Risk Management, Product Offerings, and Consumer Surplus: Evidence from the Insurance Industry[*]

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Abstract

We study the causal impact of enterprise-wide risk management (ERM) — designed to move firms away from a "siloed" structure — on product decisions and consumer surplus. Exploiting the staggered rollout of an industry-wide ERM mandate in the insurance sector, we analyze life insurers' offerings of annuities, which now account for nearly 70% of their premium revenues. We find that insurers respond by reducing risky guarantees, raising fees on the riskiest products, and shifting from traditional variable annuities toward index-linked products that provide natural hedges. To examine mechanisms and welfare outcomes, we develop a structural model that links consumer demand with multi-product supply. The ERM mandate imposes regulatory costs and corrects firms' misperceptions about guarantee risk and cross-product risk interactions. Higher marginal costs for risky guarantees raise equilibrium prices and decrease their offerings, leading to substantial losses in consumer surplus. Overall, ERM reshapes insurers' product strategies and risk exposures, enhancing financial stability but at a cost to consumers.

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In imperfect capital markets, risk management affects the fragility of financial institutions' balance sheets by shaping how they respond to market frictions. Prior research emphasizes how risk management can constrain risk-taking activities or strengthen hedging practices (Berger et al., 2016; Ellul and Yerramilli, 2013; Landier et al., 2009; Laeven and Levine, 2009; Stulz, 2008; Basel Committee on Banking Supervision, 2010). Firms have historically managed risks within individual product categories or business units (i.e., "siloed") without accounting for cross-product (or cross-units) risk and hedging interdependencies, leading to sub-optimal outcomes. Recent shifts toward enterprise-wide risk management (ERM) aim to overcome these limitations by promoting the comprehensive assessment, quantification, and management of risk across the entire organization. Because ERM can reshape how a firm perceives risks and understands their propagation across its balance sheets, moving from a siloed to an enterprise-wide approach may influence not only the firm's asset portfolio—long the focus of the literature—but also its product offerings and, in turn, consumer surplus.

This paper examines the product-offering effects of ERM within the life insurance industry, where insurers supply a variety of retirement and savings products that expose them to differing types and levels of risk, with direct implications for their financial resilience. Identifying empirical evidence on this previously unexplored mechanism contributes to a deeper understanding of how risk management practices may influence balance sheet fragility.

In theory, firms should take risk in a value-maximizing manner, with risk management steering them toward this optimum or, at minimum, preventing value-destroying risk-taking. In practice, however, various frictions make this difficult to achieve (Kashyap et al., 2008; Stulz, 2008). High-powered executive incentives, leverage, managerial myopia, and pressure to meet short-term performance targets can all contribute to departures from optimal risk management. In complex organizations, where risks are interdependent across products and business units, a siloed approach is unlikely to promote an optimal organizational risk management. In the financial industry, such firm-level choices can generate system-wide externalities: excessive risk-taking by one institution may trigger fire sales, contagion, and broader instability. These concerns motivate governments, at times, to impose risk management mandates requiring a firm-wide approach to how firms handle and oversee their risk exposures. In the U.S. and in Europe, the Dodd-Frank Act (for banking) and Solvency II (for insurance) are examples of such mandates. Beyond finance, the Sarbanes-Oxley Act (SOX) and SEC Rule 33-9089 on board risk oversight similarly require firm-wide approaches to risk management.[1]

[1]Other examples of governments mandating firm-wide risk management approaches include: Capital Requirements Directive IV for European Banks, "Gesetz zur Kontrolle und Transparenz im Unternehmensbereich" for publicly listed German companies, the Health Insurance Portability and Accountability Act (HIPPA) for health data collectors, the Energy Policy Act for utilities connected to the electric grid, and the General Data Protection Regulation (GDPR) for general data privacy in Europe.

Empirically identifying the causal impact of a firm's adoption of ERM on its product offerings is challenging because the adoption decision is itself endogenous. For instance, evidence shows that executive traits (Bodnar et al., 2019) and corporate culture are key determinants of risk management choices, but these same factors also drive a firm's broader business strategy, including its product offerings. Naïvely regressing changes that occur in a firm's product portfolio on a measure of risk management intensity will fail to identify causal effects. In other words, relying on the voluntary adoption of stricter risk management practices is fraught with challenges that do not allow a proper identification of the effect.

To address this endogeneity, we leverage the staggered implementation of the Own Risk and Solvency Assessment (ORSA) Model Law, a regulatory mandate grounded in ERM principles, across U.S. states. A key feature of our identification strategy is that, unlike many regulatory changes studied in prior work, ORSA (i) targets risk management practices rather than governance or other regulatory issues, thereby limiting concerns about confounding regulatory channels, and (ii) was adopted state-by-state based on the domicile of the insurer's lead company. Our preliminary evidence indicates that the staggered adoption across states was driven primarily by differences in regulatory sophistication and enforcement priorities, rather than systematic differences across insurers. While adopting firms vary in size and product mix, they display similar pre-adoption ERM ratings, balance sheet characteristics, and trends in product portfolio adjustments. Moreover, although insurers are domiciled in different states, they typically operate nationwide and face common demand conditions across markets. Taken together, these facts support our identifying assumption that the timing of ORSA adoption is plausibly unrelated to unobserved firm-level trends—such as shifts in consumer demand—that might otherwise influence product offerings.

Why should ERM, as represented by ORSA in our setting, affect risk taking and product choices? ORSA requires insurers to assess current and prospective risks on an enterprise-wide basis, particularly under adverse scenarios, and to report these assessments to state regulators. By forcing firms to quantify and aggregate risks across business lines, ORSA can influence product strategy in two main ways.[2] First, better measurement and forward-looking stress analysis can move firms toward their optimal level of risk—either scaling back exposures that were previously underappreciated or, in some cases, increasing risks that are now understood to be manageable. Second, enterprise-wide evaluation can reveal natural hedges across product lines, allowing firms to redesign products or adjust hedging strategies to reduce net risk and lessen capital pressures.[3]

[2]These effects require that ORSA induces real changes in risk management practices, rather than merely symbolic compliance. A key alternative hypothesis is that ERM may be implemented superficially—for example, by appointing risk managers without granting them meaningful authority—allowing insurers to satisfy reporting requirements without altering product strategies or risk exposures. Our empirical analysis is designed to distinguish between substantive and purely formal responses to the mandate.

[3]The importance of this approach for the financial industry was explicitly stated by the Basel Committee on Banking Supervision (2010).

We use life insurers' annuity product offerings as a natural testing ground. With the decline of employer-sponsored defined benefit plans in the U.S., annuities have increasingly served as a substitute mechanism for retirement security, representing almost 70% of the direct premiums as well as the liabilities of life insurers in 2024 (National Association of Insurance Commissioners, 2025; American Council of Life Insurers, 2024, respectively). Historically, the main annuity products are traditional variable annuities (TVAs), which over time have become a key liability category for life insurers. While these contracts appeal to policyholders by offering equity market participation, many have embedded guarantees, which can expose insurers to sizable aggregate market risks (Ellul et al., 2022). Specifically, the guarantee feature of these annuity products are similar to long-dated out-of-the-money put options, exposing insurers to undiversifiable tail risk. Periods of financial distress magnify these exposures, making TVAs a prime laboratory for studying how risk management mandates alter product decisions (Koijen and Yogo, 2015).

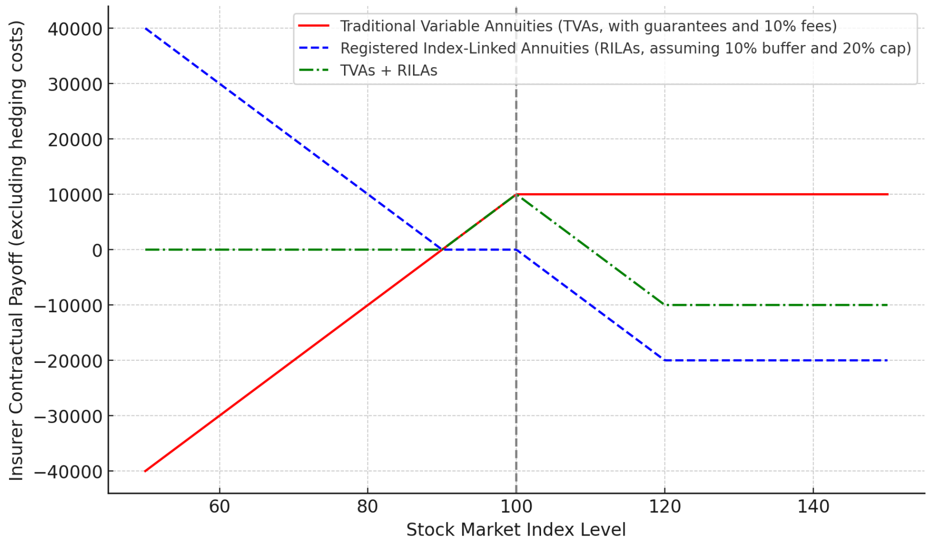
A separate product line that has recently emerged and grown rapidly is registered index-linked annuities (RILAs). In 2023, RILA sales surpassed TVA sales for the first time (Almazora, 2024). Like TVAs, RILAs offer equity-based returns, but compared to TVAs, are less "guarantee-loaded": they provide partial downside protection through buffers or floors. In the more common buffer design, the policyholder is protected from the initial portion of market decline (e.g., the first 10–15% decline in the reference index) but is responsible for losses beyond this threshold. Economically, this structure (with a deposit contract as the base) is equivalent to the policyholder writing an out-of-the-money put option to the insurer, thereby offsetting the payoff profile of TVA guarantees. More generally, both buffer and floor designs limit the insurer's downside exposure (in exchange for some upside exposure) and thus serve as a natural hedge against the risks inherent in TVA guarantees (Barbu and Sen, 2024).[4]

In our setting—-where insurers hold substantial legacy liabilities from guaranteed TVAs—-if ORSA induces meaningful changes in risk management and product strategy, we would expect a shift in the product mix away from TVAs, which heighten volatility and capital strain, and toward RILAs, which naturally offset these exposures. For the TVAs that continue to be offered, we also expect less generous guarantees and higher fees. Using an imputation staggered difference-in-differences design following Borusyak et al. (2024),[5] we find evidence consistent with these predictions.

[4]Although insurers can, in principle, hedge the downside risk embedded in TVA guarantees using derivatives or reinsurance, practical and regulatory constraints often make such hedging costly or incomplete (Ellul et al., 2022; Sen, 2023). By contrast, hedging risks within the product portfolio—such as through the introduction of RILAs—is generally more flexible and is viewed more favorably by relevant regulations.

[5]This approach avoids using early-treated firms as controls for later-treated ones and allows us to estimate causal effects on multiple product attributes jointly by predicting counterfactual outcomes using untreated insurer-years.

Figure 1: Insurer Contractual Payoffs Under TVAs, RILAs, and Combined Portfolio



Specifically, we show that firms newly subject to ORSA reduce their offering of TVAs and expand their offering of RILAs, while leaving their offering of traditional fixed annuities unchanged, consistent with the fact that fixed annuities do not provide comparable hedging benefits. In other words, ORSA leads to a substantive reallocation within the product portfolio. Moreover, for the TVAs that remain, affected insurers are less likely to offer the most generous guarantees and significantly increase fees. We interpret these patterns as the causal effects of ERM, as represented by ORSA. Because ORSA was adopted at different times across states, it is unlikely that our results are driven by shifts in consumer demand or preferences. Any demand-based explanation would require that changes in consumer preferences for specific annuity features occurred precisely and exclusively in the states where insurers happened to be domiciled at the moment of ORSA adoption—an implausible scenario given that insurers operate nationally and face largely uniform demand conditions across markets.

With our DiD results as motivation, we develop a structural model of annuity supply to explore the underlying mechanisms through which ERM causes insurers to alter their product mix. In contrast to traditional supply-side models, we explicitly allow for cross-product hedging to lower marginal costs. However, prior to the adoption of ERM, firms may not fully recognize the hedging effects and instead set prices based on the "siloed" first order conditions. This structure and the staggered roll-out of ORSA allow us to identify how the correction of cost misperceptions and the recognition of natural, product-led hedging affect pricing. We combine our supply-side model with a demand model, similar to Koijen and Yogo (2022), to estimate the hidden costs of the changed product design caused by risk management. TVA guarantees are risky to insurers because there are no financial derivatives that insurers can use to perfectly hedge the risk. This also means there are no direct substitutes for the market risk insurance that TVA guarantees provide that consumers can turn to when the product menu changes, and our demand model allows us to estimate this lost consumer surplus directly.

In our structural model analysis, we couple a BLP demand system with a multi-product supply model in which marginal costs include (i) guarantee and rollup components and (ii) a natural-hedge component that decreases TVA marginal costs with the firm's non-TVA volume. Pre-ORSA, firms partially recognize these components via perception weights; we estimate that they recognize these costs at roughly 53–93% relative to their recognition post-ORSA. (Fees are converted to present-value dollars using a 12-year horizon, 3

Our structural estimates indicate that pre-ORSA, firms substantially under-recognized portfolio-level natural-hedge benefits ($\approx$53% accuracy in weak-ERM firms versus $\approx$64% in strong-ERM), while recognizing guarantee costs at $\approx$88–93%. We allow for time and firm fixed effects; we do not separately identify a post-ORSA compliance-cost shifter in the current specification. The welfare implications are substantial and adverse. Consumer surplus peaks around \$13–14B and falls to $\approx$\$2.4–5B post-ORSA, implying losses on the order of \$7–11B per year under our logit welfare measure. This loss reflects a fundamental tension: while ORSA corrects cost misperceptions and enhances risk management, resulting price increases exceed any consumer benefits from improved pricing accuracy. The 36.3 percentage-point decline in the probability of offering TVAs suggests reduced systemic risk, achieving ORSA's macroprudential objectives. However, this stability imposes significant costs on retirement savers who depend on guaranteed annuities, transferring investment risk to consumers at the life-cycle stage when they are least capable of bearing it.

