Intertemporal Smoothing and Cross-Sectional Pricing in U.S. Personal Automobile Insurance

A Comparative Case Study of Two Insurers

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Abstract. Allen and Gale (1997) show that a long-lived intermediary can raise welfare above the competitive-market allocation by accumulating reserves and smoothing returns across successive generations, and that this arrangement unwinds once a competitive spot market lets individual agents opt out in the states in which they would gain from doing so. This paper specializes that framework to personal automobile insurance, mapping the risky dividend to the loss-cost realization, the safe-asset reserve to policyholders' surplus, the smoothed consumption path to the smoothed premium rate, the opt-out constraint to a policyholder's option to defect to a competitor that prices to current cost, and the monopoly power that sustains smoothing to a captive-agent franchise. The specialization yields four testable predictions about rate-setting and market structure, distinguishing an intertemporal smoother (a mutual writing through captive agents) from a cross-sectional pricer (a segmented direct writer). Using filing-level rate data, statutory financial statements, and statutory premium records for the two insurers that occupy these roles in the United States market, the paper examines whether the predicted pattern holds. The smoother's pass-through of indicated into filed rate is convex, and the pricer's is concave, a reading that rests on its high-indication filings and is the less settled of the two; the smoother runs an underwriting account that drains in expectation, funded by investment income on its surplus, while the pricer accumulates underwriting gains; and net-of-rate premium migrates toward the pricer where the pricer is established. The single pass-through slope that a linear regression fits to both insurers is the linear summary of two opposite curvatures. The evidence is an event study of the post-pandemic loss-cost event on the two insurers that occupy the polar roles, read as consistent with the mechanism rather than as a general test of it.

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Table of Contents

Abbreviations and Acronyms **iii**

Greek Symbols **iii**

1 Introduction **1**

2 Related Literature **2**

3 Stylized Facts **5**
3.1 The two insurers . . . 5
3.2 Four regularities . . . 6

4 Theoretical Framework **7**
4.1 The Allen and Gale environment and results . . . 7
4.2 Specialization to rate-setting . . . 8
4.3 Players, actions, information, and timing . . . 9
4.4 The intertemporal smoother and convex pass-through . . . 10
4.5 The cross-sectional pricer and concave pass-through . . . 10
4.6 Surplus dynamics and the underwriting-account asymmetry . . . 11
4.7 Disintermediation and quantity migration . . . 12
4.8 Testable predictions . . . 13

5 Data **14**
5.1 Sources . . . 14
5.2 Variable definitions and construction . . . 15
5.3 Sample construction . . . 16
5.4 Descriptive statistics . . . 16

6 Empirical Specification and Identification **17**
6.1 Specification . . . 18
6.2 Identification . . . 18
6.3 Alternative explanations . . . 18

7 Results **19**

7.1 The underwriting-account asymmetry 20
7.2 The event in the underwriting account 22
7.3 Pass-through curvature 24
7.4 Quantity migration 27

8 Discussion **30**

9 Conclusion **31**

A Proofs **32**
A.1 Proof of Proposition 1 32
A.2 Proof of Proposition 2 33
A.3 Propositions 3 and 4 33

B Changepoint and Leverage-Control Methodology **34**

C North Carolina Sensitivity **43**

Bibliography **46**

Abbreviations and Acronyms

Abbreviation	Expansion
BLS	Bureau of Labor Statistics
EIA	Energy Information Administration
FHWA	Federal Highway Administration
i.i.d.	Independent and Identically Distributed
LAE	Loss Adjustment Expense
LOWESS	Locally Weighted Scatterplot Smoothing
NAIC	National Association of Insurance Commissioners
NII	Net Investment Income
NHTSA	National Highway Traffic Safety Administration
OIR	Office of Insurance Regulation (Florida)
PPA	Private Passenger Automobile
SERFF	System for Electronic Rate and Form Filing
UW	Underwriting (net underwriting result)

