumer series has never approached: the empirical minimum during the ZIRP era was 2.70% (Apr 2021), implying a bank-lending margin of ≈ 3.2 pp held even when policy rates were negative. The 0% floor exists to prevent simulation-only paths from generating economically implausible negative consumer borrowing costs; the central mass of the path distribution is well above it.

2. Simulation configuration

All five lenses share the same seed (20260529), horizon (360 months), and path count (50,000). Vasicek lenses use antithetic variates to halve sample noise without altering the simulation expectation. The translation curve is the same quadratic fit for every lens, evaluated path-wise and month-wise.²

Parameter	Value
Path count	50,000
Horizon	360 months (30 years)
RNG seed	20260529
Antithetic variates	Yes (Vasicek lenses)
Starting Irish rate r_0	3.50 % (CBI MIR, latest)
Starting ECB DFR r_0	2.00 % (ECB SDW, latest)
Irish-rate floor	0% (asymmetric; no driver floor)
Translation curve	Quadratic fit through workbook M5 anchors, floored at zero
Discounting	EIOPA EUR RFR (no-VA), 30-Apr-2026; 30y spot = 3.188 %
PDH stock multiplier	697,964 households (€12.34m / €17.68)

Discount factors are derived from the EIOPA risk-free EUR no-volatility-adjustment term structure published for 30-Apr-2026, with monthly interpolation between integer-year spot rates. The 30-year spot is 3.188% (no VA), producing a month-360 discount factor of ≈ 0.391 .

Figure 4 · Rate-to-HARM-A translation curve

Quadratic fit through MWP-03-Workbook M5 anchors · floored at zero · used to translate every simulated rate path into a harm path



Figure 4. Rate-to-HARM-A translation curve. Quadratic fit through the MWP-03-Workbook M5 anchor points (3%, 4%, 5%), evaluated for every simulated rate and floored at zero. Above $\approx 5.99\%$ the M5 model produces no excess premium.

3. Rate path distributions

Figure 1 shows the Irish mortgage-rate fan under each lens. The Bootstrap-Irish lens drifts gently toward the 2003–2026 historical mean (3.49%), with a wide 5–95% cone reaching from 0.08 % to 7.21 % at year 30. Vasicek C1+MS2 starts from the higher Irish-rate spot (5.0% ≈ DFR 2% + MS2-mixture spread ≈ 3%) and reverts to its long-run mean of ≈3.8%. The reinsurance C2 lens reverts quickly to its fixed long-run mean of 2.50% + flat spread, and the near-RW C3 lens diffuses widely with weak central tendency.

Figure 1 · Simulated 30-year Irish mortgage rate distribution by lens
 50,000 paths over 360 months · fan bands: 5-95 % outer, 25-75 % inner · dotted line = 4 % base case modal rate

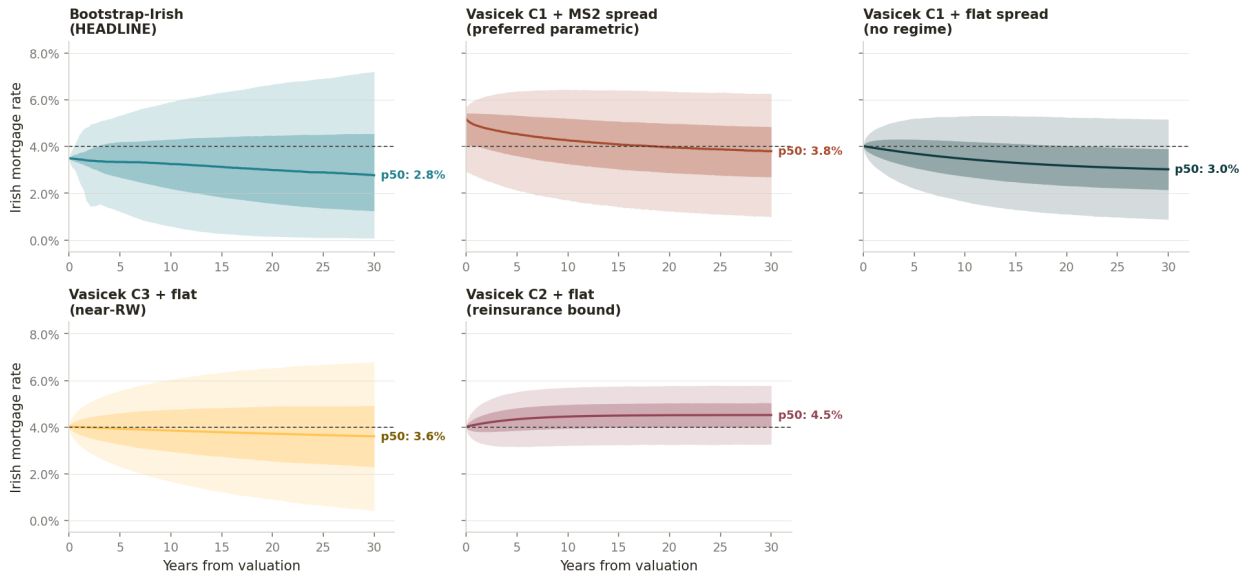


Figure 1. Simulated 30-year Irish mortgage-rate distribution by lens. 50,000 paths per panel. Inner band: 25–75%. Outer band: 5–95%. Solid line: median. Dotted reference: 4% modal base-case rate.

Lens	Final rate p05	p50	p95	Mean 30y p50
Bootstrap-Irish (HEADLINE)	0.08 %	2.77 %	7.21 %	3.13 %
Vasicek C1 + MS2	1.02 %	3.80 %	6.27 %	4.10 %
Vasicek C1 + flat	0.88 %	3.03 %	5.17 %	3.37 %
Vasicek C2 + flat	3.27 %	4.52 %	5.77 %	4.44 %
Vasicek C3 + flat	0.42 %	3.61 %	6.80 %	3.79 %

Two observations. First, the four parametric lenses agree to within 150 bps on the median final rate (3.0–4.5%) but disagree sharply on the 5–95 spread — a direct reflection of the calibration uncertainty in κ documented in the diagnostics pack. Second, the Bootstrap-Irish median (2.77%) is meaningfully below all parametric medians because the bootstrap inherits the 2014–2022 ZIRP plateau in its source diffs.

4. HARM A — per-household distribution

Translating each simulated rate path through the workbook M5 curve produces a HARM A path per household. Figure 2 shows the distribution of the 30-year mean annual HARM A per household. Distributions are right-skewed in the parametric lenses (more upside in low-rate paths since harm rises as rate falls) and approximately symmetric in the bootstrap lens (whose source diffs include both regimes).