Our paper contributes first to the literature on enterprise-wide risk management and its impact on firm risk-taking. While this literature highlights ERM's importance, it has faced persistent challenges in establishing causality because ERM adoption and intensity are endogenous (Ellul and Yerramilli, 2013; Chen et al., 2020; Nocco and Stulz, 2022; Amiraslani et al., 2025; Li et al., 2025; Neel and Xu, 2025). The staggered implementation of ORSA provides a plausibly exogenous shock to insurers' organizational risk management structures, allowing us to isolate how strengthened ERM affects the design and selection of products that determine insurers' liabilities and risk exposures—an important but previously underexplored channel.

Our findings also speak to the broader literature on financial regulation and its economic effects. Prior work shows that regulation can shape market outcomes (Barbu et al., 2024; Koijen and Yogo, 2016), but credible identification is difficult when reforms are broad-based and treated and untreated firms operate in overlapping regulatory environments (Houston et al., 2012; Ongena et al., 2013; Aiyar et al., 2014; Frame et al., 2020). By exploiting within-industry variation in the timing of ORSA adoption, we provide clean causal evidence that risk management mandates can materially reshape firms' product strategies and risk exposures, clarifying a mechanism through which financial regulation can influence both firm behavior and consumer welfare.

We also contribute to the extensive literature on TVAs, where numerous studies examine their guarantee structures, risk exposures and hedging, and capital implications (e.g., Ellul et al., 2022; Koijen and Yogo, 2015; Hufeld et al., 2017; Koijen and Yogo, 2022; Li, 2024; Barbu, 2023; Rogers and Tonetti, 2023). Our findings highlight how regulatory requirements can reshape product portfolios, adding a new dimension to the analysis of TVA pricing, market dynamics, and risk management. In addition, we complement an emerging literature on RILAs (e.g., Friedberg and Webb, 2021; Barbu et al., 2024; Mezger, 2024; Moenig and Xu, 2023; Ellis et al., 2025) by showing that insurers respond to enterprise-wide oversight not simply by retreating from risky contracts but by adopting products like RILAs that permit strategic risk sharing with policyholders. It emphasizes risk management's ability to generate upside opportunities by promoting product innovation.

Our findings have implications beyond insurance and financial institutions. Life insurers' liabilities arise directly from the contractual promises embedded in the products they sell, so shifts in product mix reflect changes in risk management on the liability side of the balance sheet. A similar dynamic applies in many industries where firms offer products or services with deferred or contingent obligations, such as warranties, guarantees, advance payments, or long-duration service commitments. In these settings (e.g., airlines, healthcare, energy, and consumer goods), our findings suggest that organizational risk management can directly shape the design of contractual promises and the capital required to support them.

1 Institutional Background and Hypotheses

1.1 Enterprise Risk Management

Enterprise Risk Management (ERM) represents a firm-wide approach to organizational risk management that evaluates risks and their interconnectedness across the entire firm, rather than within isolated business units. Unlike traditional silo-based methods—where individual departments manage risks independently, ERM integrates risk identification, assessment, and control into a unified framework that links risk management with strategic and regulatory objectives. If done effectively, ERM should allow the firm to improve capital allocation, and strengthen organizational resilience and decision-making (COSO, 2004; SEC, 2007; Hoyt and Liebenberg, 2011).

The strategic, enterprise-wide view provided by ERM should allow top management to identify interdependencies across risks or projects and recognize how they interact and influence one another. Such an integrated understanding allows firms to exploit **natural hedges**—instances where the dynamics of one risk or project offset the effects of another.[6]

The importance of ERM's comprehensive approach was highlighted in a 2011 speech by the U.S. Securities and Exchange Commission (SEC) Chairman Mary L. Schapiro, who emphasized that a commitment to ERM is essential to prevent the formation of silos and the overlooking of interdependencies between risk categories and across the product and asset classes. Real-world anecdotes also illustrate the challenges of silo-based approaches and the advantages ERM provides in addressing them. For example, in 1984, Lufthansa, Germany's largest airline, signed a 3 billion U.S. dollar contract to purchase aircraft from Boeing and entered into a 1.5 billion U.S. dollar forward contract to hedge exchange rate risk, fearing continued appreciation of the U.S. dollar. However, a significant portion of Lufthansa's cash flow was U.S. dollar-denominated, naturally offsetting the exchange rate exposure. By overlooking this natural hedge and managing the risk in isolation, Lufthansa incurred a major and unnecessary foreign exchange loss when the U.S. dollar depreciated against the mark in 1985 (The Economist, February 10, 1996, p. 16-17).

In the finance industry, recent capital adequacy frameworks—Basel III for banks and Solvency II for insurers—represent a clear shift toward enterprise-wide, risk-sensitive supervision, replacing the compartmentalized approaches of earlier regimes. Under prior systems such as Basel I, Basel II, and Solvency I, capital standards relied on standardized formulas and separate treatment of credit, market, and operational risks. By contrast, Basel III and Solvency II adopt a holistic view of firm-wide risk, emphasizing diversification and the aggregation of exposures across business lines. They also introduce forward-looking stress testing, internal models, and governance requirements that link capital to the institution's overall risk profile rather than to individual assets or liabilities. Together, these changes align regulatory capital more closely with economic risk and ERM as a central element of prudential oversight.

The insurance industry offers a natural laboratory for studying ERM. Because insurers' business models center on risk transfer and pooling, they face a broad range of exposures—from policy performance and asset-liability mismatches to demographic, operational, and strategic risks. Effective risk management must therefore operate not only at the product or subsidiary level but also enterprise-wide, where interdependencies among risks are recognized and managed collectively. Reflecting this view, regulators have embedded the ERM concept in recent initiatives such as the Own Risk and Solvency Assessment (ORSA) in the United States and Solvency II in Europe.

[6] A key feature of ERM is its emphasis on a "tone from the top" framework, where the board of directors plays a key role in guiding enterprise-wide risk management practices (Braumann et al., 2020; Neel and Xu, 2025). This leadership ensures that risk management strategies are consistent across the organization and aligned with the firm's mission, vision, and core values (COSO, 2017; Li et al., 2025).

1.2 Own Risk and Solvency Assessment Requirements

ORSA is a U.S. regulatory framework designed to enhance insurers' financial stability by embedding ERM into a verifiable and recurring process. Introduced by the NAIC following the 2008 financial crisis, ORSA moves beyond principles-based guidance toward a structured, evidence-based regime that integrates risk management, capital planning, and board oversight at both the legal-entity and group-wide levels. It requires insurers not only to identify and assess their material risks but also to demonstrate—through documentation and analysis—their ability to remain solvent under adverse scenarios. The assessment is documented in an ORSA Summary Report, submitted confidentially to the insurer's lead state commissioner (NAIC, 2012).[7]

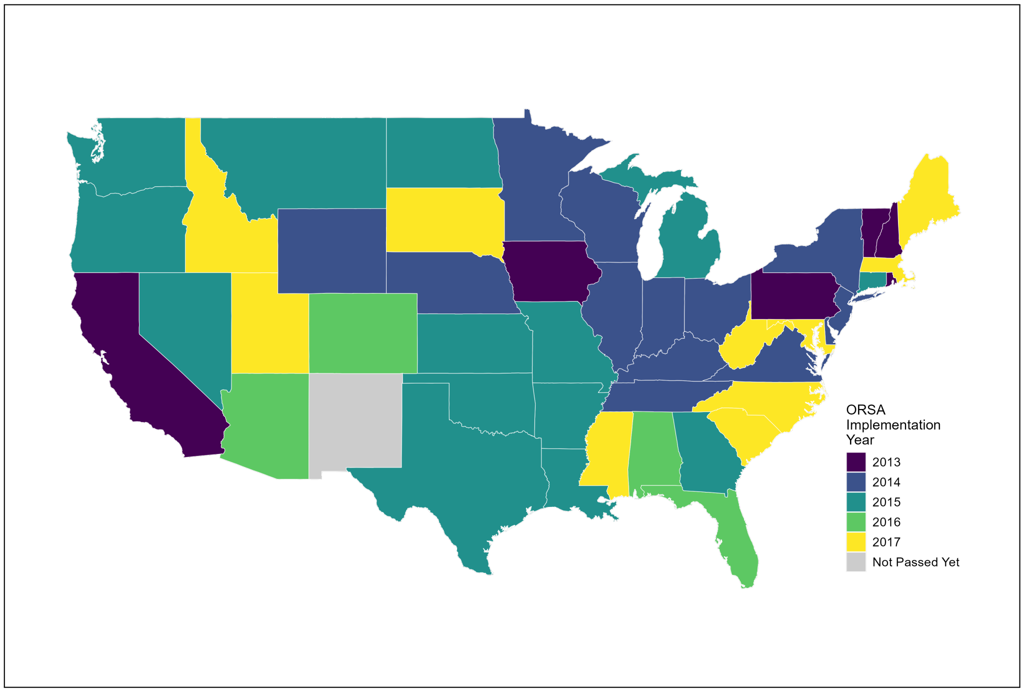
A defining feature of ORSA is that it makes **enterprise-wide risk management and stress testing** verifiable through enforceable reporting and governance requirements. Each ORSA Summary Report must be signed by the Chief Risk Officer (or equivalent) and delivered to the board, creating a documented trail that distinguishes genuine implementation from symbolic compliance (Liu and Xu, 2024; Li et al., 2025). Conducted at least annually, ORSA turns ERM into a continuous, enterprise-level assessment of solvency under stress, rather than a one-off disclosure, with penalties for noncompliance. Regulators further shape the process by prescribing stress-test parameters and economic scenario assumptions, constraining insurers' discretion to produce overly optimistic projections. The ORSA Manual also specifies key report elements—accounting basis, data scope, solvency projections, and management actions under capital shortfalls—allowing supervisors to evaluate the firm's overall resilience and planned responses to systemwide stress.

The ORSA reporting requirement is outlined in the NAIC's Risk Management and Own Risk and Solvency Assessment Model Act (#505) (NAIC, 2012). U.S. states and jurisdictions adopted the Model Act between 2013 and 2017 in a staggered manner, as represented in Figure 2. As of 2024, 53 out of 56 U.S. jurisdictions have formally enacted the Model Act.

We emphasize from the outset that the adoption of ORSA is very different from the other regulatory-related mandates in one important aspect, crucial for our identification of the effects of ERM. Government mandates such as Dodd-Frank Act, Solvency II or SOX typically take effect across entire sectors (or even countries) at the same time. It is thus difficult to untangle their true causal impact on firm risk-taking because of the multiple effects on various dimensions of the

[7]ORSA applies to U.S. insurers with more than $500 million in annual direct written and assumed premiums, or to insurance groups with over $1 billion. These insurers are required to conduct and document an ORSA on a regular basis. Because annuity writers are typically large insurers, all firms in our sample fall within the ORSA mandate.

Figure 2: Map of ORSA Roll-out



Note: Figure shows which the roll-out of ORSA regulations for insurer lead states.

firms' operations. Prior studies have attempted various identification strategies. However, since uniform regulatory roll-outs rarely generate clean control groups, they typically rely on either extremely strong assumptions or yield only "local" evidence.[8]

Eastman and Xu (2021) examine the market reactions of insurers with and without voluntary ERM adoption on key dates leading up to the passage of ORSA. Krupa (2024) finds that, due to ORSA's integrated approach in considering all firm-wide risks, insurers' managers are required to assess both tax and non-tax risks when making tax strategies. This leads to increased awareness of previously underestimated non-tax risks and a significant reduction in tax aggressiveness. The study also shows that this effect holds regardless of whether insurers had voluntarily adopted ERM prior to ORSA, suggesting that ORSA elevates ERM practices to a higher level, likely due to its mandatory nature and the detailed self-assessment reports required by regulators.

[8]Identification strategies include: Exemptions for very small companies (e.g., Balasubramanyan et al., 2024; Jiang and Ji, 2024); Cross-country comparisons (e.g., Houston et al., 2012; Ongena et al., 2013; Frame et al., 2020); Assumed variation in treatment intensity (e.g., Aiyar et al., 2014); and the inclusion of fixed effects (e.g., Amiraslani et al., 2025). A large separate literature also examines firms that voluntarily adopt ERM. Within this literature, earlier studies mainly rely on treatment effects models (e.g., Hoyt and Liebenberg, 2011; Eckles et al., 2014; Berry-Stölzle and Xu, 2018), while more recent research often employs difference-in-differences strategies with endogenous treatment, typically in matched samples (e.g., Eastman et al., 2024; Li et al., 2025; Neel and Xu, 2025).

1.3 Product Lines

Life insurers' two primary product lines are annuities and life insurance (both individual and group). Over the past two decades, annuities have become the dominant source of premium income for U.S. life insurers, representing roughly 65–75% in recent years, depending on the accounting basis. This paper focuses on annuities because (a) they represent the principal driver of insurers' risk exposures, particularly systematic risk (Koijen and Yogo, 2022), and (b) the state-contingent payoffs across different annuity types exhibit rich cross-sectional heterogeneity and potential natural hedging opportunities within insurers' product portfolios.

Traditional Variable Annuities: Traditional Variable Annuities (TVAs) are hybrid financial instruments that combine investment products, typically mutual funds, with insurance features designed to provide a degree of income stability and downside protection. These products often offer an assortment of guaranteed benefits (many of which can be combined) in exchange for fees, with each benefit type shifting varying degrees of risk to the insurer. For detailed descriptions of specific annuity benefit types—including Guaranteed Minimum Death Benefits (GMDB), Guaranteed Minimum Accumulation Benefits (GMAB), Guaranteed Minimum Income Benefits (GMIB), Guaranteed Minimum Withdrawal Benefits (GMWB), and Guaranteed Lifetime Withdrawal Benefits (GLWB)—and their associated risk profiles, see Appendix A.

Among guaranteed benefits, lifetime living benefits—notably GMWB and GLWB—pose the greatest complexity and risk for insurers, as they depend on both market performance and policyholder longevity.[9] Financially, these guarantees resemble put options written on mutual fund portfolios, often combining index-based and actively managed funds. Hedging these exposures is costly and imperfect, despite affording partial relief under Risk-Based Capital (RBC) requirements.[10] In practice, insurers often under-hedge due to regulatory frictions (Sen, 2023), and the marginal effectiveness of hedging declines as coverage expands (Ellul et al., 2022). Consequently, substantial basis risk remains in most portfolios (Ankirchner et al., 2014; Bauer, 2020).