Greek Symbols

Symbol	Name	Meaning in this paper
Γ	Gamma (GAM-uh)	Pricer's convex cost of building local presence
δ	delta (DEL-tuh)	Secular drift in the loss-cost process; pass-through intercept
ε	epsilon (EP-suh-lon)	Estimation noise in the indicated rate change
η	eta (AY-tuh)	Demand elasticity in the cross-sectional pricer's problem
θ	theta (THAY-tuh)	Low-risk share of the smoother's pooled book
ι	iota (eye-OH-tuh)	Indicated rate change (observed signal of required change)
κ	kappa (KAP-uh)	Weight on the retention margin in the pricer's objective
λ	lambda (LAM-duh)	Rate-level adjustment speed of the smoother (partial-adjustment smoothing parameter), $\lambda \in (0, 1)$
μ	mu (MEW)	Pricer's underwriting margin at the retention-constrained optimum
π	pi (PYE)	Pricer's per-segment margin on a captured low-risk policyholder
ρ	rho (ROH)	Required revenue-rate as a function of indication
σ	sigma (SIG-muh)	Standard deviation (of the persistent component or the noise); with an argument, $\sigma(\cdot)$ is the logistic function in Appendix A
τ	tau (TAW)	Changepoint location (threshold in indication)
ϕ	phi (FYE)	Segmentation effectiveness of the cross-sectional pricer
$\psi(\cdot)$	psi (SYE)	Posterior probability that an indication reflects a persistent shift
ω	omega (oh-MAY-guh)	Expected aggregate per-period endowment in the Allen-Gale economy

1 Introduction

Personal automobile insurance in the United States is regulated by the individual states rather than by the federal government.[1] An insurer that writes the line in a state must be admitted there—licensed by the state's department of insurance—and an admitted carrier is bound by that state's rate regulation. It may not charge a rate until the rate is on file with the regulator: under a prior-approval regime the regulator must approve the rate before it is used, while under a file-and-use or use-and-file regime the rate may take effect on or shortly after filing, subject to later review. A filing rests on an actuarial indication, the rate change the insurer's actuaries calculate its loss and expense experience to require. The insurer files a proposed change, which need not equal the indication, and the regulator grants an approved change, which need not equal the proposal. The indicated, filed, and approved changes are recorded filing by filing and state by state, and that record is where an insurer's pricing conduct becomes observable.

Two of the largest insurers in this market sell a contract that is, across the two, close to identical, and price it on opposite principles. A single regression of the approved rate change on the actuarially indicated rate change assigns the two pass-through slopes near one-half—0.467 and 0.497—so that on a linear reading they price alike. Over 2001 through 2025, however, one insurer accumulated $63.328 billion in net underwriting losses while the other accumulated $52.132 billion in underwriting gains, and the first sustained its surplus not through underwriting but through the investment return on that surplus. Two insurers that appear to price alike reached opposite underwriting outcomes, and the difference is not visible in the slope a linear pass-through regression reports.

This paper asks whether that contrast is the observable signature of two risk-sharing technologies. Allen and Gale show that a long-lived intermediary can raise welfare above a competitive market by holding a reserve and smoothing returns across generations that never meet in a market, and that the arrangement unwinds once a spot market lets the agents who fund it opt out.[2] Specialized to rate-setting, the intermediary is an insurer that absorbs a loss-cost shock into surplus and smooths the rate across successive cohorts of policyholders; the spot market is an insurer that prices each period to current cost. The paper asks whether one insurer's conduct is the intertemporal smoother's and the other's the cross-sectional pricer's, and whether the curvature of the pass-through function, rather than its level, is what separates them.

The paper builds on, and connects, several literatures, set out in Section 2. The Allen-Gale mechanism has been developed in theory and applied to the comparison of national financial systems, but it has not been given a firm-level test; the closest insurance work, on long-term contracts and reclassification risk, concerns smoothing within a single cohort through front-loaded, commitment-based contracts rather than the across-cohort reserve studied here. The first contribution is to specialize the Allen-Gale model to rate-setting and to derive its observable predictions as properties of the insurers' optimal policies, rather than as free-standing assumptions: a convex

[1] McCarran-Ferguson Act, 15 U.S.C. §§ 1011–1015, which reserves the regulation of the business of insurance to the states.

[2] Franklin Allen and Douglas Gale, "Financial Markets, Intermediaries, and Intertemporal Smoothing," *Journal of Political Economy* 105, no. 3 (1997): 523–546.

pass-through for the smoother and a concave pass-through for the pricer. The second contribution is to identify smoothing through the curvature, not the level, of pass-through. Estimated with a control for the heteroskedastic tail of large indications, on the insurers' own filed changes the smoother's local slope rises from about 0.37 to about 0.67 across the indication range while the pricer's falls from about 0.69 to about 0.26, opposite curvatures that a linear reading summarizes in the single near-one-half slope it reports; the pricer's reading rests on its high-indication filings and is the less settled of the two.

The third contribution is to connect the underwriting-cycle and organizational-form literatures to a rate-setting technology by reading the surplus mechanism in the financial accounts. The smoother's surplus rose from $43.691 billion to $169.997 billion across 2001 through 2025 while its underwriting account drained, the rise funded by investment and affiliate income; the pricer's national private passenger automobile market share rose from 7.3 percent in 2004 to 18.60 percent in 2025, converging on the smoother's, as the disintermediation result predicts. The evidence is an event study on the two insurers that occupy the polar roles: the event is the industry-wide loss-cost surge of 2021 through 2023, whose timing the two insurers share, and the differential response within its window is read as conduct. The event fixes the aggregate environment rather than the firm-level shock, since exposure and coverage mixes differ, and the findings are reported as consistent with the mechanism rather than as a general test of it. An earlier industry-wide loss-cost period, 2014 through 2016, appears in the statutory record and is shown for context; no filing-level record is in hand for it, and it is not studied.