Figure 2 · HARM A per-household annual cost — distribution by lens

Mean annual € over 30-year horizon, per household · solid: median · dashed: 5 / 95 percentiles

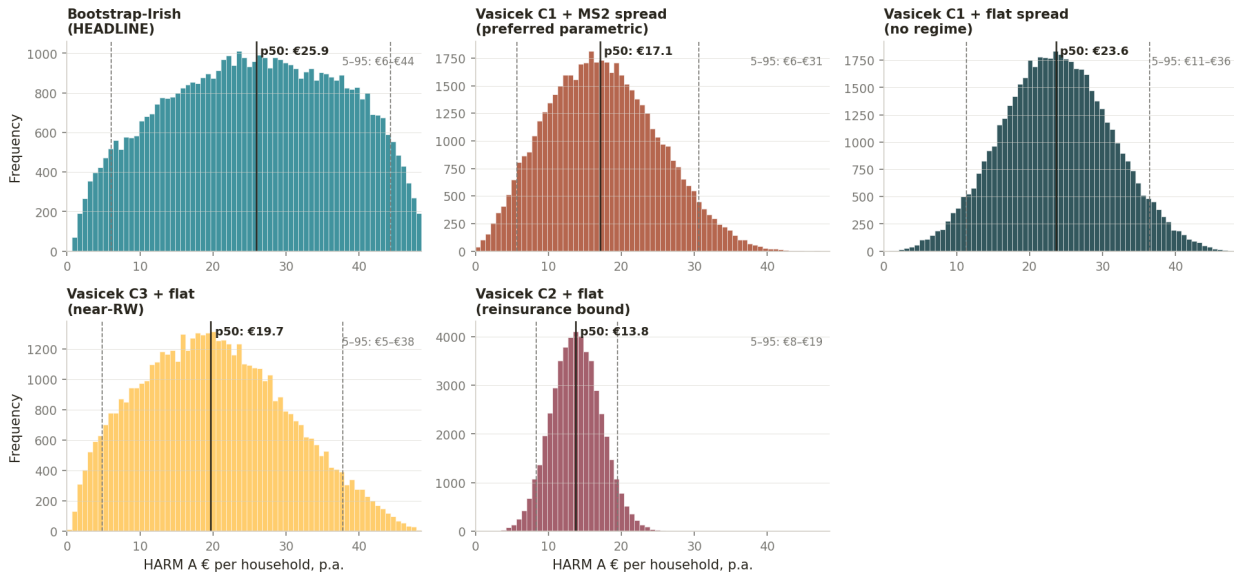


Figure 2. HARM A per-household annual cost — distribution by lens. Histogram of 50,000 paths' 30-year mean annual HARM A per household. Solid vertical: median. Dashed: 5 / 95 percentiles.

Lens	p05	p25	p50	p75	p95	Mean
Bootstrap-Irish	€6.07	€16.40	€25.94	€35.36	€44.35	€25.73
Vasicek C1 + MS2	€5.65	€11.83	€17.09	€22.67	€30.66	€17.47
Vasicek C1 + flat	€11.36	€18.49	€23.60	€28.81	€36.41	€23.70
Vasicek C2 + flat	€8.35	€11.49	€13.76	€16.08	€19.48	€13.82
Vasicek C3 + flat	€4.83	€12.57	€19.70	€27.21	€37.74	€20.22

Reading the table. The deterministic base case prints €17.68 per household per year. The Bootstrap-Irish median is €25.94 — about 47% higher — because the bootstrap inherits the low-rate years 2014–2022 directly into its source diffs. The C1+MS2 parametric median (€17.09) sits just below the base case because its long-run mean is anchored higher (~3.8%, where harm is lower).

Figure 5 · HARM A median annual cost trajectory by lens
 Median across 50,000 paths · shows how the harm bill evolves across the 30-year term

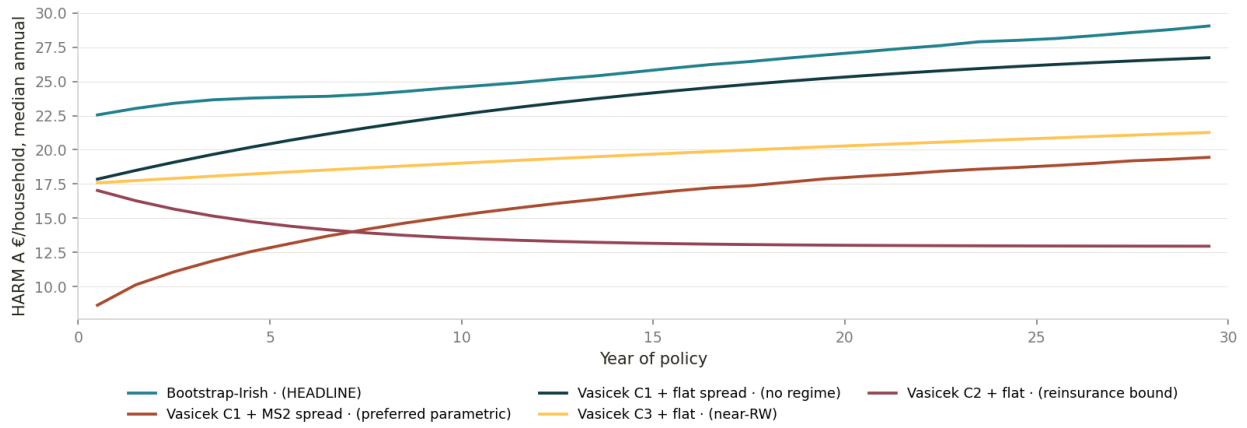


Figure 5. HARM A median annual cost per household over the 30-year policy term. All five lenses converge to within 30% of one another by year 30; the divergence is concentrated in the first decade and is driven by the different starting rates and mean-reversion speeds.

5. HARM A – Irish PDH-stock 30-year present value

Scaling the per-household path-PV by the implied PDH-stock multiplier ($\approx 697,964$ households) and discounting at the EIOPA EUR risk-free rate at 30-Apr-2026 gives the aggregate 30-year present value of HARM A under each lens. This is the closest analogue in this annex to the ‘HARM B’ construct in the parent paper — a stock-wide, discounted measure of the modernisation-cost overhang.³

Figure 3 · HARM A – Irish PDH stock 30-year present value, by lens
 50,000 paths summarised · boxes show inter-quartile range · whiskers show 5-95 percentiles · dot = median



Figure 3. HARM A across the Irish PDH stock, 30-year present value at the EIOPA EUR risk-free rate (€ millions). Boxes: 25–75%. Whiskers: 5–95%. Dot: median.

Lens	p05 €m	p25 €m	p50 €m	p75 €m	p95 €m	Mean €m
Bootstrap-Irish	100	232	345	461	587	346
Vasicek C1 + MS2	77	156	224	296	400	229
Vasicek C1 + flat	158	248	313	379	475	314
Vasicek C2 + flat	119	161	192	223	268	192
Vasicek C3 + flat	78	178	265	357	488	271

Spread across lenses. The Bootstrap-Irish median PV (€345m) is approximately 1.54x the C1+MS2 median (€224m) and 1.80x the reinsurance-bound C2 median (€192m). The full 5–95 envelope across all lenses runs €77m to €587m.

Directional read. Every lens places the median 30-year PV of HARM A across the Irish PDH stock between €190m and €350m, with the parametric central tendency near €225–315m and the bootstrap headline at €345m. The simulation does not move the qualitative conclusion of the parent paper: the modernisation case rests on the persistent existence of a non-trivial excess-premium overhang under the legacy product. What the simulation adds is a quantified bracket on the size of that overhang under rate-environment uncertainty.

6. Interpretation and limitations

Why the Bootstrap-Irish lens sits high

The Bootstrap-Irish lens draws its monthly differences from the 2003–2026 Irish-mortgage-rate history. Approximately one-third of that window (Sep 2014–Aug 2022) lies in the ZIRP plateau, where Irish mortgage rates sat in the 2.7–3.5% band. The bootstrap therefore generates rate paths that re-enter that band with a probability close to its historical frequency. Because HARM A is monotonically decreasing in rate over the relevant range, rate paths spending time in the 2.7–3.5% band produce higher harm than paths centred on 4%. This is not a forecast that rates will return to ZIRP — it is a statement that, in the only Irish-rate cycle we have, ZIRP-like conditions were a non-trivial fraction of the regime mix.

Why the parametric lenses sit lower

Each parametric lens anchors its long-run mean at a level above 3%: C1+MS2 at $\approx 3.8\%$, C1+flat at $\approx 3.0\%$, C2 at 4.5%, C3 at $\approx 3.6\%$. The translation curve is convex (steeper at low rates), so a parametric distribution that revisits the ZIRP band less often than the bootstrap will produce a lower median harm. The reinsurance-convention C2 lens sits lowest because its $\kappa = 0.20$ pulls paths quickly back to its fixed 4.5% (including spread) long-run mean.