Registered Index-linked Annuities: Registered Index-linked Annuities (RILAs) are a new form of variable annuity. RILAs have drastically gained in popularity in recent years, with annual sales exceeding \$40 billion in 2022, after being virtually non-existent a decade earlier (Ellis et al., 2025). A RILA entails an investment into a separate account managed by an insurance company. The account evolution is linked to the performance of a popular market index—such as the S&P 500—over a crediting term of usually one year (but potentially up to six years). At the end of the year, the insurer credits the investor's account with the index return, subject to downside protection in

[9] By contrast, GMDBs are less complex, with more predictable triggers and shorter horizons. We focus on the lifetime benefits of GMWB and GLWB and classify the rest as non-lifetime benefits. Results are robust to including GMAB and GMIB as lifetime benefits, though magnitudes weaken somewhat.

[10] Insurers typically hedge through futures, ETF short positions, or index put options to offset guarantee deltas.

the form of a Floor or Buffer. For instance, with a 10% Floor the investor can lose at most 10% of her funds over the crediting term, and with a 10% Buffer the loss from the index decline would be reduced by up to 10%. In exchange, the investor accepts an upside limit, usually in the form of a Cap, that the credited return cannot exceed. When combined with a target-date glide path that gradually reduces equity exposure, these target-date RILAs (TD-RILAs) offer a passive, risk-adjusting investment option well-suited for qualified retirement plans (QRPs), such as 401(k) and 403(b) plans.

For insurers, RILAs offer several advantages. The embedded equity risk can be hedged efficiently with exchange-traded European options on major indices, avoiding the complex and dynamic hedging required for traditional variable annuity (TVA) guarantees. RILAs also provide pricing flexibility, as carriers can reset the Cap each term to reflect current option market conditions—an adjustment used effectively during the 2020 volatility spike (Moenig, 2022). Finally, RILAs are generally lower-fee products (Moenig, 2022; Moenig and Samuelson, 2024), reflecting their efficient risk structure and regulatory treatment: since investors have no direct exposure to the index, insurers invest premiums at their discretion (typically in corporate bonds) and earn a credit spread that helps offset costs and sustain profitability.

Synergies Between TVAs and RILAs: RILAs provide a natural hedge against TVA guarantees by effectively transferring part of the downside risk back to investors (Barbu and Sen, 2024). In TVAs, insurers provide downside protection to policyholders, whereas in RILAs, the policyholders accept some downside risk in exchange for some upside potential, effectively "selling" a put option to the insurer. This offsetting exposure allows carriers to hedge large realizations of equity (and interest rate) risk within their product portfolio. Unlike exchange-traded options, RILAs involve cash premiums held by insurers, which can be invested in safe assets—eliminating collateral, counterparty, and liquidity risks. Because these products are typically held in tax-advantaged retirement accounts, insurers naturally intermediate market risk, matching households seeking protection (typically older and more risk-averse) with those willing to bear limited downside exposure (yournger and more risk-tolerant). The result is lower capital volatility, a reduced need for external hedging, and a more balanced allocation of equity market risk across households with different risk profiles.

Figure 1 builds on the explanations above and illustrates insurer contractual payoffs under three product structures: TVAs, RILAs, and a portfolio combining one unit of each, assuming a 10% TVA fee and ignoring hedging costs. TVAs expose insurers to significant downside risk due to embedded guarantees, while passing through gains to policyholders when equity markets rise. The illustrative RILA example in the figure assumes a 10% buffer and a 20% cap (actual product designs vary). When combined, the TVA and RILA payoffs offset each other in both tails of the return distribution, flattening the insurer's aggregate exposure and creating a natural hedge.

1.4 Hypotheses

Taken together, ORSA's enterprise-wide requirements can influence insurers' product strategies through two mutually reinforcing channels. First, by compelling insurers to quantify and aggregate risks across business lines—especially under stress scenarios—ORSA improves forward-looking risk assessment and may correct prior misperceptions about the full risk distributions of different products, particularly their tail-risk exposures. This sharper understanding can move firms toward their optimal level of risk, leading them to scale back exposures that were previously underestimated or, in some cases, expand those now viewed as more manageable. Second, ORSA's emphasis on enterprise-wide evaluation can uncover natural hedging opportunities across product lines—such as the offsetting risk profiles of TVAs and RILAs—encouraging insurers to redesign product offerings or adjust hedging strategies to reduce net risk and relieve capital pressures.

We begin by assuming that ORSA's ERM requirements place greater weight on risk reduction than insurers would under their own objective functions (see, e.g., Kim and Santomero, 1988). This implies that prior to ORSA, insurers may have taken on more risk than regulators preferred—either to boost revenues or profits.[11] In this context—where insurers already hold substantial legacy liabilities from guaranteed TVAs—ORSA should push firms to rebalance their product portfolios: away from TVAs, whose embedded guarantees heighten volatility and capital strain, and toward RILAs, which are less guarantee-loaded and naturally offset TVA exposures (as illustrated in Figure 1). Among TVAs that remain in the market, we expect insurers to shift toward less generous guarantees and higher-fee designs that better compensate for their risk and, perhaps, incentivize customers to switch to RILAs.

As noted above, some insurers had already implemented ERM prior to ORSA. To the extent that an insurer's pre-ORSA risk management practices were already comprehensive and stringent, the introduction of ORSA would be expected to have little incremental effect on its product offerings or guarantee pricing. Conversely, for insurers whose earlier ERM frameworks were less comprehensive or insufficiently robust, ORSA should prompt meaningful adjustments in product design, product mix, and fee structures, consistent with the mechanisms discussed above.

Finally, it is important to consider the welfare implications for households arising from ORSA-driven shifts in insurers' annuity product design and pricing. Many households value TVAs with lifetime guarantees because these contracts embed a long-term put option that has no close substitute in broader financial markets. If so, any reduction in the availability of guaranteed TVAs—or

[11] Such frictions as high-powered compensation and limited internalization of failure externalities may lead insurers to underweight tail risks or the broader systemic consequences of distress.

any increase in the cost of these guarantees—is likely to produce a meaningful decline in consumer surplus. This loss cannot be offset by greater availability of RILAs, which offer attractive investment features but do not replicate the insurance protection inherent in lifetime guarantees.

2 Data

2.1 Data Sources

We combine data from multiple sources to construct firm-level, contract-level, and benefit-level panels for our analysis. Morningstar Annuity Intelligence is our primary source for product-level data. From Morningstar, we obtain comprehensive annuity contract characteristics including product type classifications (TVA, fixed, and index-linked), benefit rider descriptions and features, fee schedules, contract inception and close dates, and sales data for TVA contracts.[12] Morningstar's coverage is comprehensive for TVA products but more limited for non-TVA products (fixed and index-linked annuities). Consequently, sales data are available primarily for TVA contracts, though we observe contract offerings (inception and close dates) for all annuity types.

NAIC filings provide firm-level financial and operational data. From insurers' annual statements reported to the NAIC, obtained through S&P Global Market Intelligence, we obtain insurer characteristics including net total assets, surplus, direct and net premiums written, asset allocations, and capitalization measures such as RBC ratios. The NAIC data also include total annuity account values and gross reserves associated with annuities with guarantees, reported in the General Interrogatories (2003-2016) and the Variable Annuities Supplement, Parts 1 and 2 (2017 onward).[13] Separate NAIC data provide each firm's lead state—typically the state in which the firm (if unaffiliated) or its affiliated group (if part of a group) is domiciled or headquartered—which determines ORSA treatment timing in our staggered difference-in-differences design.

We merge Morningstar product-level data with NAIC firm-level data by company name and year, using a combination of automated string matching and manual validation to establish firm linkages. This merged dataset allows us to analyze how firm characteristics and regulatory treatment affect product-level decisions. For sales analyses, we use Morningstar's product-level TVA sales data aggregated to the firm level, supplemented by NAIC firm-level total annuity sales where appropriate to capture non-TVA products.

[12] The Morningstar annuity data were collected, with permission, through web scraping from Morningstar document archives and AnnuityIntel.com.

[13] These aggregate reserve and account value data from NAIC filings represent totals across all of a firm's annuity products with guarantees, complementing the product-level detail from Morningstar.

To explore heterogeneity based on prior usage of ERM, we obtain S&P ERM ratings from S&P Global. These ratings evaluate insurers' risk management practices across five dimensions: risk management culture, risk controls, emerging risk management, risk models, and strategic risk management. The ratings are scored on a 5-point scale: (1) Weak, (2) Adequate, (3) Adequate with strong risk controls, (4) Strong, (5) Very Strong/Excellent. The ratings assess whether insurers execute risk management practices in a systematic, consistent, and strategic manner across the enterprise. We use pre-ORSA ERM ratings (from 2010) as a proxy for firms' prior level of risk management sophistication.[14]

We calculate shadow insurance usage from Schedule S reinsurance filings obtained through S&P Global Market Intelligence. Shadow insurance is identified using three criteria: (1) the reinsurer is unauthorized (not licensed in the ceding company's state), (2) the reinsurer is affiliated with the ceding company, and (3) the reinsurer is not rated by A.M. Best. We measure shadow insurance usage as the sum of life reserves credit taken and modified coinsurance ceded to these shadow reinsurers. We match reinsurer names from Schedule S to A.M. Best rating data to identify unrated reinsurers, using automated string matching with manual review. We use pre-ORSA shadow insurance usage (from 2010) as a proxy for firms' prior level of risk management sophistication.

2.2 Sample Construction

Our full sample covers the period from 2005 to 2023. The reduced-form analyses use data from 2008 to 2016, which provides a balanced pre- and post-treatment window around the staggered ORSA adoption period (2013-2017) while maintaining a meaningful control group throughout. We end in 2016 because firms in the final adopting states became subject to ORSA in 2017, eliminating the control group necessary for our identification strategy. In contrast, the structural model is estimated using data from 2005 through 2023 to capture the longer-run evolution of annuity sales and consumer surplus after ORSA implementation, allowing us to examine whether the observed post-ORSA patterns persist over time.

We construct three nested panels from our merged data sources. First, for firm-level sample, we start with the universe of insurance companies that filed annual statements with the NAIC and offered at least one annuity contract in Morningstar during 2008-2016. This yields 941 firm-year observations at annual frequency across 120 unique firms. Second, in the contract-level sample, we observe all annuity contracts from Morningstar at quarterly frequency to capture the timing of contract introductions and removals precisely. This yields 173,744 contract-quarter observations across 5,198 unique contracts. Third, for benefit-level hazard and fee analyses, we focus on guar-

[14] We assign a value of 0 to firms that are not rated by S&P.

anteed benefit riders offered within TVA contracts. Benefits are observed at quarterly frequency. This hierarchical structure—where each contract may offer multiple benefit riders—yields 947,900 benefit-quarter observations across 27,525 unique benefit-contract combinations and 2,596 contracts. [15]

Summary statistics in Table 1 are reported at the observation-unit frequency used in the corresponding regression analyses: annual for firm-level variables (Panel A), quarterly for contract-level variables (Panel B), and quarterly for benefit-level variables (Panel C). The observation counts in Table 1 match exactly the samples used in our reduced-form analyses.

2.3 Variable Construction

Our firm-level variables, including assets, surplus, premiums, and RBC ratios, are taken directly from the NAIC data and are standard. Morningstar classifies contracts into four types of annuities: (1) fixed, (2) fixed-index, (3) index-linked, and (4) traditional variable annuities (TVAs).[16] We track whether each contract is being offered in a given year-quarter using its inception and close dates. Other variables, including mortality and expense risk fee and sales numbers, are taken directly from Morningstar. Contract sales are available only for TVA contracts. See Appendix B for the full definition list and unit conventions.

The annuity contracts in our data, particularly traditional variable annuities (TVAs), offer various guaranteed living benefit riders that shift different types of risk to the insurer.[17] These life guarantees include Guaranteed Minimum Withdrawal Benefits (GMWB), and Guaranteed Lifetime Withdrawal Benefits (GLWB). Each benefit type protects policyholders against different risks across the accumulation, annuitization, and post-retirement phases of the contract. The benefits—particularly GMWB and GLWB—expose insurers to both market risk and longevity risk, making them especially challenging to hedge and manage. We classify the benefits broadly into life guaranteed benefits and non-life guaranteed benefits. Specifically, the benefit names that contain the following words—"GMWB", "GLWB", and "Lifetime"—are considered life guaranteed benefits. Finally, we track whether each benefit rider is active in a given year-quarter using its inception and close dates.

[15]The benefit-level sample exceeds the contract-level sample because TVA contracts typically offer multiple benefit riders, reflecting the common practice of bundling different types of guarantees (e.g., GMWB combined with GMDB) within a single annuity product.

[16]Fixed annuities contain no equity exposure, while fixed-index and index-linked annuities are linked to an index and have downside protection. In our analysis, we group fixed-index and index-linked annuities together as index-linked annuities.

[17]See Appendix A for detailed descriptions of each benefit type.