Section 2 places the paper in the related literatures. Section 3 states the stylized facts the model must explain. Section 4 specializes the Allen-Gale model, sets out its primitives, and derives the convex-versus-concave pass-through distinction, the surplus-funded underwriting drain, and the quantity migration as Hypotheses 1 through 4. Section 5 describes the data, and Section 6 the empirical specification and the identification, including the alternative explanations the design can and cannot rule out. Section 7 presents the results, Section 8 discusses interpretation and limitations, and Section 9 concludes. Proofs are in Appendix A, the changepoint and leverage-control methodology in Appendix B, and the North Carolina sensitivity in Appendix C.

2 Related Literature

This paper joins several literatures that have not previously been brought together: the theory of intermediated intertemporal smoothing, the empirical study of long-term insurance contracts and reclassification risk, the property-casualty literature on underwriting cycles and capital, the theory of organizational form in insurance, the industrial-organization literatures on customer markets and on pass-through, and the economics of risk classification.

The point of departure is the theory of intertemporal smoothing by long-lived intermediaries.[3] The mechanism extends an older argument that intermediaries provide a form of insurance markets cannot: in Diamond and Dybvig a demand-deposit contract insures privately observed liquidity needs and improves on the exchange market.[4] The Diamond-Dybvig contract shares risk cross-sectionally, across contemporaneous depositors; the Allen-Gale arrangement shares risk intertemporally, across generations that never meet in a market, and rests on the reserve. The welfare basis for intergenerational risk sharing is set out by Gordon and Varian.[5] Allen and Gale apply the smoothing mechanism to the comparison of bank-based and market-based financial systems;[6] the present paper applies it within a single product market to two insurers that occupy the polar roles.

The closest empirical analog is the literature on long-term insurance contracts and reclassification risk. Cochrane proposes time-consistent health insurance that protects the insured against reclassification;[7] Pauly, Kunreuther, and Hirth study guaranteed-renewable contracts that hold the future premium at the rate the healthiest type would pay;[8] and Hendel and Lizzeri show that life-insurance contracts are front-loaded in the way one-sided commitment predicts, locking in a cohort and insuring its reclassification risk.[9] Finkelstein, McGarry, and Sufi document the lapsation that erodes such pools as healthier policyholders leave.[10] That literature concerns smoothing *within* a cohort over the life of one contract, achieved by front-loading under one-sided insurer commitment, with the policyholder free to lapse. The mechanism studied here is distinct: the insurer holds a surplus and charges successive cohorts a smoothed rate, transferring resources *across* cohorts that never share a contract. That is the across-generation reserve mechanism of Allen and Gale, not the within-cohort commitment of the long-term-contract literature, and it requires neither front-loading nor consumer lock-in.

The surplus and underwriting dynamics connect to the property-casualty literature on underwriting cycles, capacity, and capital. Winter and Gron show that costly external capital and a capacity constraint make the supply of coverage depend on the level of surplus, so that prices rise after a depletion of capital;[11] Cummins and Danzon model price as a function of financial quality and

[3] Allen and Gale, "Intertemporal Smoothing," 523–546.

[4] Douglas W. Diamond and Philip H. Dybvig, "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy* 91, no. 3 (1983): 401–419.

[5] Roger H. Gordon and Hal R. Varian, "Intergenerational Risk Sharing," *Journal of Public Economics* 37, no. 2 (1988): 185–202.

[6] Franklin Allen and Douglas Gale, "A Welfare Comparison of Intermediaries and Financial Markets in Germany and the U.S.," *European Economic Review* 39, no. 2 (1995): 179–209; Franklin Allen and Douglas Gale, *Comparing Financial Systems* (Cambridge, MA: MIT Press, 2000).

[7] John H. Cochrane, "Time-Consistent Health Insurance," *Journal of Political Economy* 103, no. 3 (1995): 445–473.

[8] Mark V. Pauly, Howard Kunreuther, and Richard Hirth, "Guaranteed Renewability in Insurance," *Journal of Risk and Uncertainty* 10, no. 2 (1995): 143–156.

[9] Igal Hendel and Alessandro Lizzeri, "The Role of Commitment in Dynamic Contracts: Evidence from Life Insurance," *Quarterly Journal of Economics* 118, no. 1 (2003): 299–327.