Robustness of the directional conclusion

Despite the spread across lenses, every lens produces a median annual HARM A per household between €13.8 and €25.9 — the entire range sits well above zero. No simulated lens, and no 5–95 lower tail, places median harm below €5/HH/yr. The modernisation thesis (move from the legacy product to a balance-tracking design that closes the excess-premium overhang) is robust to the rate-environment uncertainty modelled here.

What the simulation does not address

(a) Prevalence uncertainty (D1–D4): the simulation holds the locked base-case stack. (b) PDH-stock multiplier: held at $\approx 698k$ households. (c) Lapse behaviour: held at the base-case schedule. (d) Reinsurance treaty terms: held at base case. (e) Solvency capital under the M2 modernised design: this annex projects HARM A under legacy; the modernised SCR consequence (the +27% headline) is taken from the parent paper as a structural calibration, not re-simulated.

Data limitations carried through from diagnostics

All limitations documented in Annex A §6 remain: approximately 1.5 ECB policy-rate cycles in the available EUR sample; the bootstrap cannot extrapolate beyond the observed regime mix; the parametric κ is weakly identified. The five-lens architecture is the response to those limits, not a way around them.

7. Run provenance and locked outputs

Item	Locked value
Simulator	/mwp3/stochastic/simulate.py (vectorised numpy, deterministic seed)
Chart builder	/mwp3/stochastic/build_sim_charts.py
PDF builder	/mwp3/stochastic/build_sim_annex.py (this document)
Results JSON	/mwp3/stochastic/sim_outputs/results.json
Path arrays (5 lenses)	sim_outputs/paths_{bootstrap,c1_flat,c1_ms2,c2_flat,c3_flat}.npz
Harm arrays (5 lenses)	sim_outputs/harm_{bootstrap,c1_flat,c1_ms2,c2_flat,c3_flat}.npz
RNG seed	20260529
Path count	50,000
Horizon	360 months
Discount curve	EIOPA EUR risk-free, no-VA, 30-Apr-2026 (cached at sim_outputs/eiopa_eur_rfr_20260430.json)

Sources and footnotes

¹ MWP-2026-03 Annex A — Stochastic-Rates Diagnostics Pack. Locked calibration values and methodology journey for the five-lens architecture. Companion document to this results pack.

² Politis, D. N. and Romano, J. P. (1994), 'The Stationary Bootstrap', Journal of the American Statistical Association, 89(428), pp. 1303–1313. DOI: [10.1080/01621459.1994.10476870](https://doi.org/10.1080/01621459.1994.10476870). The reference for the block-bootstrap method.

³ EIOPA, 'Risk-Free Interest Rate Term Structures — monthly publication', 30-Apr-2026 EUR no-volatility-adjustment curve. Available at eiopa.europa.eu/tools-and-data/risk-free-interest-rate-term-structures_en. 30-year spot 3.188%.

⁴ ECB Statistical Data Warehouse, 'Cost of borrowing for households for house purchase' (MIR.M.IE.B.A2C.AM.R.A.2250.EUR.N), and 'Deposit Facility Rate' (FM.D.U2.EUR.4F.KR.DFR.LEV). Available at data-api.ecb.europa.eu — [MIR series](#) and [FM — DFR series](#).

⁵ Central Bank of Ireland, 'Retail Interest Rates' monthly release. Available at centralbank.ie/statistics/.../retail-interest-rates.

⁶ MWP-03-Workbook.xlsx, sheet M5 (rate-sensitivity grid for the legacy decreasing-cover representative product). Anchor points (3%, €27.03), (4%, €17.68), (5%, €8.65) per household per year.

ANNEX B

Diagnostics and workbook

Stochastic-rates calibration, methodology journey, and pre-simulation diagnostics.

The annex that follows was originally circulated as a standalone document and is reproduced here in its original typesetting and pagination. In this combined edition it is the second of two annexes, denoted Annex B, matching the labelling used throughout the working paper. Note that the diagnostics pack's own running header, title block and dateline still read 'Annex A · May 2026 · Stochastic-Rates Diagnostics Pack' — these are the original internal labels from when the document was the sole Annex A, retained intact under the original-typesetting policy. In this combined edition the divider page and front-matter rename it Annex B.

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WORKING PAPER MWP-2026-03 · ANNEX A · MAY 2026

Stochastic-Rates Diagnostics Pack

Calibration and methodology

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Purpose of this annex. MWP-2026-03 (Mortgage-Protection Modernisation) uses a deterministic 4.0% mortgage interest rate in its base case. Interest rates are not, in practice, deterministic. This annex documents the calibration of a stochastic-rates framework that we propose to run as a 50,000-path overlay on the base case, to test the directional robustness of the HARM A, HARM B and SCR_{mort} numbers under rate paths that are consistent with what the Eurosystem and Irish mortgage data permits.

Executive summary

We calibrate four lenses on Irish mortgage-rate uncertainty. None of them alone is sufficient; together, they bracket the directional risk in a way that is defensible given the limited Eurosystem rate-cycle history available.

Lens	Role	Key parameter(s)
Primary — block bootstrap of the Irish mortgage rate	Headline Irish translation; no parametric assumption.	Stationary bootstrap, block = 24 months on monthly differences of CBI/ECB MIR (n = 278 source diffs).
Vasicek C1 · data-MLE	Parametric ECB-driver sensitivity. What the data alone identifies.	$\kappa = 0.063 (\pm 0.063)$, $\theta = 0.83\%$, $\sigma = 0.467$
Vasicek C2 · reinsurance convention	Industry-standard mean-reversion parameters.	$\kappa = 0.20$ [fixed], $\theta = 2.50\%$ [fixed], $\sigma = 0.481$
Vasicek C3 · near-random-walk	Conservative-persistence end of the sensitivity range.	$\kappa = 0.02$ [fixed], $\theta = 1.09\%$ [fixed at data mean], $\sigma = 0.466$
Markov-switching spread (2-state)	Sensitivity overlay on Vasicek C1; captures the post-2010 structural break.	State 0 $\mu = 1.92$ pp, State 1 $\mu = 3.38$ pp; $P[0,0] = 0.991$, $P[1,1] = 0.993$.

An AR(1) Irish-spread model was attempted as a simpler alternative. We report its calibration and its diagnostic failure (Section 5) as the methodology journey: the Ljung-Box test rejects white-noise residuals decisively, and the persistence parameter sits within two standard errors of a unit root. This evidence is the basis for moving the headline lens to a non-parametric bootstrap on the Irish rate directly.

1. Data sources and calibration windows

Two authoritative series underpin the entire pack. Both are obtained from the ECB Statistical Data Warehouse via its public CSV-data API; the Irish mortgage-rate series is the same MIR statistic published by the Central Bank of Ireland in its monthly money-and-banking release.¹

Series	Identifier	Window	n
ECB Deposit Facility Rate	FM.D.U2.EUR.4F.KR.DFR.LEV	1999-01 to 2026-05	329
Irish mortgage interest rate	MIR.M.IE.B.A2C.AM.R.A.2250.EUR.N	2003-01 to 2026-03	279
Irish mortgage spread	Irish mortgage rate – ECB DFR	2003-01-31 to 2026-03-31	279

The ECB DFR is the policy-rate driver because the Irish mortgage market is dominated by variable-rate, tracker and short-fix products; pillar Irish lenders price their funding off Eurosystem facilities, not against long-dated Bund yields.² A backward-extended Bundesbank five-year Pfandbrief or hypotheken-rate series would import a different monetary regime (predominantly long-dated fixed rates) and is therefore rejected as inappropriate for Irish mortgage projection.