2.4 Summary Statistics

Table 1: Summary Statistics

Panel A: Firm-level variables (annual)

Variable	Mean	SD	p25	Median	p75	N
Total Assets ($M)	39,736.2	65,540.8	4,432.4	11,591.7	37,684.0	941
Surplus ($M)	2,196.8	3,961.1	281.9	760.5	2,140.7	941
RBC Ratio	10.172	28.005	4.072	4.894	6.475	941
Capital/Assets Ratio (%)	18.562	20.217	7.978	11.135	18.023	941
Has Shadow Insurance	0.312	0.464	0.000	0.000	1.000	941
ERM Rating (1-5)	2.190	0.392	2.000	2.000	2.000	522

Panel B: Contract-level variables (quarterly)

Variable	Mean	SD	p25	Median	p75	N
Traditional Variable Annuity	0.847	0.360	1.000	1.000	1.000	173,744
Fixed Annuity	0.053	0.223	0.000	0.000	0.000	173,744
Index-Linked Annuity	0.100	0.300	0.000	0.000	0.000	173,744
Contract Offered	0.331	0.471	0.000	0.000	1.000	173,744

Panel C: Benefit-level variables (TVA contracts only, quarterly)

Variable	Mean	SD	p25	Median	p75	N
Benefit Offered	0.3882	0.4873	0.0000	0.0000	1.0000	947,900
Life Guarantee	0.5566	0.4968	0.0000	1.0000	1.0000	947,900
Current Fee (bps)	81.99	65.39	30.00	85.00	125.00	947,900
Rollup Rate (bps)	564.62	149.02	500.00	500.00	600.00	359,796
Contract Sales ($M)	250.94	925.28	0.30	7.55	105.49	433,384

Notes: This table presents summary statistics at the observation-unit frequency used in our reduced-form analyses, covering 2008-2016 for all panels. Panel A reports firm-year statistics (annual frequency) for 941 observations across 120 unique firms, combining NAIC financial data with Morningstar products. Firm-level variables including assets, surplus, and RBC ratios are from NAIC filings. Panel B reports contract-quarter statistics (quarterly frequency) for 173,744 observations across 5,198 unique contracts, representing all annuity contracts from Morningstar. Panel C reports benefit-quarter statistics (quarterly frequency) for 947,900 observations across 27,525 unique benefit-contract combinations and 2,596 contracts, representing benefit riders within TVA contracts from Morningstar. The benefit-level sample exceeds the contract-level sample because TVA contracts typically offer multiple benefit riders.

Table 1 presents summary statistics for our reduced-form analysis sample. Panel A shows firm-level statistics across 941 firm-year observations from 120 unique firms. Firms in our sample exhibit substantial heterogeneity in size and financial strength. Average total assets are $39.7 billion (standard deviation of $65.5 billion), with the median firm holding $11.6 billion in assets, reflecting the presence of both small specialized insurers and large diversified financial institutions in the annuity market. Average surplus is $2.2 billion (standard deviation of $4.0 billion), and the average RBC ratio is 10.172 (standard deviation of 28.005), indicating that most firms maintain capital well above regulatory minimums though with considerable variation. Among the 522 firm-year observations with ERM ratings, the average rating is 2.19 on the 1-5 scale (standard deviation of 0.39), with the median firm rated 2.0 (Adequate). Shadow insurance usage is present in 31% of firm-year observations, indicating substantial variation in firms' use of affiliated reinsurance structures.

Panel B shows contract-level statistics across 173,744 contract-quarter observations from 5,198 unique contracts. In our sample, 84.7% of contract-quarter observations are traditional variable annuities (TVAs), 5.3% are fixed annuities, and 10.0% are index-linked annuities, reflecting the dominance of variable annuities with life guarantees in the annuity market during this period. On average, 33% of contract-quarter observations show the contract as actively offered in a given quarter, reflecting the panel structure where contracts may exist in firms' product lineups but not be actively marketed in all periods. The ORSA treatment indicator equals one for 31% of observations, reflecting the staggered adoption across states. Strong ERM rating (indicating strong pre-ORSA risk management practices) characterizes 27% of contract-quarter observations, showing substantial variation in firms' ERM sophistication.

Panel C shows benefit-level statistics for benefit riders across 947,900 benefit-quarter observations from 27,525 unique benefit-contract combinations spanning 2,596 contracts. The benefit-level sample is larger than the contract-level sample because each TVA contract typically offers multiple benefit riders, with many contracts bundling different guarantee types (e.g., GMWB combined with GMDB) within a single product. Across all benefit-quarter observations, 55.7% are classified as life guaranteed benefits (GMWB and GLWB), while 44.3% are non-life guaranteed benefits. Among observations with fee data, the average current fee is 0.82% (standard deviation of 0.65%), with the median fee at 0.85%. Among the 359,796 observations with rollup rate data, the average rollup rate is 5.65% (standard deviation of 1.49%), with most benefits offering a 5.0% rollup rate. Contract sales average $250.9 million (standard deviation of $925.3 million) across the 433,384 observations with sales data, though the median is just $7.6 million, reflecting the highly skewed distribution of annuity sales concentrated among a few large products.

3 Reduced-Form Methodology: Imputed Difference-in-Differences

We exploit the staggered adoption of ORSA regulations across states to investigate the impact of ERM on annuity companies using a DiD approach. Specifically, we examine whether the roll-out of ORSA caused insurers to (1) offer fewer TVAs and substitute towards more index-linked annuities; (2) offer fewer of the riskiest benefit types on those TVAs; and (3) increase the fee charged for those risky benefits.

Our DiD analysis replies on two primary assumptions. The first is that in the absence of ORSA, the treatment and control groups would have had parallel trends over time. Any deviation in trends between the two groups after the policy change is then attributed as the causal effect of the policy. While we cannot directly check the parallel post-trends assumptions, we do check for parallel pre-trends using a staggered event study analysis. The second primary assumption is known as the "stable unit treatment value" assumption (or SUTVA). This assumption requires that the response of a particular insurer depends only on the treatment value of that insurer, and not on the treatment value of other insurers. For our analysis, this assumption likely holds in the first order, however there may be second-order feedback mechanisms such as competitive effects. For example, treated firms raising their prices may also lead to non-treated firms raising their prices in response. As long as the "non-treated" impact is in the same direction the true treatment, this will attenuate our results.

In our setting, where states adopt ORSA at different times, the traditional two-way fixed effects (TWFE) DiD approach can yield biased results. This occurs because, in addition to comparing treated insurers with those not yet treated, TWFE also compares insurers incorporated in newly adopting states to those in states that adopted ORSA earlier. If the treatment effects are not homogeneous across time, then TWFE will be biased.[18] Once a state has adopted ORSA, insurers incorporated in that state can no longer serve as valid controls for insurers in states that adopt ORSA later.

Recent developments in the literature have established methods to address this limitation.[19] All of these new methods, some more explicitly than others, rely on a common framework of "imputing" the missing, untreated potential outcomes for treated units by assuming that the observed trend from an appropriate comparison group also happens in the treated group and then averaging, in some manner, the difference between the actual and predicted outcomes for the dependent variable of interest (Borusyak et al., 2024). Where the methods differ is in how the common trends are estimated and how the resulting treatment effects are weighted to get the average treatment effect on the treated (ATT).

[18]See Goodman-Bacon (2021) for discussions of the drawbacks of two-way fixed effects with differential timing.

[19]For example, Callaway and Sant'Anna (2020), Athey et al. (2021), Borusyak et al. (2024), Gardner (2021), and Jakiela (2021).

Borusyak et al. (2024) formalizes this imputation idea. For all of our reduced form models, we first fit a fixed effects model with OLS using data from insurers in the untreated state-years and then use that model to predict individual counterfactual outcomes for insurers in the treated state-years. We then regress the difference between the actual and predicted outcomes for the dependent variable of interest on the treatment variables. By not including the treated units in the first-stage fixed effects model, we avoid the bias that would arise from the treated units being used as their own control. To account for correlation in treatment assignment, we cluster standard errors at the lead state $\times$ annuity type (or guarantee type) level (Abadie et al., 2023).

Contract Offerings: We first examine the opening and closing of individual contracts. We transform our contract-level data into a "long"-balanced panel with one observation per contract-quarter and a binary indicator for whether the contract is offered.[20] We then estimate an imputation-based specification on this contract-level panel.

Formally, we index time at the year-quarter level and write "qt" to denote a specific quarter q in year t (e.g., 2020Q4 and 2021Q4 are distinct). For annuity contract k, (potentially) offered by insurance company j in quarter q of year t, we estimate the following model using the imputation approach:

$$P(y^0_{kjqt} = 1) = \alpha_j + \delta_{a(k)qt} + \epsilon_{kjqt} \tag{1}$$

$$P(y^1_{kjqt} = 1) - \widehat{y^0_{kjqt}} = \sum_{m \in \{TVA, Index, Fixed\}} \beta_m \times ORSA_{jqt} \times \mathbb{1}[Annuity\_Type_k = m] + \nu_{kjqt} \tag{2}$$

where y_{kjqt} is a binary indicator for if annuity contract k is offered in quarter q of year t; α_j are firm fixed effects; $\delta_{a(k)qt}$ are annuity-type-by-year-quarter fixed effects, with $a(k) \in \{TVA, Index, Fixed\}$ denoting the type of contract k and qt denoting a specific year-quarter; $Annuity\_Type_k$ is the associated one-hot (3-dimensional) type indicator so that $\mathbb{1}[Annuity\_Type_k = m] = \mathbb{1}[a(k) = m]$; and β_m captures the differential effect of ORSA on each annuity type.

Equation (1) uses untreated contract-quarters to predict potential counterfactual outcomes for the treated contract-quarters, which are then used in Equation (2) to estimate the differential impact of ORSA adoption on contract offerings across product types.

[20] By "long" we mean one row per contract-quarter over the sample window, with $y_{kjqt} = 1$ if contract k offered by firm j is available for new sales in quarter q of year t and 0 otherwise. This yields a balanced panel across quarters for each contract so that entries and exits are captured by changes in the offered indicator rather than changes in the set of rows. For example, a contract that is offered in the first 3 periods and then closed in the fourth period will have $y_{kjt} = 1$ for $t = 1, 2, 3$ and $y_{kjt} = 0$ for $t = 4$. This is also known as a "discrete" hazard model.

Benefit Offerings: We next examine the offering of different types of benefits for TVAs. For annuity contract k and benefit i, (potentially) offered by insurance company j in quarter q of year t, we estimate the following model using the imputation approach:

$$P(y^0_{ikjqt} = 1) = \alpha_k + \delta_{g(i)qt} + \epsilon_{ikjqt} \tag{3}$$

$$P(y^1_{ikjqt} = 1) - \widehat{y^0_{ikjqt}} = \beta_G \times ORSA_{jqt} \times LifeGuarantee_i \tag{4}$$

$$+ \beta_N \times ORSA_{jqt} \times (1 - LifeGuarantee_i) + \nu_{ikjqt} \tag{5}$$

where y_{ikjqt} is a binary indicator for if benefit i is offered on contract k in quarter q of year t; α_k are contract fixed effects; $\delta_{g(i)qt}$ are life-guarantee-group-by-year-quarter fixed effects, with $g(i) \in \{G, N\}$ indicating whether benefit i is a life guarantee (G) or non-life guarantee (N); $LifeGuarantee_i$ is a binary indicator for whether the benefit is a life guarantee benefit; and $ORSA_{jqt}$ is a binary indicator for insurance firm j being exposed to ORSA regulation in quarter q of year t.

Benefit Fees: Finally, we examine TVAs benefit fees, measured in basis points (bps), conditional on the benefit and contract being actively offered. Using the same benefit-contract-quarter panel, we estimate:

$$Fee^0_{ikjqt} = \alpha_k + \delta_{g(i)qt} + \epsilon_{ikjqt} \tag{6}$$

$$Fee^1_{ikjqt} - \widehat{Fee^0_{ikjqt}} = \gamma_G \times ORSA_{jqt} \times LifeGuarantee_i \tag{7}$$

$$+ \gamma_N \times ORSA_{jqt} \times (1 - LifeGuarantee_i) + \nu_{ikjqt} \tag{8}$$

where Fee_{ikjqt} is the total fee (mortality and expense risk (M&E) plus benefit rider fees) charged for benefit i on contract k in quarter q of year t, measured as an annualized rate in basis points. The specification mirrors the benefit hazard regressions, with contract fixed effects and life-guarantee-group-by-year-quarter fixed effects. The coefficients γ_G and γ_N capture the differential impact of ORSA on fees for life guarantee versus non-life guarantee benefits.

4 Reduced-Form DiD Results

4.1 Baseline Analysis

We begin by estimating average effects of ORSA adoption on insurers' product design and pricing decisions. Our analysis focuses on three margins of adjustment: contract-level offering decisions (whether to offer a particular TVA, RILA, or fixed annuity product), benefit-level design choices (whether to offer a particular guarantee benefit rider in offered TVA products), and pricing adjustments (fees charged on offered guarantee benefit riders in offered TVA products). Table 2 presents our main DiD estimates, while Figures 3–5 provide event study evidence supporting the parallel trends assumption.

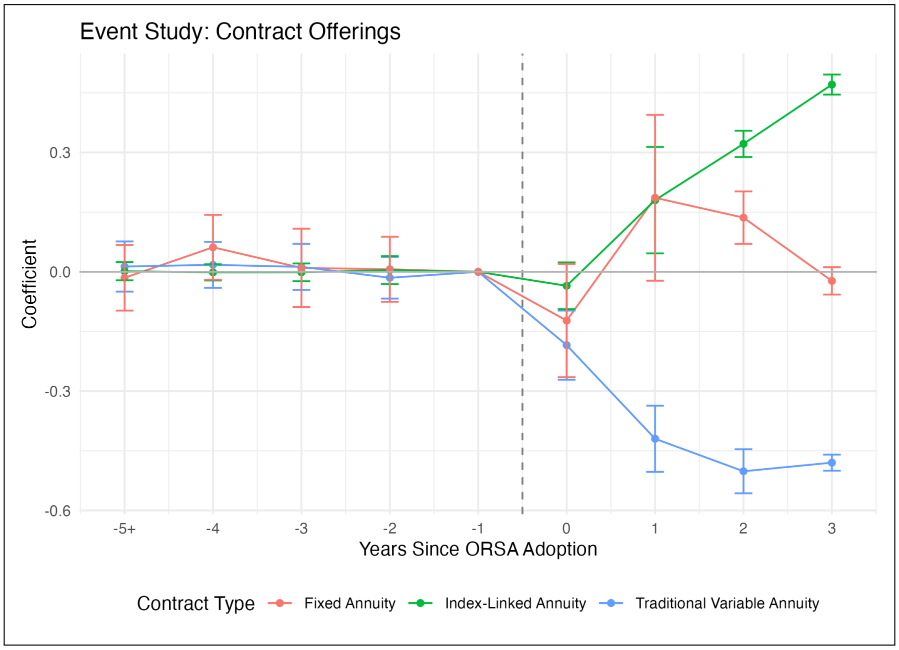
Table 2: Impact of ORSA on Annuity Contract Offering

	P(Contract Offered)	P(Benefit Active)	Fee (bps)
Dependent Variables:			
ORSA x Traditional Variable Annuity	-0.363^{***}		
	(0.036)		
ORSA x Fixed Annuity	0.054		
	(0.070)		
ORSA x Index-Linked Annuity	0.180^{***}		
	(0.019)		
ORSA x Life Guarantee		-0.200^{***}	8.437^{***}
		(0.016)	(1.938)
ORSA x Non-life Guarantee		0.021	1.029
		(0.034)	(7.345)
Firm FE	Yes		
Annuity Type $\times$ Year $\times$ Quarter FE	Yes		
Contract FE		Yes	Yes
Guarantee Type $\times$ Year $\times$ Quarter FE		Yes	Yes
Observations	173,744	947,900	178,436

Notes: This table reports reduced-form regression results of the impact of ORSA adoption on annuity product offerings, benefit activation, and benefit fees. Column (1) reports the probability a contract type is offered. Column (2) reports the probability a benefit rider is active (benefit-level) for TVA contracts. Column (3) reports benefit rider fees (in basis points) among active benefits for TVA contracts. The interaction terms capture how the effect of ORSA varies across product and guarantee types. Standard errors are clustered at the lead state x annuity type level for Column (1) and the lead state x guarantee type level for Columns (2) and (3). * p < 0.1, ** p < 0.05, and *** p < 0.01.