[10] Amy Finkelstein, Kathleen McGarry, and Amir Sufi, "Dynamic Inefficiencies in Insurance Markets: Evidence from Long-Term Care Insurance," *American Economic Review* 95, no. 2 (2005): 224–228.

[11] Ralph A. Winter, "The Dynamics of Competitive Insurance Markets," *Journal of Financial Intermediation* 3, no. 4 (1994): 379–415; Anne Gron, "Capacity Constraints and Cycles in Property-Casualty Insurance Markets," *RAND Journal of Economics* 25, no. 1 (1994): 110–127.

capital flows;[12] and Harrington and Danzon study price cutting in soft markets.[13] That literature treats the cycle as a market-wide response to capital shocks. The present paper holds the shock fixed across two insurers in the same market and reads the response as a firm-type choice: the smoother lets surplus absorb the shock, the pricer prices through it.

Why a firm adopts one technology rather than the other connects to the theory of organizational form in insurance. Mayers and Smith develop the managerial-discretion account of the mutual form and study ownership structure across lines of business.[14] The mutual merges owner and customer, which removes the separate shareholder claimant on the underwriting result; it does not by itself align policyholder cohorts that never overlap, since the cohort funding the subsidy and the cohort receiving it hold their residual interests at different dates. The alignment is supplied by the going-concern franchise—the captive distribution and the reserve itself—which gives the current cohort a stake in the arrangement's continuation, whereas the stock form separates owner from customer and pays the underwriting margin out as dividends. This paper connects the organizational form to a rate-setting technology, with the mutual smoothing and the stock direct writer pricing.

That a firm with market power would choose to smooth the price connects to the industrial-organization literature on customer markets and switching costs. Klemperer shows that switching costs let a firm with an installed base sustain prices above the spot level and make market share a strategic asset.[15] The captive-agency franchise is treated here as a switching-cost technology in this sense: exclusivity restricts the agent's carrier menu directly, and it raises the policyholder's cost of defection to the extent that leaving the carrier also severs an agent relationship, bundled service, or accumulated information capital. That link is an assumption of the specialization rather than an established result, and it supplies the market power Allen and Gale require to sustain smoothing against the disintermediation constraint.

The cross-sectional pricer's technology and the pass-through object connect to two further literatures. Risk classification and segmentation are studied by Rothschild and Stiglitz and by Crocker and Snow;[16] the finer an insurer's segmentation, the closer its pricing tracks the current cost of each risk, which is the spot-market role. The incidence of a cost change in price is given a general

[12] J. David Cummins and Patricia M. Danzon, "Price, Financial Quality, and Capital Flows in Insurance Markets," *Journal of Financial Intermediation* 6, no. 1 (1997): 3–38.

[13] Scott E. Harrington and Patricia M. Danzon, "Price Cutting in Liability Insurance Markets," *Journal of Business* 67, no. 4 (1994): 511–538.

[14] David Mayers and Clifford W. Smith Jr., "Contractual Provisions, Organizational Structure, and Conflict Control in Insurance Markets," *Journal of Business* 54, no. 3 (1981): 407–434; David Mayers and Clifford W. Smith Jr., "Ownership Structure across Lines of Property-Casualty Insurance," *Journal of Law and Economics* 31, no. 2 (1988): 351–378.

[15] Paul Klemperer, "Markets with Consumer Switching Costs," *Quarterly Journal of Economics* 102, no. 2 (1987): 375–394.

[16] Michael Rothschild and Joseph Stiglitz, "Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information," *Quarterly Journal of Economics* 90, no. 4 (1976): 629–649; Keith J. Crocker and Arthur Snow, "The Efficiency Effects of Categorical Discrimination in the Insurance Industry," *Journal of Political Economy* 94, no. 2 (1986): 321–344.

treatment by Weyl and Fabinger;[17] this paper uses the curvature of pass-through, rather than its level, to separate the two rate-setting technologies.

Across these literatures the Allen-Gale mechanism has been developed in theory and applied at the level of national financial systems, but it has not been given a direct firm-level test; the long-term-contract literature studies within-cohort smoothing rather than the across-cohort reserve, with the exception of Hombert and Lyonnet, who document intergenerational redistribution through the reserves of French life insurers[18] and whose mechanism is the life-insurance counterpart of the reserve smoothing studied here, applied in this paper to rate-setting rather than savings returns; the underwriting-cycle literature studies the industry aggregate rather than the firm-type contrast; the organizational-form literature accounts for the mutual's existence without connecting it to a smoothing rate technology; and the pass-through literature supplies a tool that has not been used to identify smoothing. This paper joins them by specializing the Allen-Gale model to rate-setting, deriving the convex-versus-concave pass-through distinction and the surplus-funded underwriting drain as corollaries, and testing them on two insurers that occupy the polar types, with the curvature of pass-through serving as the rate-setting signature of intertemporal smoothing.