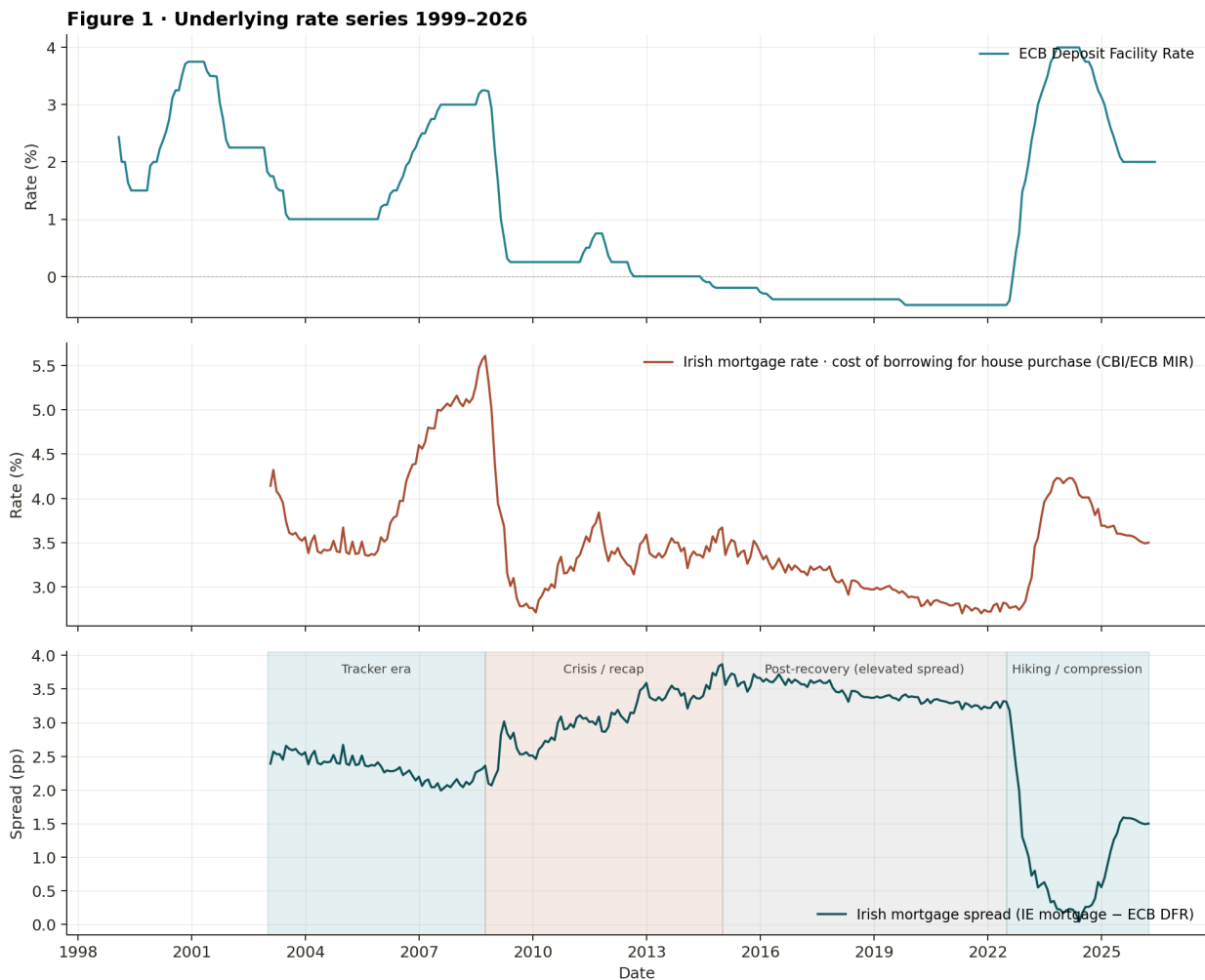


Figure 1. ECB Deposit Facility Rate (top), Irish mortgage rate (middle), and the Irish mortgage spread (bottom) with regime annotations. Sources: ECB SDW, CBI MIR.

2. Primary architecture · block bootstrap of the Irish rate

The headline Irish translation is a stationary block bootstrap of the Irish mortgage-rate monthly differences. Each simulated path is built by drawing geometrically-distributed blocks of historical first differences (mean block length 24 months) and accumulating them from the spot rate (3.49% modal at March 2026 in the underlying series; 3.50% at the last available observation).

Why bootstrap is the headline

Three reasons. First, the bootstrap makes no parametric distributional assumption and therefore inherits the regime mix observed in 2003-2026 rather than asserting it. Second, it is robust to the diagnostic failure of the AR(1) spread model (Section 5). Third, block bootstrapping preserves the within-block autocorrelation of the differences (rate increases tend to come in runs) without requiring us to specify a functional form for that persistence.³

The trade-off is honest: the bootstrap cannot extrapolate beyond the regime mix it has seen. If the true future regime is materially different from anything in 2003-2026 (sustained 8% rates, for example), the bootstrap will understate that tail. The parametric variants in Section 3 are presented precisely to address this concern: they permit the long-run mean to differ from the historical mean by construction.

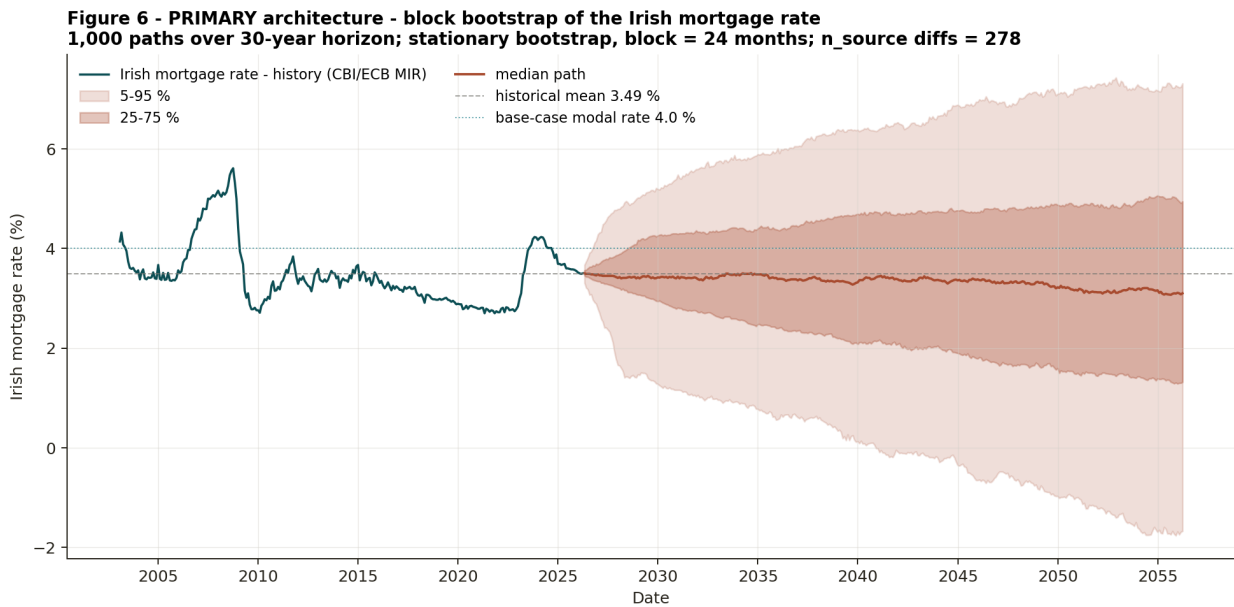


Figure 2. Primary architecture — 1,000-path block-bootstrap fan for the Irish mortgage rate over a 30-year horizon. The dashed grey line is the 2003-2026 historical mean; the dotted teal line is the base case's deterministic 4.0% modal rate.