The contract-type coefficients in column (1) of Table 2 reveal a pronounced portfolio reallocation following ORSA adoption. Insurers reduce their probability of offering TVAs by about 36.7 percentage points and simultaneously increase their probability of offering RILAs by 18.5 percentage points. Both effects statistically significant at the 1% level. Relative to the pre-ORSA baseline, this represents a significant reduction in the number of TVA offerings and a substantial expansion in RILAs. This pattern suggests direct product substitution, with insurers shifting from mutual fund-like products with guaranteed benefits toward structured products that offer downside protection through indexed participation rather than explicit guarantees. The coefficient on Fixed Annuities is positive but small (5.4 percentage points) and statistically insignificant, indicating that the primary substitution occurs within equity-linked products rather than toward simpler fixed instruments. The specification has both firm fixed effects and annuity type $\times$ year-quarter fixed effects. This means that any time invariant firm-level characteristic, such as the insurer's preferences vis-a-vis the type of annuity it wants to offer, is absorbed by the fixed effects. Similarly, the interactive fixed effects absorb any other changes in the insurers' or consumers' preferences that vary with time outside of the adoption of ORSA.

Figure 3: Event Study Estimates: Contract Type

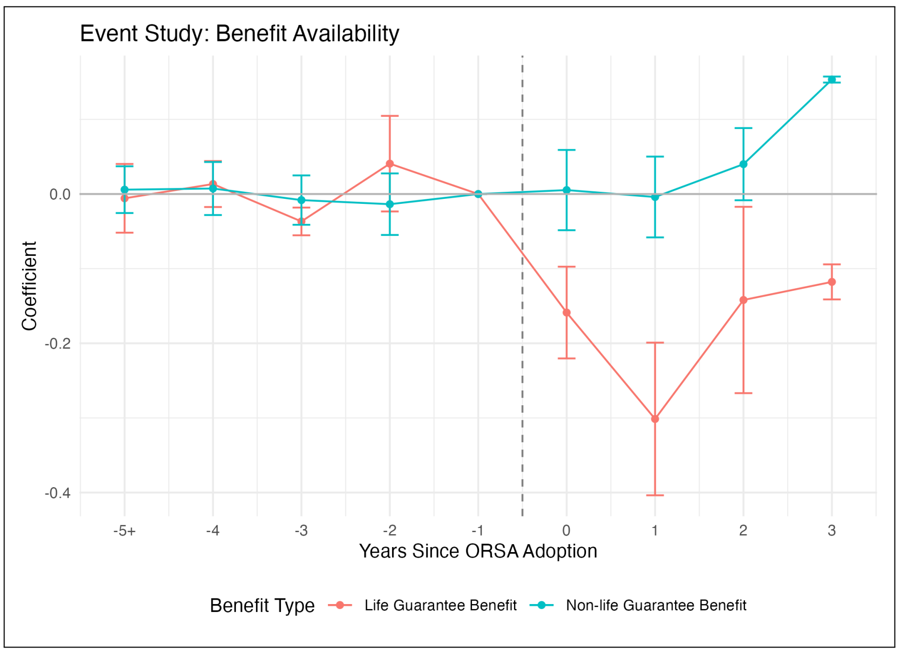


Note: Event-study coefficients are shown for contract types, corresponding to column (1) of Table 2. 90% confidence intervals are shown with standard errors clustered at the lead state x annuity type level.

Figure 3 provides dynamic evidence supporting a causal interpretation of these contract-level shifts. The event study estimates show no differential pre-trends in the five years preceding ORSA adoption, with pre-treatment coefficients centered near zero and statistically indistinguishable from the reference period (t-1). Following adoption, TVA offerings decline sharply and persistently, while RILA offerings increase in a mirror pattern. The temporal alignment of these effects with ORSA implementation, combined with flat pre-trends, strengthens the inference that regulatory mandates drove portfolio restructuring rather than pre-existing firm trajectories.

Beyond these annuity-type (contract-level) decisions, we also want to investigate what happens within the TVA product line to study whether insurers start offering less of the TVAs with onerous guarantees and offer more of the TVAs with less generous guarantees. To do so, we run a specification shown in column (2) of Table 2 that examines benefit-level adjustments within the TVA products that insurers continue to offer. The coefficient on Life Guarantee benefits is -0.200, statistically significant at the 1% level. This estimate implies that ORSA adoption reduces the probability of offering life guarantee riders by 20.0 percentage points, a decline of 58% relative to the pre-ORSA baseline of 34.3%. In contrast, the coefficient on Non-life Guarantee benefits is small (2.1 percentage points) and statistically insignificant, suggesting that simpler riders like GMDBs and GMABs remain largely unaffected. This differential response indicates that insurers respond to enterprise risk management mandates by selectively removing the most complex and tail-risk-sensitive guarantees while preserving features with more tractable risk profiles. The specification has contract fixed effects, absorbing any contract-specific characteristic that may affect the decision outside of ORSA, and also guarantee type $\times$ year-quarter fixed effects.

Figure 4: Event Study Estimates: Benefit Type

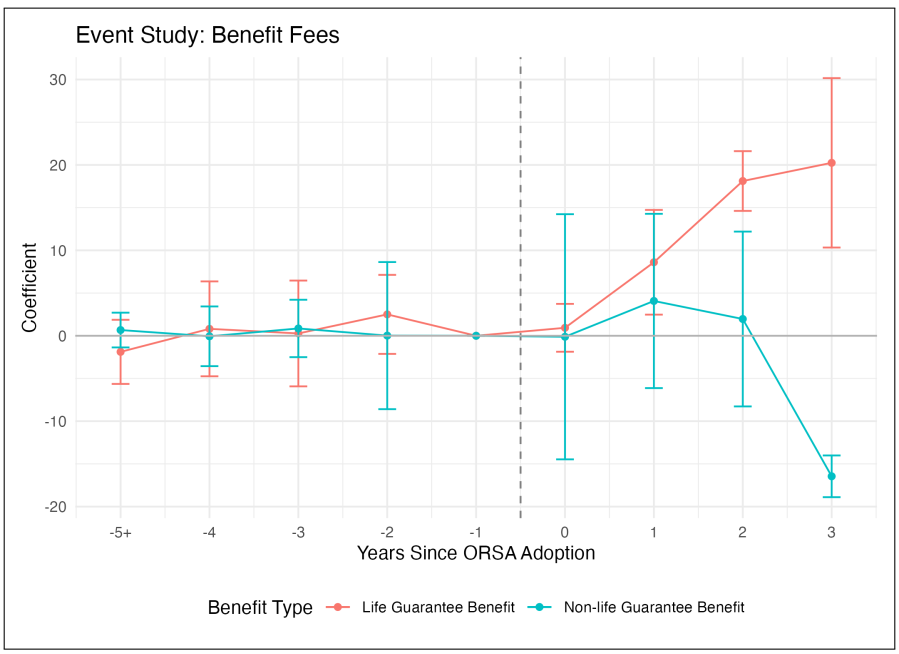


Note: Event-study coefficients are shown for benefit types, corresponding to column (2) of Table 2. 90% confidence intervals are shown with standard errors clustered at the lead state x guarantee type level.

Figure 4 reinforces these findings with event study evidence. Life guarantee TVA offerings exhibit flat pre-trends followed by a sharp, sustained decline beginning at adoption. The absence of differential pre-treatment dynamics supports the parallel trends assumption and suggests that the observed benefit removals reflect regulatory responses rather than secular trends. The event study pattern for non-life guarantees remains relatively flat throughout, consistent with the small and insignificant DiD coefficient.

Finally we investigate the impact on fees charged by the insurers for the TVA offerings. Column (3) examines pricing adjustments on benefits that remain actively offered following ORSA adoption. The coefficient on Life Guarantee fees is 8.437 basis points, statistically significant at the 1% level. Relative to the pre-ORSA baseline of 120.2 basis points, this represents a 7.0% fee increase on the riskiest riders that insurers choose to retain. This intensive-margin adjustment complements the extensive-margin removals documented in column (2), suggesting that insurers employ both quantity (removing products) and price (raising fees) mechanisms to manage tail risk. The coefficient on Non-life Guarantee fees is small (1.029 basis points) and statistically insignificant, indicating that fee adjustments concentrate on the products with the most substantial guarantee obligations. The specification has contract fixed effects, absorbing any contract-specific characteristic that may affect the decision outside of ORSA, and also guarantee type $\times$ year-quarter fixed effects.

Figure 5: Event Study Estimates: Fees



Note: Event-study coefficients are shown for fees, corresponding to column (3) of Table 2. 90% confidence intervals are shown with standard errors clustered at the lead state x guarantee type level.

Figure 5 provides temporal evidence on TVA offerings fee dynamics. Life guarantee fees exhibit no differential pre-trends but increase sharply following ORSA adoption, with effects that persist and potentially grow over subsequent years. This pattern suggests that fee adjustments respond to regulatory implementation rather than anticipatory pricing changes. Non-life guarantee fees remain relatively flat throughout the event window, consistent with the insignificant DiD estimate.

Collectively, these reduced-form results demonstrate that ORSA induces systematic product redesign across multiple margins. At the portfolio level, insurers substitute from TVAs toward RILAs, reallocating capital toward products with natural hedging properties. Within retained TVA product lines, they remove life guarantee riders that expose them to longevity and market risk simultaneously. On the TVA products they continue offering, they raise fees to better align pricing with the economic costs of embedded guarantees. This comprehensive adjustment pattern is consistent with the hypothesis that ORSA impacts the organizational risk management of insurers: this enterprise risk management mandate leads to a change of insurers' product lines consistent with our maintained hypothesis that insurers start internalizing cross-product risk dependencies rather than evaluating each product line in isolation. By forcing a holistic assessment of solvency risk, ORSA appears to reveal cost complementarities and hedging opportunities that insurers previously overlooked under siloed risk management frameworks.

It is worth noting that demand-based explanations for these three findings—i.e., that consumer preferences rather than ORSA drove the outcomes—are highly implausible. For such an explanation to hold, one would need to argue that consumer preferences for specific annuity features shifted exactly at the time of ORSA adoption, and only in the states where insurers happened to be domiciled. This scenario is unlikely, given that insurers operate nationally and face largely uniform demand conditions across markets (Wenning, 2024).

The next subsection examines heterogeneity in these treatment effects to further probe the mechanisms underlying these responses.

4.2 Heterogeneity Analysis

To better understand which firms respond most strongly to ORSA mandates, we examine heterogeneous treatment effects across two dimensions that capture firms' pre-existing risk management sophistication and regulatory arbitrage behavior. Tables 3 and 4 present interaction effects for contract hazard, benefit hazard, and fee outcomes, along the same specifications shown in Table 2 but with the difference that we additionally investigate the differential effect of ORSA on insurers that had high risk management capabilities in the pre-ORSA period. These heterogeneity analyses shed light on the mechanisms through which ORSA influences product design and pricing decisions.

4.2.1 ERM Rating Heterogeneity

Table 3: Heterogeneous Treatment Effects by ERM Rating

	Contract Hazard	Benefits Hazard	Fees (bps)
ORSA × Traditional Variable Annuity	-0.389^{***}		
	(0.036)		
ORSA × Traditional Variable Annuity × Strong ERM	0.123^{**}		
	(0.052)		
ORSA × Fixed Annuity	0.035		
	(0.086)		
ORSA × Fixed Annuity × Strong ERM	0.103		
	(0.131)		
ORSA × Index-Linked Annuity	0.191^{***}		
	(0.023)		
ORSA × Index-Linked Annuity × Strong ERM	-0.065^{**}		
	(0.032)		
ORSA × Life Guarantee		-0.210^{***}	8.163^{***}
		(0.021)	(3.094)
ORSA × Life Guarantee × Strong ERM		0.030	0.643
		(0.020)	(3.533)
ORSA × Non-life Guarantee		0.001	-8.380^{*}
		(0.044)	(4.650)
ORSA × Non-life Guarantee × Strong ERM		0.092^{*}	26.826^{***}
		(0.048)	(7.926)
Firm FE	Yes		
Annuity Type × Year × Quarter FE	Yes		
Contract FE		Yes	Yes
Guarantee Type × Year × Quarter FE		Yes	Yes
Observations	173,744	947,900	178,436
Firms	120	100	84

Notes: This table reports cross-sectional differences in ORSA treatment effects on annuity product offerings, benefit availability, and pricing. The heterogeneity is based on insurers' pre-ORSA voluntary ERM strength (2012). The contract hazard model reports coefficients for all annuity types (TVA, fixed, and Index-Linked annuities). The benefit hazard and fee models (in basis points) are estimated within TVA contracts for both lifetime and non-lifetime guaranteed benefits. Standard errors are clustered at the lead state x annuity type level for Column (1) and the lead state x guarantee type level for Columns (2) and (3). * $p<0.1$, ** $p<0.05$, and *** $p<0.01$.