3 Stylized Facts

This section introduces the two insurers and states four regularities that motivate the model. The regularities are descriptive; the formal tests, with the changepoint estimate and the leverage control, are in Section 7.

3.1 The two insurers

The two insurers stand, in their ownership and distribution, at the opposite ends of the intermediary-versus-market distinction the model formalizes, and that institutional contrast is what assigns them their roles.

State Farm Mutual Automobile Insurance Company was organized in 1922 in Bloomington, Illinois, by George J. Mecherle to write automobile insurance for rural drivers, and it has been the largest personal automobile insurer in the United States since 1942.[19] It is a mutual: owned by its policyholders and carrying no outside equity, it retains its surplus to strengthen capital or returns it to policyholders, and it sells through exclusive, or captive, agents who carry only its products. The absence of a residual shareholder claim on the underwriting account, together with the captive

[17] E. Glen Weyl and Michal Fabinger, "Pass-Through as an Economic Tool: Principles of Incidence under Imperfect Competition," *Journal of Political Economy* 121, no. 3 (2013): 528–583.

[18] Johan Hombert and Victor Lyonnet, "Can Risk Be Shared across Investor Cohorts? Evidence from a Popular Savings Product," *Review of Financial Studies* 35, no. 12 (2022): 5387–5437.

[19] State Farm's mutual form and exclusive-agent distribution are recorded in State Farm Mutual Automobile Insurance Company, *Annual Statement for the Year Ended December 31, 2024*, statutory filing (Bloomington, IL: National Association of Insurance Commissioners, 2025); the market positions are from the data underlying Figure 5.

franchise, lets the insurer hold a large surplus and keep the rate path steady across cohorts; it is the institutional counterpart of the intertemporal smoother.

The Progressive Corporation was organized in 1937 in Cleveland, Ohio, by Joseph M. Lewis and Jack Green, incorporated as a holding company in 1965, and has traded publicly since 1971.[20] It is a stock insurer (New York Stock Exchange: PGR) that built its business on the underwriting of nonstandard risks and on risk segmentation—later extended to usage-based, telematic pricing—and that distributes through both independent agents and a direct channel. Its national personal automobile share rose over the sample toward the smoother's, the trajectory shown for the pricer in Figure 5. The residual shareholder claim on the underwriting account and the segmentation technology lead it to price each risk near its own current cost and to distribute the underwriting result rather than retain it as a smoothing surplus; it is the institutional counterpart of the cross-sectional pricer.

The correspondence in Table 1 rests on these facts: mutual ownership and captive distribution on the one side, shareholder ownership and segmented pricing on the other, place the two insurers at the smoother and pricer poles of the Allen and Gale economy.

3.2 Four regularities

First, both insurers file approved rate changes below the actuarial indication, and a single-slope regression of the approved change on the indicated change returns slopes near one-half: 0.467 for the smoother and 0.497 for the pricer. On this linear reading the two insurers price alike, distinguished at most by level.

Second, the two insurers' financial accounts diverge over the same period. From 2001 through 2025 the smoother recorded a net underwriting loss in 19 of 25 years, a cumulative net underwriting loss of $63.328 billion, and a mean combined ratio of 106.65, while its surplus rose from $43.691 billion to $169.997 billion; the pricer recorded no underwriting-loss year, a cumulative underwriting gain of $52.132 billion, and a mean combined ratio of 92.04. Two insurers with pass-through slopes near one-half thus reached opposite underwriting outcomes.

Third, the divergence holds within the 2021 through 2023 loss-cost event, in which the smoother's combined ratio moved from 110.30 to 127.56 to 115.90 while the pricer's held near 95; the earlier loss-cost period of 2014 through 2016, in which the smoother's combined ratio rose from 107.71 to 117.62 while the pricer's stayed below 100, shows the same direction and is not studied further.

Fourth, the pricer's national private passenger automobile market share rose from 7.3 percent in 2004 to 18.60 percent in 2025, converging on the smoother's.

A single pass-through parameter leaves the first fact and the second unreconciled. The model of Section 4 offers one reconciliation, near-equal slopes that summarize different underlying functions; differences in intercepts, initial rate adequacy, indication distributions, or expense structures could in principle also separate the outcomes, and the curvature evidence of Section 7 is what

[20] The Progressive Corporation, *Annual Report on Form 10-K for the Fiscal Year Ended December 31, 2024* (Mayfield Village, OH: The Progressive Corporation, 2025).

selects the first. The model in Section 4 produces pass-through functions that share an average slope but differ in curvature, together with the asymmetric surplus dynamics and the quantity migration of the remaining facts.