Plain-English read-out

Under the bootstrap, the median path drifts gently toward the historical mean (3.49%), reflecting the symmetric mix of easing and tightening episodes in the source window. The 25-75% cone holds the mortgage rate broadly between 2% and 5% over the 30-year horizon. The 5-95% cone reaches negative territory at the lower edge by the end of the horizon. This is not a forecast: it is the consequence of the source window including the 2014-2022 ZIRP / NIRP regime. The realised Irish mortgage rate did not become negative; the ECB policy rate did. The bootstrap, being non-parametric, does not impose a zero lower bound. We address this by truncating to a 0% floor in the harm-metric overlay (consistent with how Irish lenders priced products through the ZIRP era).

3. Parametric ECB–driver sensitivity · three Vasicek variants

The Vasicek short-rate model $dr_t = \kappa(\theta - r_t)dt + \sigma dW_t$ is the canonical Gaussian Ornstein-Uhlenbeck process used in life and general-insurance ALM. Three parameters: κ (mean-reversion speed), θ (long-run mean), σ (instantaneous volatility). The half-life of a shock is $\log(2) / \kappa$.

The 27-year EUR sample contains approximately one and a half ECB policy-rate cycles. Maximum-likelihood identification of κ on data of this length is intrinsically weak; the data informs σ well, but the data alone cannot tell us whether the rate process is highly mean-reverting around a low long-run mean (C1), modestly mean-reverting around a moderate long-run mean (C2), or a near-random-walk with whatever central tendency the sample average implies (C3). The honest response is to present all three.

Variant	κ	θ (%)	σ	Half-life	Log-lik
C1 · Data-MLE (free κ, θ, σ)	0.063 SE 0.063	0.83 SE 1.44 pp	0.467 SE 0.018	11.0 y	192.9
C2 · Reinsurance convention (κ, θ fixed; σ free)	0.200 [fixed]	2.50 [fixed]	0.481	3.5 y	185.1
C3 · Near-random-walk (κ, θ fixed; σ free)	0.020 [fixed]	1.09 [fixed]	0.466	34.7 y	192.6

Note the standard error on κ in C1: SE = 0.063 against an estimate of 0.063. The data is unable to distinguish C1's κ from zero at conventional levels. This is not a model failure — it is the data telling us that 27 years is too short to identify mean reversion precisely. Presenting C1 alone would imply false precision. C2 and C3 bracket the range; we make no claim that any one of the three is the ‘right’ calibration.⁴

Figure 2 · Vasicek calibration diagnostics

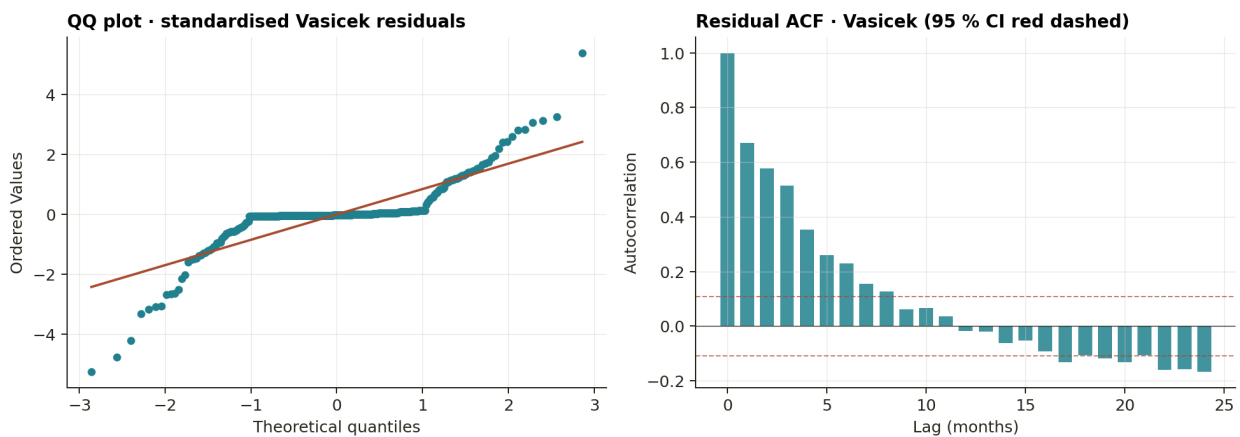


Figure 3. Vasicek C1 diagnostics: standardised-residual QQ plot and residual ACF. QQ shows approximate normality in the body with heavier tails than Gaussian on both sides (consistent with the ZIRP plateau and 2022 hiking shock). The ACF exhibits significant positive autocorrelation through approximately lag 8, exceeding the 95% bands — the discrete-time AR(1)-equivalent fit absorbs persistence imperfectly on monthly data; the bracketing C2 and C3 calibrations and the non-parametric bootstrap in Section 2 are presented precisely because the data does not support a single Vasicek point estimate.