We first examine whether firms with stronger pre-ORSA risk management systems respond differently to the regulatory mandate. Insurers that already maintained strong risk-management frameworks were more likely to implement an ERM system following their decision. If their existing ERM practices had already met the stringent ORSA requirements, we would expect ORSA adoption to produce only a modest effect—or none at all.

Table 3 interacts ORSA treatment with an indicator for high ERM rating (measures as "strong" or better on S&P's 5-point scale, measured in 2012 thus before the beginning of the ORSA adoption). We find that the baseline treatment effects demonstrate that insurers with weaker ERM ratings (a) reduce TVA contract offerings by 39 percentage points while raising the RILAs offerings by 19 percentage points (column (1)), (b) reduce life guarantee benefit offerings within the TVA product line by 21.0 percentage points (column (2)), and (c) raise fees on remaining life guarantees by 8.16 basis points. All three baseline effects are statistically significant at the 1% level.

Interestingly, the interaction coefficients reveal modest differential responses for firms with high ERM ratings. Starting from column (1) we observe the coefficient of the interaction variable as 0.123, statistically significant at the 5% level, indicating that high-ERM firms reduce TVA offerings by 12.3 percentage points less than low-ERM firms. This yields a total effect of $-0.389 + 0.123 = -0.267$ for high-ERM firms, representing around a one-third smaller reduction in TVA contracts relative to low-ERM firms. We find the opposite effect in the case of RILAs: we observe the coefficient of the interaction variable as -0.065, statistically significant at the 5% level, indicating that high-ERM firms increase RILAs offerings by 6.5 percentage points less than low-ERM firms. This yields a total effect of $0.191 - 0.065 = -0.126$ for high-ERM firms, again representing around a one-third smaller increase in RILAs contracts relative to low-ERM firms.

In column (2) we present the specification for the benefit hazard within the TVA product line. We find the coefficient of the interaction variable to be 0.030 but statistically insignificant, suggesting that high-ERM firms do not significantly differ in their propensity to remove life guarantee benefits relative to low-ERM firms. In column (3) we present the results for the fees specification. We find that the coefficient of the interaction term for the life guarantee products to be small and statistically insignificant (0.643 basis points), whereas that for the non-life guarantee products to be large (26.83, and statistically significant) undoing the decrease that we find for the firms with low-ERM scores (a coefficient of -8.38 and statistically significant at the 10% level).

These patterns suggest that firms with sophisticated pre-ORSA risk management capabilities maintain more of their TVA contract offerings following ORSA adoption, though they still reduce offerings substantially. One interpretation is that strong ERM systems position firms to better navigate ORSA's integrated risk assessment requirements, allowing them to sustain complex product lines through enhanced risk measurement and capital management rather than wholesale product exits. Alternatively, high-ERM firms may have already incorporated enterprise-wide risk considerations into product design, making incremental adjustments less necessary. The lack of heterogeneity in benefit-level decisions suggests that product feature adjustments operate similarly across the ERM distribution, even as contract-level portfolio choices diverge.

4.2.2 Shadow Insurance Heterogeneity

Table 4: Heterogeneous Treatment Effects by Shadow Insurance Use

	Contract Hazard	Benefits Hazard	Fees (bps)
ORSA × Traditional Variable Annuity	-0.401^{***}		
	(0.050)		
ORSA × Traditional Variable Annuity × Shadow Ins.	0.056		
	(0.063)		
ORSA × Fixed Annuity	0.185^{***}		
	(0.053)		
ORSA × Fixed Annuity × Shadow Ins.	-0.134^{*}		
	(0.080)		
ORSA × Index-Linked Annuity	0.168^{***}		
	(0.025)		
ORSA × Index-Linked Annuity × Shadow Ins.	-0.003		
	(0.051)		
ORSA × Life Guarantee		-0.175^{***}	15.624^{***}
		(0.022)	(2.534)
ORSA × Life Guarantee × Shadow Ins.		-0.032	-9.910^{***}
		(0.034)	(3.051)
ORSA × Non-life Guarantee		-0.023	1.539
		(0.055)	(1.828)
ORSA × Non-life Guarantee × Shadow Ins.		0.070	-0.732
		(0.122)	(11.517)
Firm FE	Yes		
Annuity Type × Year × Quarter FE	Yes		
Contract FE		Yes	Yes
Guarantee Type × Year × Quarter FE		Yes	Yes
Observations	167,568	934,224	176,152
Firms	100	86	75

Notes: This table reports cross-sectional differences in ORSA treatment effects on annuity product offerings, benefit availability, and pricing. The heterogeneity is based on insurers' pre-ORSA shadow insurance use (2010). The contract hazard model reports coefficients for all annuity types (TVA, fixed, and Index-Linked annuities). The benefit hazard and fee models (in basis points) are estimated within TVA contracts for both lifetime and non-lifetime guaranteed benefits. Standard errors are clustered at the lead state x annuity type level for Column (1) and the lead state x guarantee type level for Columns (2) and (3). * $p<0.1$, ** $p<0.05$, and *** $p<0.01$.

Table 4 examines heterogeneity by shadow insurance usage, measured as an indicator for firms that employed shadow insurance transactions in 2010. We use shadow insurance as a proxy for the insurer's regulatory arbitrage sophistication and experience managing complex capital structures through affiliated reinsurance arrangements.

The baseline treatment effects for insurers with no shadow insurance (a) reduce TVA contract offerings by 40 percentage points while raising the RILAs offerings by 17 percentage points (column (1)), (b) reduce life guarantee benefit offerings within the TVA product line by 17.5 percentage points (column (2)), and (c) raise fees on remaining life guarantees by 15.62 basis points. All three baseline effects are statistically significant at the 1% level.

Interestingly, the coefficients of the interaction variables to distinguish firms with high sophistication from those with lower sophistication, reveal very limited - if any - differential responses for shadow insurance users across product offering decisions. From the contract hazard specification (column (1)), we find the coefficient of the interaction term to be 0.056, which has no statistical significance. We find a similar effect in the case of RILAs: we observe the coefficient of the interaction variable to be -0.003, also statistically insignificant. These results show that the impact of ORSA adoption on insurers with high sophistication was very similar to , indicating similar TVA contract reductions across shadow insurance status.

For benefit hazard (results shown in column (2)), the interaction is -0.032 and statistically insignificant, suggesting that shadow insurance users do not exhibit significantly different propensities to remove life guarantee benefits. However, the results in column (3) for fees show that the coefficient estimate for the interaction variable is -9.910 basis points and statistically significant at the 1% level, implying that shadow insurance users raise fees by 9.91 basis points less than non-shadow firms. This yields a total fee effect of $15.624 - 9.910 = 5.714$ basis points for shadow insurance users.

The pronounced fee heterogeneity indicates that shadow-insurance users experience smaller fee increases following ORSA adoption. This pattern is consistent with the role of shadow insurance as a form of regulatory arbitrage that provides capital relief through affiliated reinsurance arrangements. Because these firms had already shifted portions of their liabilities off balance sheet before ORSA, their effective capital costs were lower, and the incremental tightening imposed by ORSA was less binding. As a result, shadow-insurance users required smaller price adjustments to meet solvency requirements. In other words, firms that previously engaged in regulatory arbitrage were partially insulated from ORSA's impact on pricing.

These heterogeneity patterns provide insight into how firms' prior risk management practices and regulatory arbitrage strategies shape their adaptation to integrated risk management mandates. Firms with strong ERM ratings demonstrate greater ability to maintain TVA contract offerings, while shadow-insurance users exhibit more muted fee responses, reflecting differing mechanisms for meeting ORSA's enterprise risk standards.

5 Structural Model Set-Up

We analyze consumer welfare around ORSA adoption with a structural model that links firms' pricing, costs, and demand in the variable annuity market. We begin with the supply side, then describe demand and estimation.

5.1 Supply and Cost Structure

Firms choose prices to maximize profits given demand and perceived marginal costs. True marginal costs combine guarantee and rollup components with a natural-hedge term that depends on non-TVA volumes:

$$c_{jt}^{\text{true}} = \beta_{\text{guarantee}} \cdot \text{Guarantee}_{jt} + \beta_{\text{rollup}} \cdot \text{Rollup}_{jt} - \gamma \cdot \log(1 + Q_{ft}^{\text{non-TVA}}) + X_{jt}\gamma_X + \theta_f + \tau_t + \xi_{jt} \quad (9)$$

where Guarantee_{jt} indicates lifetime withdrawal guarantees, Rollup_{jt} is the benefit base rollup rate, $Q_{ft}^{\text{non-TVA}}$ is firm f's non-TVA sales, X_{jt} contains controls, and θ_f, τ_t are firm and year fixed effects. The parameter γ captures portfolio diversification: $\gamma >< 0$ implies cost-reducing natural hedges, and the log term imposes diminishing returns.

Perceived costs blend true components with possible misperceptions via two weights:

$$\begin{aligned} c_{jt}^{\text{perceived}} &= \alpha_i^{(1)} \cdot (\beta_{\text{guarantee}} \cdot \text{Guarantee}_{jt}) \\ &+ \alpha_i^{(2)} \cdot \gamma \cdot \log(1 + Q_{ft}^{\text{non-TVA}}) \\ &+ \beta_{\text{rollup}} \cdot \text{Rollup}_{jt} \\ &+ X_{jt}\gamma_X + \theta_f + \tau_t + \varepsilon_{jt} \end{aligned} \quad (10)$$

with $\alpha_i^{(1)}, \alpha_i^{(2)} \in [0, 1]$ mapping pre-ORSA awareness of guarantee costs and natural-hedge benefits to perceived costs. We parameterize these perceptions as

$$\alpha_i^{(k)} = \begin{cases} \frac{1}{1+\exp(-(\alpha_{\text{base}}^{(k)} + \alpha_{\text{ERM}}^{(k)} \cdot \text{ERM}_i))} & \text{if } t < \text{ORSA}_{ft} \\ 1 & \text{if } t \geq \text{ORSA}_{ft} \end{cases} \quad \text{for } k \in \{1, 2\} \quad (11)$$

so ORSA forces integrated cost recognition with $\alpha_i^{(1)} = \alpha_i^{(2)} = 1$.

Multiproduct firms f then set prices by Bertrand competition:

$$\max_{p_{jt} \in \mathcal{J}_{ft}} \sum_{j \in \mathcal{J}_{ft}} (p_{jt} - c_{jt}(p_{jt})) \cdot s_{jt}(p_t) \cdot M_t \quad (12)$$

with first-order conditions that incorporate hedge feedback:

$$s_{jt} + \sum_{k \in \mathcal{J}_{ft}} (p_{kt} - c_{kt}) \frac{\partial s_{kt}}{\partial p_{jt}} - \sum_{k \in \mathcal{J}_{ft}} \frac{\partial c_{kt}}{\partial p_{jt}} s_{kt} = 0 \tag{13}$$

and, for c_{jt} depending on $\log(1 + Q_{ft}^{\text{non-TVA}})$,

$$\frac{\partial c_{kt}}{\partial p_{jt}} = \alpha_i^{(2)} \cdot \gamma \cdot \frac{1}{1 + Q_{ft}^{\text{non-TVA}}} \cdot \frac{\partial Q_{ft}^{\text{non-TVA}}}{\partial p_{jt}} \quad \text{with} \quad \frac{\partial Q_{ft}^{\text{non-TVA}}}{\partial p_{jt}} \approx M_t \cdot \frac{\partial s_{0t}}{\partial p_{jt}}. \tag{14}$$

Equilibrium prices satisfy the implicit system

$$p_t = c_t(\mathbf{p}_t) + \Omega_t^{-1}(s_t - \mathbf{b}_t), \tag{15}$$

where $\mathbf{b}_t$ has elements $b_{jt} = \sum_{k \in \mathcal{J}_{ft}} \frac{\partial c_{kt}}{\partial p_{jt}} s_{kt}$. In this specification, $\beta_{\text{guarantee}}$ and β_{rollup} capture the marginal costs of guarantees and rollups after removing firm and time effects; γ quantifies how non-TVA portfolios reduce TVA costs through natural hedging; and $(\alpha_{\text{base}}^{(1)}, \alpha_{\text{ERM}}^{(1)}, \alpha_{\text{base}}^{(2)}, \alpha_{\text{ERM}}^{(2)})$ map ERM strength into pre-ORSA perception, with ORSA forcing full integration.

Estimation proceeds by minimizing first-order-condition residuals implied by (13); full details for both demand (BLP) and supply estimation are provided in Appendix C.[21]

5.2 Demand Side

We model consumer demand for variable annuities using a discrete choice framework. Each consumer i in year-quarter t chooses among annuity products j to maximize contemporaneous utility. Throughout, t indexes year-quarter time periods.

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \varepsilon_{ijt} \tag{16}$$

where δ_{jt} is the mean utility from product j in year-quarter t, μ_{ijt} captures individual-specific deviations from mean utility, and ε_{ijt} is an i.i.d. Type I extreme value error term. The mean utility is specified as:

$$\delta_{jt} = \alpha^p p_{jt} + \lambda_{\text{guarantee}} \text{Guaranteed}_{jt} + \lambda_{\text{rollup}} \text{Rollup}_{jt} + \xi_{jt} \tag{17}$$

where p_{jt} is the NPV of future expected fees, Guaranteed_{jt} is an indicator for products with Life Guarantees, Rollup_{jt} is the scaled rollup rate for benefit bases, and ξ_{jt} is an unobserved product characteristic not absorbed by year-quarter fixed effects. We convert fees from basis points to

[21]Standard errors are computed with a state-level block bootstrap using Dirichlet($\mathbf{1}$) weights For each of 100 iterations, we weight all observations within a state, re-estimate the weighted objective, and report the standard deviation across the iterations.

present value dollar amounts to properly account for the fact that VA fees are charged over the entire contract life on growing assets.[22] We allow for heterogeneity in price sensitivity by specifying:

$$\mu_{ijt} = \sigma_p \nu_i p_{jt} \tag{18}$$

where $\nu_i \sim N(0,1)$ represents unobserved consumer heterogeneity.

Our model relies on three primary assumptions. First, price endogeneity is addressed with an instrument set that shifts costs, but is excluded from utility. We adopt the instrument set from Koijen and Yogo (2022) and use the reserve valuation ratio and the reinsurance share, along with their squares. Additionally, we use a within-firm Hausman instrument given by average group-market life insurance prices.