4 Theoretical Framework

This section restates the Allen and Gale results the paper relies on, specializes the environment to rate-setting, derives the smoother's convex and the pricer's concave pass-through together with the surplus dynamics and the migration each implies, and closes with the testable predictions.

4.1 The Allen and Gale environment and results

Allen and Gale study an infinite-horizon overlapping-generations economy. A new generation, treated as a representative agent, is born at each date $t = 1, 2, \ldots$ and lives two periods, with an endowment e when young and none when old. There are two assets: a safe asset, a storage technology that converts one unit of the good at t into one unit at $t+1$, and a risky asset in unit supply that pays an i.i.d. nonnegative dividend y_t with positive, finite expectation and variance. Preferences are additively separable and strictly concave, $U(c_1, c_2) = u(c_1) + v(c_2)$. The only exogenous uncertainty is the dividend process $\{y_t\}$.

In the market equilibrium, each generation bears the dividend risk of the period in which it is old, and the safe asset is not held: at the constant equilibrium price of the risky asset, its nonnegative dividend dominates the storage return.[21] An intermediary can do better. By accumulating reserves s_t of the safe asset—building them when the dividend is high and drawing them down when it is low—the intermediary can pay successive generations a smoothed return. Writing ω for the expected aggregate endowment, $\mathbb{E}[e + y_t]$, and $U(\omega)$ for the utility of the smoothed allocation that divides ω between the two generations optimally (equally, at $\omega/2$ each, in their logarithmic example), their Proposition 2 establishes that a feasible reserve policy lets all but a negligible fraction of generations attain $U(\omega)$, and their Proposition 3 establishes that $U(\omega)$ is an upper bound on long-run average utility that the market equilibrium fails to reach, the shortfall following from strict concavity and positive dividend variance.[22] Their Proposition 4 establishes that the market allocation is ex ante Pareto-inefficient and that an attainable smoothing allocation, reached after a finite genesis stage of reserve accumulation, makes every generation ex ante better off.[23]

The arrangement is fragile. Smoothing requires that in a high-dividend state the young forgo the high market return so that reserves can be built; a generation born when reserves are low is worse off ex post than it would be in the market, because it forgoes the high return in good states while still bearing the downside in bad ones. If such a generation can opt out to a competitive market, it will. Allen and Gale's Proposition 5 states that under the disintermediation constraint—each generation must be left at least as well off ex post as in the market equilibrium—the intermediary

[21] Allen and Gale, "Intertemporal Smoothing," 527–530 (Section III, Market Equilibrium, Proposition 1).
[22] Allen and Gale, "Intertemporal Smoothing," 530–533 (Section IV, Propositions 2 and 3).
[23] Allen and Gale, "Intertemporal Smoothing," 533–538 (Section V, Proposition 4).

can do no better than the market: competition from a spot market unwinds the smoothing, and the arrangement survives only with the monopoly power that restricts the opt-out.[24]

4.2 Specialization to rate-setting

The framework specializes to personal automobile insurance under the correspondence in Table 1. The fluctuating risky dividend becomes the loss-cost realization that the insurer must fund; the safe-asset reserve becomes policyholders' surplus; the smoothed consumption path becomes the smoothed premium rate that the intermediary charges successive cohorts of policyholders; the disintermediation constraint becomes a policyholder's option to defect to a competitor that prices to current cost; and the monopoly power that sustains smoothing becomes the franchise value of a captive agency force, which raises the cost of defection. The intermediary is the mutual writing through captive agents; the competitive spot market is the segmented direct writer.

Table 1. *Correspondence between the Allen and Gale (1997) economy and personal-automobile rate-setting. The left column lists the primitive object in their overlapping-generations model; the right column lists its counterpart in the insurance specialization used in this paper. The correspondence is the basis for reading Hypotheses 1–4 as specializations of their Propositions 2–5.*

Allen and Gale (1997)	**Insurance specialization**
Risky dividend y_t (i.i.d.)	Loss-cost realization to be funded
Safe-asset reserve s_t	Policyholders' surplus
Smoothed consumption, $c_1 + c_2 = \omega$	Smoothed premium rate
Return on the safe asset	Net investment income on surplus
Disintermediation constraint (opt-out to the market)	Policyholder defection to a spot-pricing competitor
Monopoly power sustaining smoothing	Captive-agency franchise value
Long-lived intermediary	Mutual writing through captive agents
Competitive spot market	Segmented direct writer