Figure 3 · Calibration grid · 1,000 forward paths under each variant

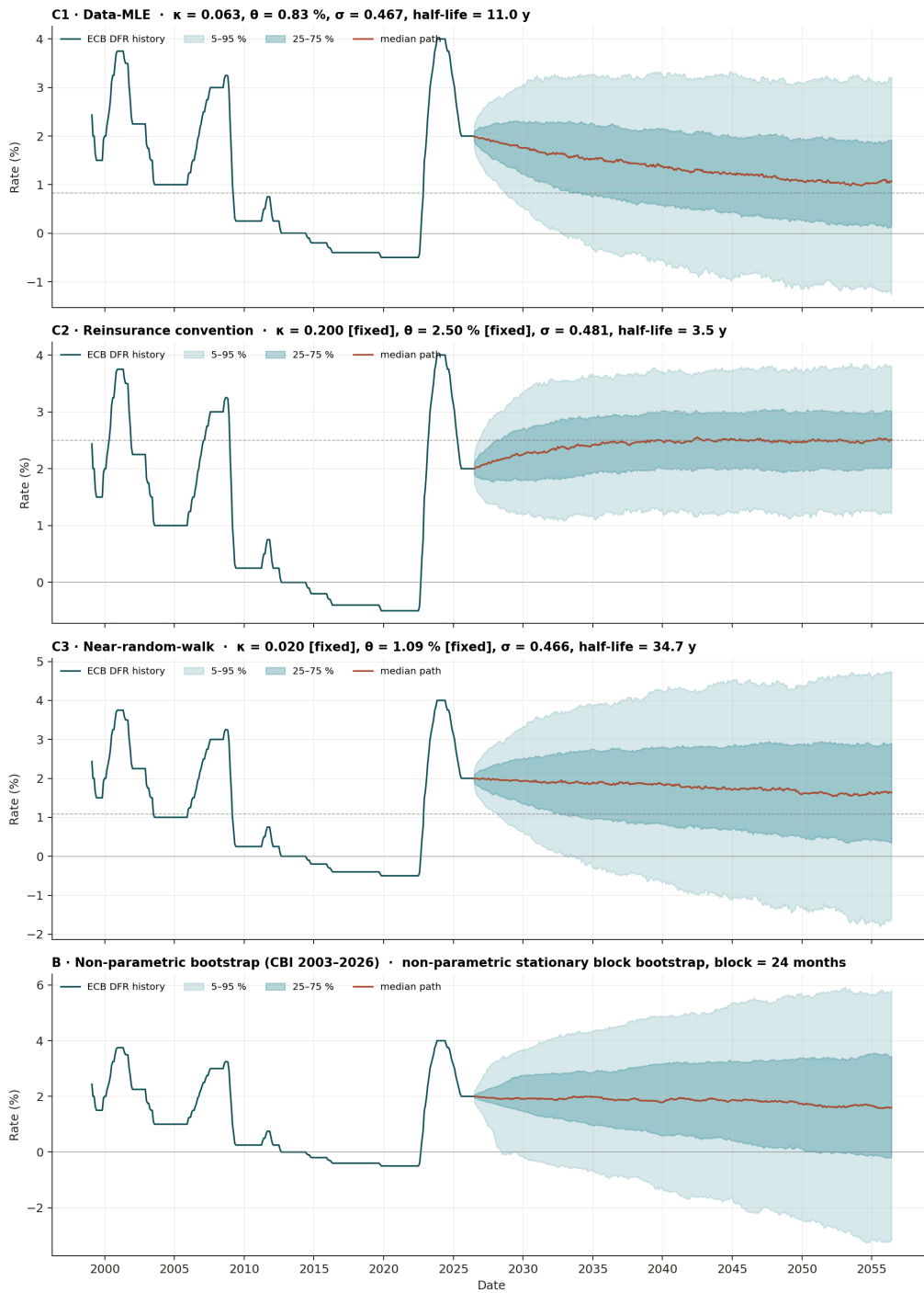


Figure 4. ECB DFR fan charts under each variant (1,000 paths, 30-year horizon). The bootstrap of the Irish mortgage rate is shown for comparison, although the ECB driver and the Irish rate are different series; the bootstrap panel uses Irish-rate differences whilst the Vasicek panels project the ECB policy rate.

4. Regime-switching spread · sensitivity overlay

To represent the documented structural break in the Irish mortgage spread, we fit a two-state Markov-switching model on the monthly spread series. The Hamilton filter with Kim's smoother is used for the E-step; EM converges in 14 iterations to a log-likelihood of -157.2.⁵

Parameter	State 0 · normal	State 1 · stressed
Mean spread μ (pp)	1.923	3.383
Volatility σ (pp)	0.817	0.210
Self-transition probability P_{kk}	0.9912	0.9931
Stationary weight	0.438	0.562
Expected duration (months)	114	146

The smoothed state probability (Figure 5a) places the entire 2003-Sep 2010 window in the normal state, the entire Oct 2010-Aug 2022 window in the stressed state, and Sep 2022 onwards back in the normal state. This matches the historical narrative: the tracker era, the post-crisis SVR elevation as Irish lenders rebuilt margins,⁶ and the recent ECB hiking cycle compressing the spread as tracker books rolled off and new business priced closer to policy.

The mixture density (Figure 5b) is visibly bimodal in the empirical histogram — a feature no stationary AR model can represent. The two-state mixture matches the empirical density well. The pack treats the regime-switching model as a sensitivity overlay rather than the headline because the 23-year window contains only one full regime transition (Oct 2010) and one partial reversal (Aug 2022); the transition probability estimates are weakly identified.

Figure 7a - Markov-switching spread regime probabilities
State 0 (normal): $\mu = 1.92$ pp, $\sigma = 0.82$ pp; State 1 (stressed): $\mu = 3.38$ pp, $\sigma = 0.21$ pp

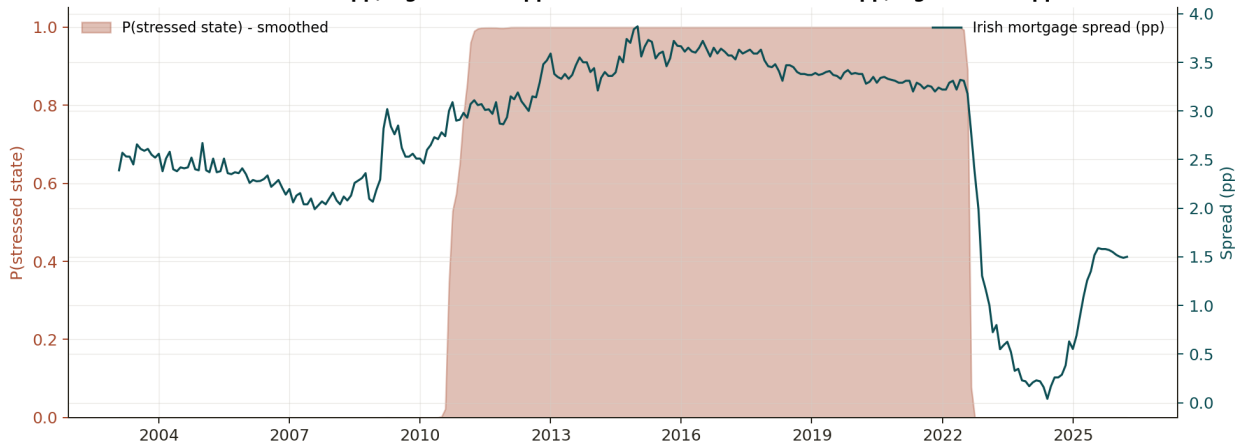


Figure 7b - Two-state mixture density vs empirical spread distribution

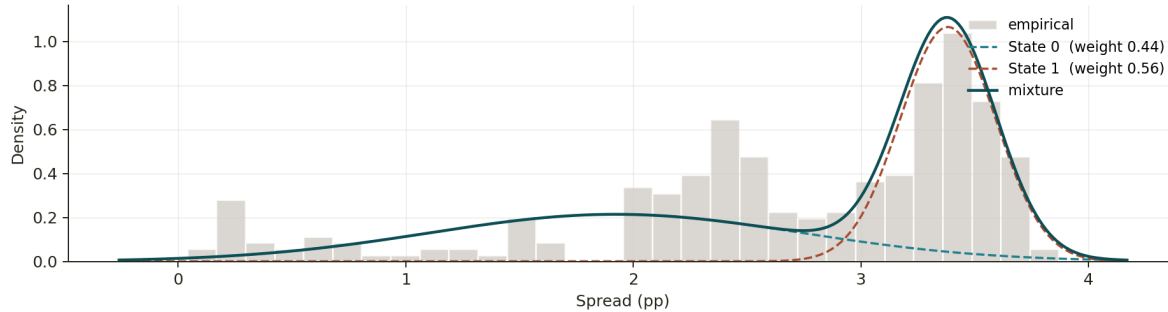


Figure 5. Markov-switching spread diagnostics. (5a) Smoothed posterior probability of the stressed state with the observed spread overlaid. (5b) Empirical histogram against the two-state mixture density.