Second, we assume ORSA roll-out is unrelated to consumer demand. This assumption has two parts: (1) we assume that consumers are either unaware of ORSA regulations or, if they are aware, indifferent towards them. This assumption is likely true, since consumers are largely protected from insurer-specific risk through state guarantee funds. We also assume (2) that there is no other event correlated with the ORSA roll-out that also impacted firm demand. This assumption is also likely true, since ORSA was adopted at the lead-state level and, once in force, applied to the insurer's entire enterprise. Because these firms are large and variable annuities are priced and marketed nationally with common menus and prices across states, the staggered lead-state roll-out is unlikely to be correlated with national demand shocks or with unobserved preference shifts that differentially load on Life or Non-Life Guarantees and rollups.

Finally, when examining welfare impacts, we adopt a rational-preferences benchmark: consumers have stable, well-behaved preferences over prices and attributes and choose to maximize the utility specified in equations (16)–(17). If, in practice, consumers make systematic mistakes or misperceive features, our estimated elasticities will still capture revealed substitution patterns and remain identified. However, welfare interpretations that treat the estimated utility as normative would then be incorrect. We estimate the demand parameters $\theta_D = \{\alpha^p, \lambda_{\text{guarantee}}, \lambda_{\text{rollup}}, \sigma_p\}$ using the generalized method of moments (GMM) following Berry et al. (1995). The estimation proceeds through the Berry-Levinsohn-Pakes (BLP) algorithm, which inverts observed shares within each year-quarter to recover mean utilities δ_{jt}, then estimates the linear and nonlinear parameters using instrumental variables. The technical details of the BLP estimation algorithm are provided in Appendix C.

[22] We assume an expected contract duration of 12 years, apply a 3% annual discount rate, and use an expected asset return of 7% per year to reflect that fees are charged on growing assets under management. The calculations are based on a normalized initial investment of \$100,000. This yields: $p_{jt} = \text{Fee Rate}_{jt} \times \$100,000 \times \sum_{t=1}^{12} \frac{(1.07)^t}{(1.03)^t}$.

At the quarter level, expected consumer surplus under logit is

$$CS_t = \frac{1}{|\alpha^p|} \log \left(1 + \sum_{j \in \mathcal{J}_t} \exp(\delta_{jt}) \right) \cdot M_t, \tag{19}$$

which we aggregate to annual averages and, where noted, report separately by guarantee segment.

6 Structural Model Results

Table 5 presents the supply-side results from the natural hedge model estimated via FOC residual minimization. This model captures how firms' perceived marginal costs incorporate both guarantee costs and portfolio-level natural hedge benefits. The specification estimates seven key parameters: $\beta_{\text{guarantee}}$, β_{rollup}, and γ (cost parameters), plus $\alpha^{(1)}_{\text{base}}$, $\alpha^{(1)}_{\text{ERM}}$, $\alpha^{(2)}_{\text{base}}$, and $\alpha^{(2)}_{\text{ERM}}$ (dual perception weights). Standard errors, shown in parentheses, are computed via firm-level block bootstrap with 100 iterations.

We estimate the supply side using an innovative natural hedge model that allows firms to misperceive different cost components with different accuracy. Unlike traditional models with a single perception weight, our specification recognizes that firms may better understand some costs (like explicit guarantee features) while significantly underestimating others (like portfolio-level natural hedge benefits). Firms set prices based on perceived marginal costs that blend their understanding of guarantee costs and natural hedge effects:

$$c^{\text{perceived}}_{jt} = \alpha^{(1)}_{ft} \cdot \beta_{\text{guarantee}} \cdot \text{Guarantee}_{jt} + \alpha^{(2)}_{ft} \cdot \gamma \cdot \log(1 + Q^{\text{non-TVA}}_{ft}) + \beta_{\text{rollup}} \cdot \text{Rollup}_{jt} + \theta_f + \tau_t \tag{20}$$

The dual perception weights $\alpha^{(1)}_{ft}$ and $\alpha^{(2)}_{ft}$ each range from 0 to 1, measuring how accurately firms perceive guarantee costs and natural hedge benefits, respectively. Both map firm ERM capabilities through logistic links: $\alpha^{(k)}_{ft} = \text{expit}(\alpha^{(k)}_{\text{base}} + \alpha^{(k)}_{\text{ERM}} \cdot \text{ERM}_f)$ for $k \in \{1, 2\}$ pre-ORSA, with ORSA implementation forcing both $\alpha^{(1)} = \alpha^{(2)} = 1$.

Table 5 presents the supply-side parameter estimates. The guarantee cost coefficient $\beta_{\text{guarantee}} = 0.0055$ is positive and statistically significant, confirming that guarantee features increase marginal costs. The rollup rate coefficient $\beta_{\text{rollup}} = 0.0005$ is marginally significant, indicating modest additional costs from step-up provisions. Most notably, the natural hedge parameter $\gamma = -0.0010$ is negative and statistically significant, confirming that larger non-TVA portfolios reduce TVA

Table 5: Natural Hedge Cost Model: Regression Results

	(1) **True Cost Parameters**		**(2)** **Perception Parameters**
log(1 + Non-TVA Sales)	-0.0010***	$\alpha^{(1)}_{base}$	1.9945***
	(0.0002)		(0.0855)
Life Guarantee	0.0055***	$\alpha^{(1)}_{ERM}$	0.6132***
	(0.0001)		(0.2199)
Rollup Rate	0.0005*	$\alpha^{(2)}_{base}$	0.1001***
	(0.0003)		(0.0154)
		$\alpha^{(2)}_{ERM}$	0.4934***
			(0.0179)
Observations	25,825		
R^2	0.4985		
Fixed Effects	Firm, Year-Quarter, Share Class		
Implied Perception Weights (Pre-ORSA):			
Guarantee: Weak ERM	88.0%		
Guarantee: Strong ERM	93.1%		
Natural Hedge: Weak ERM	52.5%		
Natural Hedge: Strong ERM	64.4%		

Notes: This table presents estimation results from the natural hedge cost model. The natural hedge effect (log(1 + Non-TVA Sales)) captures cost reductions from portfolio diversification. Life Guarantee captures the marginal cost of lifetime withdrawal benefits (GMWB/GLWB). Rollup Rate is the annual percentage increase in the benefit base. $\alpha^{(1)}$ parameters govern perception of guarantee costs, while $\alpha^{(2)}$ parameters govern perception of natural hedge benefits. Pre-ORSA perception weights vary by ERM strength (Weak = ERM rating ≤ 2, and Strong = ERM rating ≥ 3). Post-ORSA, both perception weights equal 1.0 (100%) for all firms. Standard errors in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, and $^{***}p < 0.01$. Estimation uses the first-order condition residual minimization with firm and year-quarter fixed effects. Sample: 2008Q1–2016Q4.

marginal costs through portfolio diversification. The economic magnitude indicates a 0.1% cost reduction per unit increase in $\log(1 + Q^{\text{non-TVA}})$, consistent with risk-offsetting benefits from product diversification.

The perception parameters reveal a striking asymmetry in how firms understand their cost structure pre-ORSA. For guarantee costs, firms with weak/adequate ERM ratings (2010) achieved $\alpha^{(1)} = 0.8802$ (88% accuracy), while firms with strong or better ERM achieved $\alpha^{(1)} = 0.9314$ (93% accuracy). In contrast, perception of natural hedge benefits was substantially worse: weak ERM firms had $\alpha^{(2)} = 0.5250$ (only 53% accuracy), while even strong ERM firms achieved just $\alpha^{(2)} = 0.6442$ (64% accuracy).

This differential misperception has important economic implications. Firms relatively accurately priced explicit guarantee costs—features directly visible in product design and actuarial models. However, they substantially underestimated natural hedge benefits arising from portfolio interactions between TVA and non-TVA products. This suggests that organizational silos prevented firms from recognizing cross-product cost interdependencies, even when their ERM frameworks adequately captured product-specific risks.

ORSA's requirement for integrated risk assessment forced both perception weights to unity ($\alpha^{(1)} = \alpha^{(2)} = 1$) for all firms, regardless of pre-ORSA ERM strength. This represents a discrete jump in cost perception, particularly dramatic for natural hedge awareness. Weak ERM firms' understanding of natural hedge benefits increased from 53% to 100%—a near-doubling of accuracy. Even strong ERM firms experienced a 36 percentage point increase (from 64% to 100%).

The welfare implications of this correction are complex. By forcing firms to recognize natural hedge benefits they previously ignored, ORSA should theoretically reduce perceived costs and encourage TVA product offerings with guaranteed benefits. However, this perception correction occurred simultaneously with other ORSA effects documented in our reduced-form analyses: compliance costs, increased capital requirements, and heightened regulatory scrutiny. The net effect—combining improved perception of cost-reducing natural hedges with increased regulatory burdens—determines the overall market impact.

Table 6: BLP Demand Estimation Results

	Coefficient	Heterogeneity
Demand-Side Parameters		
Price	-13.191***	2.542***
	(4.667)	(0.824)
Rollup Rate	7.635***	
	(2.705)	
Guaranteed	2.490***	
	(0.655)	
Observations	25,825	
Firm FEs:	Yes	
Year-Quarter FEs:	Yes	

Notes: Table reports BLP demand estimation results with firm and time (year × quarter) fixed effects. Reported values are coefficients with standard errors in parentheses. A random coefficient is estimated for price only, and its standard deviation is shown in the heterogeneity column. Standard errors are computed using robust two-step GMM. *** p < 0.01, ** p < 0.05, and * p < 0.10.

Table 6 reports the demand-side results. The price coefficient of -13.191 is negative and economically meaningful, indicating substantial fee sensitivity. The heterogeneity parameter of 2.542 captures meaningful dispersion in price sensitivity across households. Rollup (7.635) and guaranteed features (2.490) load positively, consistent with consumers valuing step-ups and formal protection. Overall, consistent with our model, we find that demand is very sensitive to prices, indicating consumers do not blindly purchase TVAs. The positive coefficients on guarantees and rollups suggest consumers value downside protection, which aligns with standard risk aversion.

Figure 6 summarizes how the structural model links ORSA adoption to changes in market structure and consumer welfare. As ORSA adoption rises in the model, TVA and non-TVA sales and the associated consumer surplus paths adjust to the cost and perception mechanisms documented in Tables 5 and 6.

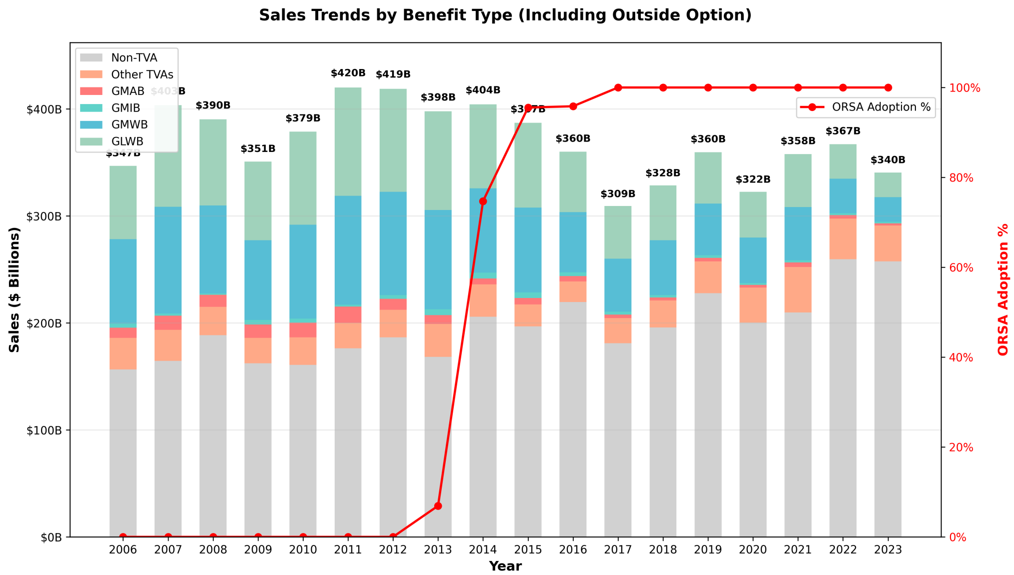
Figure 6 presents a comprehensive overview of how market structure and consumer welfare evolve in the model as ORSA adoption rises. Panel (a) highlights dramatic shifts in the composition of annuity sales across product types. Non-TVA products expand from roughly \$160 billion to about \$260 billion in annual sales, while TVA sales contract from approximately \$160 billion to around \$50 billion. Within the TVA segment, sales of contracts without embedded guarantees remain comparatively stable, whereas guaranteed TVAs—especially GLWBs and GMWBs—experience sharp declines as ORSA adoption accelerates.

These quantity responses are consistent with the incentives implied by the natural hedge cost estimates. Guarantees are genuinely costly, so the direct guarantee channel pushes TVA prices up as firms more fully account for guarantee risk under ORSA. At the same time, the interaction between TVA guarantees and non-TVA portfolios gives firms an additional motive to tilt their product mix toward non-TVAs that hedge guarantee exposures. In equilibrium, keeping TVA prices high both covers guarantee costs and nudges marginal consumers toward non-TVA products, so the natural-hedge channel also works in the direction of higher TVA prices and a shift away from guaranteed TVAs.