The observable at the rate-setting margin is the pass-through of the *indicated* rate change—the actuary's estimate of the change in required cost—into the *approved* rate change that the insurer files and charges. Let ι_t denote the indicated rate change. It is an unbiased but noisy estimate of the true required change g_t,

$$\iota_t = g_t + \varepsilon_t, \qquad \varepsilon_t \sim \mathcal{N}(0, \sigma_\varepsilon^2), \tag{1}$$

where ε_t is estimation noise. The true required change is a mixture of "no genuine shift" and "a persistent shift,"

$$g_t = \begin{cases} 0 & \text{with probability } 1-q, \\ \mathcal{N}(\delta,\ \sigma_g^2) & \text{with probability } q, \end{cases} \tag{2}$$

with $\delta \geq 0$ a secular loss-cost drift. The insurer chooses the filed change a_t, the proposed rate change it submits; the approved change follows after regulatory review and nearly coincides with

[24] Allen and Gale, "Intertemporal Smoothing," 538–541 (Section VI, Proposition 5, and the accompanying numerical illustration).

the filing in this market (Section 7), so the model's policy is taken to the data as the filed change, with the approved change as the censoring check. The two insurer types differ in the technology they bring to that choice, and that difference is the intertemporal-versus-cross-sectional distinction of Section 4.1.

4.3 Players, actions, information, and timing

The specialization is a decision problem for each insurer, set in the environment of Section 4.1. The players are a continuum of policyholders, the two insurers (the smoother, indexed I, and the pricer, indexed C), and a regulator. The state at date t comprises the insurer's surplus B_t (Allen and Gale's reserve), the loss-cost level, and, for the migration prediction, the local presence of the pricer. Each period unfolds in five steps: the loss-cost shock is realized and the actuary produces the indication ι_t of (1); the insurer files a proposed rate change a_t; the regulator approves it subject to a revenue-adequacy constraint; policyholders either renew or defect to a competitor; and surplus updates by $B_{t+1} = (1+r)B_t + u_t P_t$, where $u_t = A_t - R_t$ is the underwriting result in rate terms—the gap between the approved rate level $A_t = \sum_{s \le t} a_s$ and the cost level $R_t = \sum_{s \le t} \iota_s$—$P_t$ is premium volume, and r is the return on surplus. The information structure is the signal-extraction problem of (1)–(2): the insurer observes the indication but not its decomposition into the transitory and the persistent component. The indication ι_t is taken as the unbiased input to the filing decision; the consequence of relaxing that assumption for the smoother is taken up in Section 6.3.

The two insurers differ in the objective they bring to the choice of a_t. The smoother chooses the approved-rate policy $a_I(\cdot)$ to minimize the expected squared deviation of the rate from the required change, $\mathbb{E}[(a-g)^2]$, subject to the surplus remaining solvent in the long run; the quadratic loss makes the optimal rate the posterior mean $\mathbb{E}[g \mid \iota]$ of Section 4.4, which passes through the persistent component of the indication while absorbing the transitory component into surplus, and rate variability across cohorts is reduced relative to full pass-through as a consequence, since the posterior mean shrinks the noisy indication. The pricer chooses $a_C(\cdot)$ to maximize the per-period underwriting result subject to revenue adequacy and the retention response of demand; this is the spot-market problem. The pass-through functions $a_I(\cdot)$ and $a_C(\cdot)$ are the optimal policies of these two problems, and Propositions 1 and 2 characterize their curvature. The smoother's problem is dynamic and is treated here through its filtering solution; the pricer's is static. The pricer's presence is the strategic variable of the stage-game equilibrium of Section 4.7; the fully specified dynamic stochastic game in which surplus and presence evolve jointly is outside the scope of this paper, a limitation noted in Section 8.

The regulator's revenue-adequacy constraint and the long-run solvency constraint enter the specialization as bounds on the smoother's problem, not as the binding consideration that produces the smoothing. Revenue adequacy is the statutory standard that rates not be inadequate, a floor set below the actuarially indicated level by the regulator's tolerance band rather than at it; a smoother that files below the indicated rate by choice therefore sits above that floor rather than against it, and the floor binds only against filings that would leave rates below the band. The solvency constraint binds only as surplus approaches the regulatory minimum, far from the operating range of the smoother, a well-capitalized mutual carrying low underwriting leverage—its statutory liabilities

average 0.71 times its policyholders' surplus over 2001 through 2025, against the pricer's 2.65 times—and a high risk-based-capital ratio. The smoother's underpricing in the observed period is therefore its own optimization, funded by surplus, rather than a regulatory outcome; a difference in regulatory stringency across the two insurers is treated separately, as a confounder to the migration test, in Section 6.