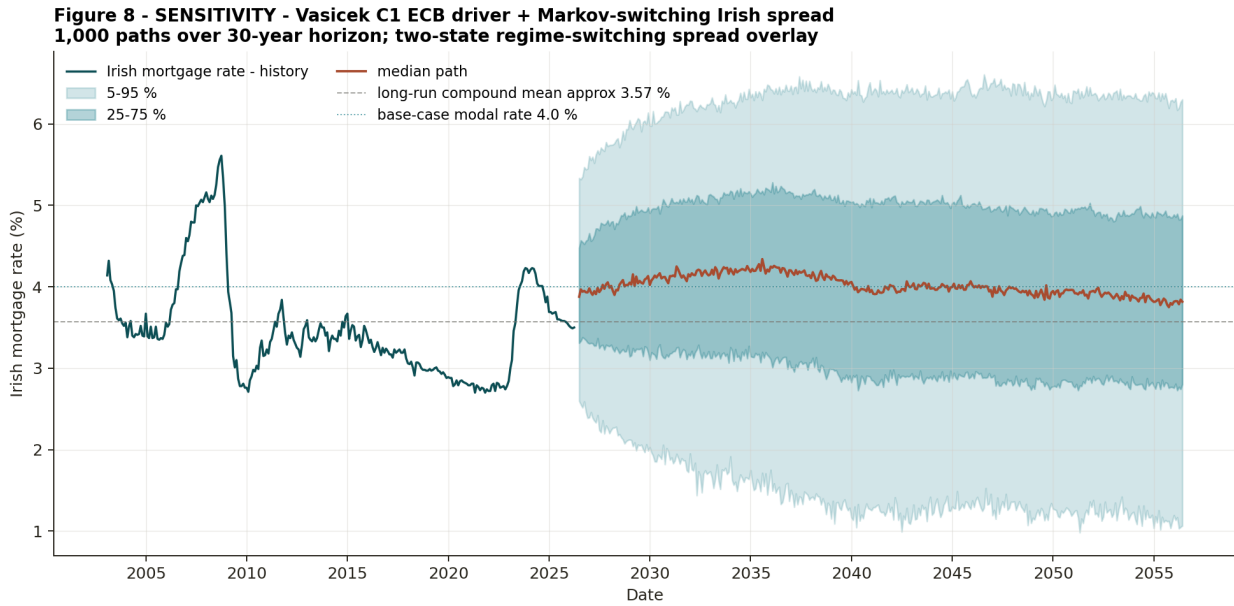


Figure 6. Compound Irish-rate fan: Vasicek C1 ECB driver + Markov-switching Irish spread. 1,000 paths over a 30-year horizon. Long-run compound mean is the C1 long-run mean plus the stationary mixture mean of the spread.

5. Methodology journey · why AR(1) was insufficient

Before reaching the bootstrap-primary architecture, we calibrated a simpler AR(1) model on the spread. This section reports that work and its diagnostic failure, in full, because the failure is the evidence that motivated the re-architecture.

Parameter	Estimate	Standard error
c (intercept, pp)	0.0100	0.0209
ϕ (persistence)	0.9951	0.0074
σ_e (residual std, pp)	0.1158	—
Implied long-run mean (pp)	2.0205	—
Ljung-Box(12) statistic	56.84	p = 8.46e-08

Note on display rounding. Implied long-run mean is computed on the unrounded parameters ($c = 0.009988$, $\phi = 0.995057$) and equals 2.0205 pp. Recomputing directly from the 4-decimal display values ($0.0100 / (1 - 0.9951) = 2.0408$) gives a different figure because both c and $(1 - \phi)$ round in the same direction; the compounded display drift is $\approx 1\%$. The AR(1) is documented here as failed methodology and is not used downstream.

Two diagnostic flags.

1. Near-unit-root persistence. $\phi = 0.9951$ with SE 0.0074. The 95% confidence interval includes values arbitrarily close to one. A persistence coefficient this close to a unit root indicates that the AR(1) is absorbing structural level shifts as ‘very slow mean reversion’ rather than modelling them explicitly.
2. Ljung-Box(12) p = 8.46e-08. The residuals retain significant autocorrelation through lag 12. The white-noise null is rejected decisively. Inspection of the residual ACF (Figure 7) and the spread history (Figure 1) identifies the cause: two structurally distinct regimes (tracker / recent-hiking vs post-crisis SVR) that no stationary AR family can represent honestly.

Figure 4 · Irish spread AR(1) calibration diagnostics

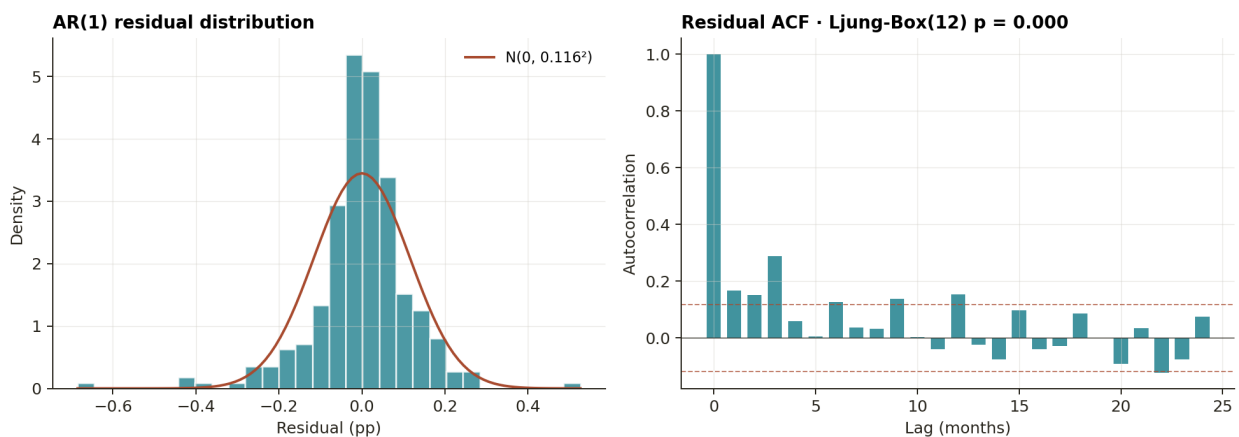


Figure 7. AR(1) diagnostic failure. Left: residual distribution against the fitted normal. Right: residual ACF with Ljung-Box(12) p-value = 8.46e-08 — the white-noise null is rejected.

Options considered

We considered four routes after the AR(1) failure. (a) Extend to ARMA(p, q) with order selection by BIC. (b) Two-state Markov-switching. (c) Accept AR(1) with the failure stated. (d) Drop the spread layer

entirely and bootstrap the Irish rate. Option (a) risks false precision: an ARMA(2, 1) might pass the Ljung-Box at the cost of disguising the regime break with extra parametric flexibility. Option (c) is honest but underplays regime-driven tail risk. Option (b) is the strongest economic story but identification of transition probabilities is weak on this sample. Option (d) sidesteps the parametric problem altogether. Our decision was to combine (d) and (b): (d) as the headline, (b) as the sensitivity overlay.

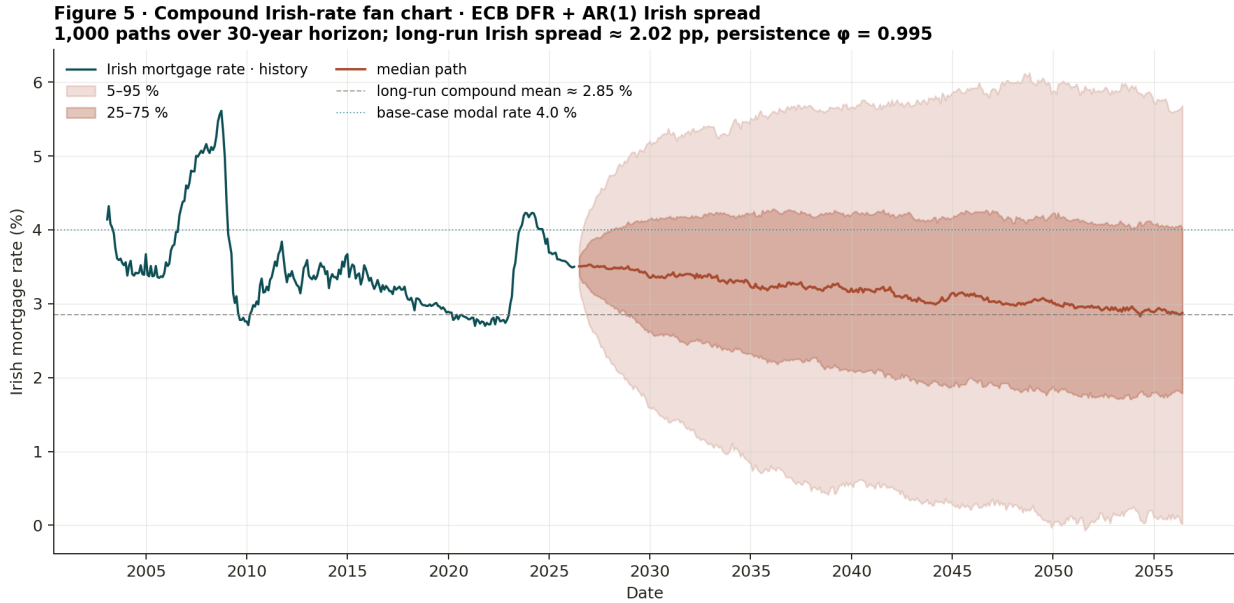


Figure 8. Compound Irish-rate fan under the rejected AR(1) spread layer (Vasicek C1 + AR(1)). Retained for reference. The Markov-switching version (Figure 6) is the preferred parametric Irish translation.