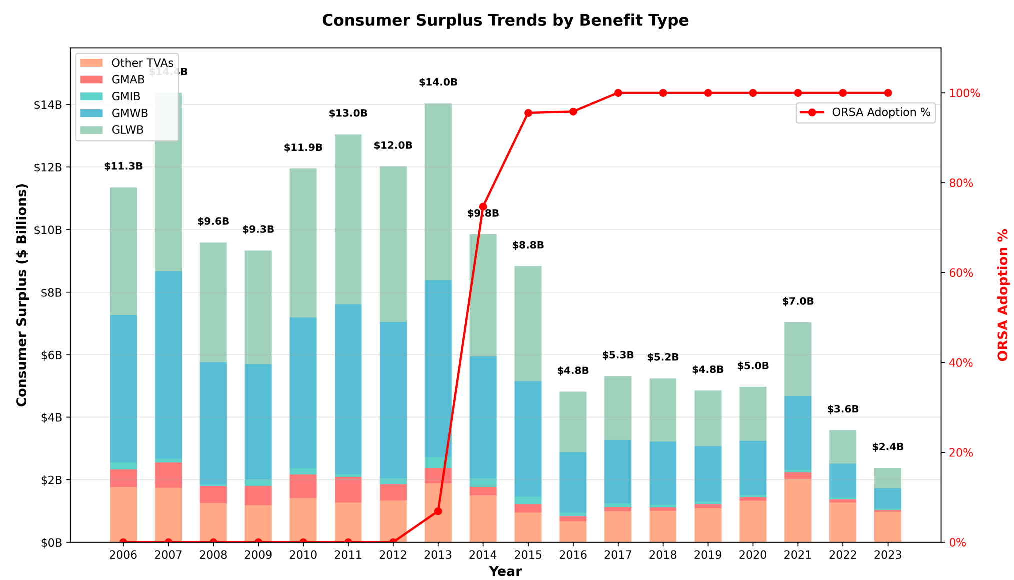
Panel (b) shows how these market structure changes translate into consumer welfare. Consumer surplus peaks around \$13–14 billion in the early 2010s, then declines to roughly \$2.4 billion by the end of the sample, with the largest losses concentrated in GLWB and GMWB products. During the period when ORSA adoption rises from about 20% to over 90% of industry sales, aggregate consumer surplus remains mostly below \$5 billion per year, mirroring the contraction in TVA sales. Even several years after ORSA adoption stabilizes near full coverage, annual consumer surplus remains around \$4–5 billion—well below pre-ORSA peaks—indicating that the combination of high guarantee costs and the natural-hedge-driven shift toward non-TVA products produces a persistent reduction in welfare relative to the pre-ORSA equilibrium.

Figure 6: Market Trends and Consumer Welfare Effects During ORSA Adoption Period

(a) Variable Annuity Sales by Benefit Type: ORSA-Induced Market Structure Changes



(b) Consumer Surplus by Benefit Type: Causal Effects of ORSA Implementation



7 Conclusions

This paper examines how ORSA requirements affect insurance companies' annuity product offerings and consumer welfare. Exploiting the staggered adoption of ORSA across U.S. states from 2013 to 2017, we find that risk management mandates reshape product markets through the correction of firms' cost misperceptions, with substantial welfare consequences. Our analysis documents sharp changes in product offerings following ORSA adoption: the probability of offering traditional variable annuities declines by 36.3 percentage points, and, within those, lifetime guarantee riders fall by 20 percentage points, with the most complex guarantees experiencing the largest reductions, while index-linked annuities increase by 18 percentage points. These effects vary systematically with firms' pre-ORSA ERM capabilities, with weak ERM firms reducing TVA offerings more significantly than strong ERM firms. Welfare losses and substitution toward RILAs are consistent with our structural estimates indicating that non-TVA activity reduces TVA marginal costs through natural hedging.

Our structural estimates reveal that pre-ORSA, firms substantially under-recognized portfolio-level natural-hedge benefits ($\approx$53% accuracy in weak-ERM firms versus $\approx$64% in strong-ERM), while recognizing guarantee costs at $\approx$88–93%. This implies that pre-ORSA, firms recognized these drivers at approximately 53–93% relative to their recognition post-ORSA. In our model, ORSA forces all firms to fully internalize the modeled cost components, eliminating these pricing distortions; our model does not separately estimate a post-ORSA compliance-cost shifter; price increases arise from corrected cost perception and natural-hedge interactions, absorbed alongside fixed effects.

The welfare implications are substantial and negative for consumers. Consumer surplus peaks around \$13–14B and falls to $\approx$\$2.4–5B post-ORSA, implying losses on the order of \$7–11B per year under our logit welfare measure. This welfare loss reflects a fundamental tension: while the regulation successfully corrects firms' cost misperceptions and improves risk management, the resulting price increases more than offset any benefits consumers receive from better-priced products. The substantial reduction in guaranteed annuity offerings suggests meaningfully reduced systemic risk, achieving ORSA's macroprudential objectives. However, this stability comes at substantial cost to retirement savers who relied on guaranteed annuities for retirement security, transferring investment risk back to consumers at precisely the life-cycle stage when they are least equipped to bear it.

This paper contributes to the literature on financial regulation by providing the first comprehensive analysis of risk management mandates' effects on product markets. While prior work examines regulations targeting capital requirements or disclosure, we show how internal risk management mandates reshape firm behavior through the correction of cost misperceptions. Our structural framework provides a tractable method for quantifying these misperceptions and evaluating whether regulatory corrections improve outcomes. The heterogeneous effects by firm ERM strength suggest opportunities for more targeted regulatory design, imposing lighter compliance burdens on sophisticated firms while focusing intensive oversight on those with weaker risk management. As policymakers worldwide strengthen financial regulation in response to systemic risk concerns, the challenge lies in designing regulations that achieve an appropriate balance between stability and consumer welfare. Future research should examine ORSA's long-run effects as the regulation matures and explore tiered regulatory structures that preserve stability benefits while minimizing compliance costs.

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Appendix A Detailed Annuity Benefit Descriptions

This appendix provides comprehensive descriptions of the various guaranteed benefit types commonly offered within variable annuity contracts. These benefits are central to understanding how insurers manage risk across different product lines and how regulatory changes affect product offerings.

Appendix A.1 Contract Phases and Risk Protection

To understand the purpose of these benefits, it is helpful to consider the three phases of a variable annuity contract:

1. **Accumulation phase** (pre-retirement): The period when the policyholder contributes funds and the contract value grows based on underlying investment performance.
2. **Annuitization phase**: The point at which the policyholder converts the accumulated value into a stream of income payments.
3. **Post-retirement phase** (retirement/withdrawal period): The period when the policyholder receives income from the contract, either through systematic withdrawals or annuitized payments.

Different guaranteed benefits protect against different risks across these phases, creating varying degrees of risk exposure for insurers.

Appendix A.2 Guaranteed Benefit Types

The following guaranteed benefits are commonly offered within traditional variable annuity (TVA) contracts:

Appendix A.2.1 Guaranteed Minimum Death Benefit (GMDB)

The GMDB provides a minimum benefit to a beneficiary upon the policyholder's death before retirement or annuitization. While it introduces some market risk during the accumulation phase, it is typically triggered only at death, so its risk exposure can be lower compared to lifetime guarantees like GLWB or GMIB. This benefit essentially ensures that beneficiaries receive at least a specified minimum amount regardless of market performance, protecting against the scenario where account values have declined due to poor investment returns.

Appendix A.2.2 Guaranteed Minimum Accumulation Benefit (GMAB)

The GMAB protects the policyholder during the accumulation phase by ensuring that the contract's account value will not fall below a specified amount at the end of a set holding period. Since it provides a floor on the contract value, it exposes the insurer to market risk if the underlying investments perform poorly. This benefit is particularly valuable during extended market downturns, as it guarantees that the policyholder will have a minimum accumulation value regardless of interim market volatility. The insurer bears the risk that market performance may require substantial payments to honor the guarantee at maturity.

Appendix A.2.3 Guaranteed Minimum Income Benefit (GMIB)

The GMIB protects the policyholder at the annuitization phase by allowing them to annuitize at a guaranteed rate, effectively locking in a minimum lifetime income that extends into the post-retirement phase. Because it combines longevity risk with market risk, GMIB can be more complex and costly for insurers to hedge. The benefit ensures that even if the account value has decreased substantially, the policyholder can still convert their contract into a lifetime income stream based on a predetermined formula, often referencing the highest historical account value or a guaranteed growth rate.

Appendix A.2.4 Guaranteed Minimum Withdrawal Benefit (GMWB)

The GMWB protects the policyholder during the post-retirement phase by guaranteeing a minimum level of withdrawals over a defined period, regardless of market fluctuations. The insurer bears the risk that the underlying account value may deplete faster than expected, particularly during market downturns. This benefit allows policyholders to withdraw a specified percentage of their benefit base annually without penalty, even if the account value falls to zero. The guarantee typically continues until the total guaranteed withdrawals have been made, providing income certainty over a fixed period.

Appendix A.2.5 Guaranteed Lifetime Withdrawal Benefit (GLWB)

The GLWB provides lifetime protection during the post-retirement phase by extending GMWB to a lifetime horizon, thereby adding significant longevity risk on top of equity market risk. As a result, GLWB is often considered one of the most challenging guarantee types to hedge cost-effectively. This benefit combines the withdrawal flexibility of GMWB with lifetime income protection, ensuring that policyholders can continue to receive guaranteed withdrawals for as long as they live, regardless of account performance or longevity. The open-ended nature of this commitment makes it particularly expensive and risky for insurers.

Appendix A.3 Risk Implications for Insurers

Among these benefits, the living benefits that continue throughout the policyholder's lifetime (notably GMIB and GLWB) tend to be the most complex and risky for insurers, since they must account for both uncertain market returns and uncertain lifespans. By contrast, GMDBs, although still risky, generally have more predictable triggers and shorter time horizons.

Although, in theory, insurers could hedge this risk through derivatives or reinsurance, practical and regulatory barriers often render such hedging strategies costly or incomplete. In the wake of the Great Financial Crisis and the COVID-19 Pandemic, many insurers faced severe financial distress on their TVA exposures, leading to higher prices, renegotiation of contract terms, and even exits from the market (Koijen and Yogo, 2022; Barbu, 2023).

Appendix A.4 Classification for Analysis

In our analysis, we focus on the "lifetime" benefits (as they are colloquially called in the industry) of GMWB and GLWB and treat the remaining benefits as "non-lifetime" benefits. This classification reflects the fundamental difference in risk exposure between benefits that provide protection for a fixed period versus those that continue for the policyholder's entire lifetime. Our results are robust to also treating GMAB and GMIB as "lifetime" benefits, though the magnitudes weaken somewhat, reflecting the intermediate risk profile of these benefits that combine elements of both accumulation protection and lifetime income features.

Appendix B Definition of Variables

This appendix lists the core variables used across our analyses.

Table B1: Variables used in the analyses

Variable Name	Definition	Source
Total assets	Firm total assets.	NAIC
Policyholder surplus	Policyholder surplus (capital and surplus).	NAIC
RBC ratio	Risk-based capital ratio, calculated as the (adjusted) statutory capital divided by the required risk-based capital.	NAIC
Capital and surplus to assets ratio	Capital plus surplus divided by assets.	NAIC
ERM rating	S&P ERM rating based on five categories—risk management culture, risk controls, emerging risk management, risk models, and strategic risk management—and mapped onto a five-point scale from Weak (1) to Very Strong/Excellent (5). A rating of 3–5 is classified as strong, and otherwise as weak.	S&P Global
Shadow insurance (indicator)	= 1 if the insurer uses affiliated and unauthorized reinsurers without an A.M. Best rating, and 0 otherwise, following Koijen and Yogo (2016).	NAIC
TVA sales	Quarterly sales of traditional variable annuity (TVA) contracts.	Morningstar
Non-TVA sales	Quarterly total sales of non-TVA products, including index-linked annuities and fixed annuities.	NAIC
Annuity product type	Product category for the contract, including TVAs, index-linked annuities, and fixed annuities.	Morningstar
Contract offered (indicator)	= 1 if the annuity contract (TVAs, index-linked annuities, or fixed annuities) is offered in a given year-quarter, and 0 otherwise, based on contract open and close dates.	Morningstar

Variable Name	Definition	Source
Benefit active (indicator)	= 1 if the benefit rider (lifetime vs. non-lifetime guarantees) of a TVA contract is offered in a given year-quarter, and 0 otherwise, based on benefit availability dates.	Morningstar
Benefit fee (current rate)	Current fee rate of a given benefit rider (lifetime vs. non-lifetime guarantees) on a TVA contract, derived from historical Morningstar prospectuses.	Morningstar
Guaranteed (indicator)	= 1 if the annuity product has lifetime guaranteed benefit riders, and 0 otherwise.	Morningstar
Roll-up rate	Annual rate at which an annuity's benefit base increases over time, regardless of investment performance.	Morningstar

Appendix C BLP Estimation Details

The BLP estimation involves three nested loops. In the outer loop, we search over candidate nonlinear parameters σ_p. For each candidate σ_p, the middle loop inverts observed market shares to recover mean utilities δ_{jt} by solving the contraction mapping:

$$\delta_{jt}^{(h+1)} = \delta_{jt}^{(h)} + \log(s_{jt}^{\text{data}}) - \log(s_{jt}(\delta^{(h)}, \sigma_p)) \tag{C1}$$

where $s_{jt}(\delta, \sigma_p)$ are the model-predicted shares computed via Monte Carlo integration over the distribution of consumer heterogeneity ν_i. In the inner loop, we simulate market shares by drawing R realizations of $\nu_i \sim N(0, 1)$ and computing:

$$s_{jt}(\delta, \sigma_p) = \frac{1}{R}\sum_{r=1}^{R} \frac{\exp(\delta_{jt} + \sigma_p \nu_r p_{jt})}{1 + \sum_{k \in \mathcal{J}_t} \exp(\delta_{kt} + \sigma_p \nu_r p_{kt})} \tag{C2}$$

We use quasi-Monte Carlo integration with Halton sequences for ν_r to improve numerical stability and reduce simulation error (Train, 2009). With $R = 500$ draws, the simulation error is negligible relative to sampling uncertainty.

Once mean utilities $\{\delta_{jt}\}$ are recovered for a given σ_p, we estimate the linear parameters $\{\alpha^p, \beta_1, \beta_2\}$ via instrumental variables regression of δ_{jt} on observed product characteristics, using cost-shifters as instruments for endogenous prices. The GMM objective function minimizes the weighted sum of squared moments formed from the interaction of instruments with demand residuals $\xi_{jt} = \delta_{jt} - \alpha^p p_{jt} - \beta_1 \text{Guaranteed}_{jt} - \beta_2 \text{Rollup}_{jt}$.

We optimize the GMM objective using L-BFGS-B with analytical gradients, converging when the change in the objective function falls below 10^{-4}. Standard errors account for simulation error and the two-step nature of the estimation procedure (Berry et al., 1995).