6. Limitations of the available data set

This pack has been built within an honestly limited evidence base. Three limitations bear on the interpretation of the simulated results.

Length of the EUR sample

ECB DFR series begins January 1999 (start of EUR); 27 years monthly = approximately one and a half full ECB policy-rate cycles. Standard errors on kappa are wide; mean-reversion speed is only weakly identified by the data alone. This is the basis for presenting three Vasicek variants plus a non-parametric bootstrap rather than a single point estimate.

Regime coverage

The 1999-2026 window observes one secular easing cycle (1999-2014), a ZIRP/NIRP plateau (2014-2022), and one tightening cycle (2022-2024). High-rate regimes (1980s-style) are absent by construction. Reviewers should treat results as a structured stress test under the observed EUR regime, not a forecast across all possible monetary regimes.

Pre-EMU extension

Pre-1999 euro-area policy rate data does not exist as a single coherent series. Synthetic backward-extension (e.g. ECB AWM, national policy rates pre-EMU) would import different monetary regimes and is not used here.

AR(1) spread inadequate

The simpler AR(1) spread model fails the Ljung-Box(12) residual independence test ($p = 8.5e-08$) and estimates $\phi = 0.995$, very close to a unit root. Inspection of the data identifies two structurally distinct regimes (tracker era and ECB hiking compression vs post-crisis elevated SVR 2010-2022). A two-state Markov-switching model resolves this; a stationary block bootstrap on the Irish rate directly sidesteps the spread model entirely.

Few regime transitions for MS calibration

The two-state Markov-switching spread identifies only one full regime transition (Sep 2010 from normal to stressed) and one partial reversal (Sep 2022 from stressed to normal) within the 23-year window. The transition probability estimates are therefore weakly identified; the model is presented as sensitivity, not headline.

Why bootstrap is the headline

The block bootstrap on the Irish mortgage rate level is the headline because (a) it makes no parametric distribution assumption, (b) it inherits the regime mix from history rather than asserting it, (c) it is robust to the Ljung-Box failure of the AR(1) spread. Vasicek variants and Markov-switching are presented as parametric sensitivities to evidence directional robustness.

Substantive caveat. The available European-rate-cycle history contains approximately 1.5 full policy-rate cycles since the foundation of the euro area. No quantitative calibration on this window can claim full-cycle robustness against monetary regimes that have not been observed (sustained double-digit-rate environments, for example). We present the simulation as a structured stress test under the observed EUR regime, not a forecast across all possible monetary regimes.

7. Calibration lock and methodology provenance

The calibration parameters are locked as follows. The 50,000-path simulation reported in the companion results pack was run against the locked MWP-2026-03 base case: representative borrower (age 35, male non-smoker, €322k sum-assured, 30-year term), prevalence stack ($D1 = 0.95$, $D2 = 0.131$, $D3 = 0.08$, $D4 = 0.18$), real-world projection measure for paths and $S(t)$, EIOPA Q2 2026 risk-free rate for SCR/BEL discounting.

Item	Locked value
Architecture choice	Bootstrap-primary on Irish mortgage rate; Vasicek C1/C2/C3 as ECB-driver sensitivity; two-state Markov-switching spread as Irish-translation sensitivity; AR(1) documented as methodology journey only.
Data sources	ECB DFR (FM.D.U2.EUR.4F.KR.DFR.LEV) 1999-01 to 2026-05; Irish mortgage rate (MIR.M.IE.B.A2C.AM.R.A.2250.EUR.N) 2003-01 to 2026-03; both via ECB SDW.
Bootstrap parameters	Stationary block bootstrap, mean block = 24 months on monthly differences. $n_source = 278$.
Vasicek parameters	C1, C2, C3 calibrated as reported in Section 3, parameters locked in diagnostics.json.
Markov-switching parameters	Two-state, EM-converged; means, sigmas and transition matrix as reported in Section 4.
Disturbance prevalences	Held constant at base-case values for the rates overlay ($D1=0.95$, $D2=0.131$, $D3=0.08$, $D4=0.18$). Sensitivity to prevalence is a separate exercise.
Path count and horizon	50,000 paths, 360 months (30-year base-case term).
Output metrics	Distribution of HARM A (annual aggregate), HARM B (aggregate cumulative), SCR_mort (under each variant), and the median, 5/95 and 1/99 percentiles of each. Backtest under the bootstrap is the headline; each Vasicek variant + spread choice is a sensitivity.
Discounting	EIOPA Q2 2026 risk-free curve for SCR/BEL discounting on each path. Real-world measure for projection.
Output deliverable	MWP-03-Annex-Stochastic-Rates.pdf with results.

Sources and footnotes

¹ ECB Statistical Data Warehouse, 'Cost of borrowing for households for house purchase (MIR.M.IE.B.A2C.AM.R.A.2250.EUR.N)'. Available at <https://data-api.ecb.europa.eu/service/data/MIR/M.IE.B.A2C.AM.R.A.2250.EUR.N?format=csvdata>.

² Central Bank of Ireland, 'Retail Interest Rates' (monthly), and 'Behaviour and Choices in Mortgage Refinancing', Quarterly Bulletin Q3 2019. See [centralbank.ie/statistics/data-and-analysis/credit-and-banking-statistics/retail-interest-rates](https://www.centralbank.ie/statistics/data-and-analysis/credit-and-banking-statistics/retail-interest-rates).

³ Politis, D. N. and Romano, J. P. (1994), 'The Stationary Bootstrap', Journal of the American Statistical Association, 89(428), pp. 1303-1313. DOI: [10.1080/01621459.1994.10476870](https://doi.org/10.1080/01621459.1994.10476870). The reference for the block-bootstrap method used in Section 2.

⁴ EIOPA, 'Technical documentation of the methodology to derive EIOPA's risk-free interest-rate term structures', 2025 update. Available at [eiopa.europa.eu/tools-and-data/risk-free-interest-rate-term-structures_en](https://www.eiopa.europa.eu/tools-and-data/risk-free-interest-rate-term-structures_en). Reinsurance κ convention is industry practice rather than EIOPA mandate; the 0.20 value is widely cited (e.g. Munich Re ALM disclosures, Swiss Re ESG model documentation).

⁵ Hamilton, J. D. (1989), 'A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle', *Econometrica*, 57(2), pp. 357-384. DOI: [10.2307/1912559](https://doi.org/10.2307/1912559). Kim, C-J. (1994), 'Dynamic Linear Models with Markov-Switching', *Journal of Econometrics*, 60(1-2), pp. 1-22. DOI: [10.1016/0304-4076\(94\)90036-1](https://doi.org/10.1016/0304-4076(94)90036-1).

⁶ Central Bank of Ireland, 'The future of mortgage lending in Ireland', remarks by Director General Sharon Donnery, 2017; CBI Financial Stability Review 2014 H2 (post-crisis NIM widening). See [centralbank.ie/news-media/publications](https://www.centralbank.ie/news-media/publications).