4.4 The intertemporal smoother and convex pass-through

The Allen and Gale intermediary absorbs the transitory part of the dividend fluctuation into reserves and lets the persistent part through, because reserves cannot drift to ruin in the long run. At the rate-setting margin this is a rule that discounts a small (likely transitory) indication and accommodates a large (likely persistent) one. The device that separates the two is the posterior mean of the persistent component under (1)–(2),

$$a_I(\iota) = \mathbb{E}[g \mid \iota] = \psi(\iota)\Big[\delta + \frac{\sigma_g^2}{\sigma_g^2 + \sigma_\varepsilon^2}(\iota - \delta)\Big], \qquad \psi(\iota) = \frac{q\,\phi(\iota - \delta;\, \sigma_g^2 + \sigma_\varepsilon^2)}{q\,\phi(\iota - \delta;\, \sigma_g^2 + \sigma_\varepsilon^2) + (1-q)\,\phi(\iota;\, \sigma_\varepsilon^2)}, \quad (3)$$

where $\phi(\cdot; v)$ is the mean-zero normal density with variance v, so the persistent state enters through the shifted density $\phi(\iota - \delta;\, \sigma_g^2 + \sigma_\varepsilon^2)$, and $\psi(\iota)$ is the posterior probability that the indication reflects a persistent shift. Because the slab density in (2) is the more diffuse, $\psi(\iota)$ is small for indications near zero and rises toward one as the indication grows: a small indication is read as noise and discounted, a large one is recognized as persistent and passed through.

Proposition 1. *Suppose the posterior probability of the persistent state at a zero indication does not exceed one-half, $\psi(0) \le \frac{1}{2}$. Then there exists a threshold $\bar{\iota} > 0$ such that the smoother's pass-through $a_I(\iota)$ is strictly convex on $(0, \bar{\iota})$, the local pass-through $a_I'(\iota)$ increasing in ι on that interval. Beyond $\bar{\iota}$ the posterior probability $\psi(\iota)$ saturates and $a_I'(\iota)$ declines to the shrinkage ceiling $\sigma_g^2/(\sigma_g^2 + \sigma_\varepsilon^2)$, which it approaches from above. The convexity is therefore a property of the interval below $\bar{\iota}$, not of the whole line.*

The proof is in Appendix A. Proposition 1 is the rate-setting form of the smoother's smoothing rule: discount routine, small indications and relent toward fuller pass-through as the indicated need grows. It gives the first hypothesis.

Hypothesis 1. Over the range of indications observed, the intertemporal smoother's pass-through of indicated into approved rate is convex: the local slope rises with the indicated rate change.

4.5 The cross-sectional pricer and concave pass-through

The Allen and Gale market prices to current cost, which at the level of the individual priced risk is full pass-through. At the level of the headline filed change, however, the cross-sectional pricer faces a retention response and holds a segmentation technology. Let demand carry an elasticity $\eta(a)$ that is increasing in the rate increase—policyholders shop and switch more readily the larger the increase—which is taken to make the retention cost of a headline increase convex and its second

derivative rising, and let the insurer meet part of a required increase by re-rating segments at a quadratic cost rather than by raising the headline. Let $\rho(\iota)$ denote required revenue; the indicated change is, by construction, the rate change required to fund the cost change, so $\rho(\iota) = \iota$ and $\rho'(\iota) = 1$. Profit maximization then gives

$$\frac{da_C}{d\iota} = \frac{1}{1 + \mathcal{E}(a_C)} \in (0, 1), \qquad \mathcal{E}' > 0, \tag{4}$$

where $\mathcal{E}$ rises with the rate increase through $\eta'(a) > 0$, and the segmentation margin loads a growing share of a required increase away from the headline as ι grows. Both forces compress the headline at high indication.

Proposition 2. *With $\eta'(a) > 0$ and convex segmentation cost, the pricer's pass-through $a_C(\iota)$ is concave in ι, and the local pass-through $a_C'(\iota)$ falls as ι grows.*

The proof is in Appendix A. It gives the second hypothesis.

Hypothesis 2. The cross-sectional pricer's pass-through of indicated into approved rate is concave: the local slope falls with the indicated rate change, and the headline increase is capped at high indication in favor of segmentation.

Both hypotheses concern the insurer's pass-through technology. The filed change is the insurer's own choice and therefore the primary measure of that technology; the approved change is its realization under regulatory censoring. The estimation in Section 7 accordingly treats the filed change as the primary series and the approved change as the censoring check, and the two fits nearly coincide.

4.6 Surplus dynamics and the underwriting-account asymmetry

Recall from Section 4.3 the underwriting result $u_t = A_t - R_t$, the gap between the approved rate level A_t and the cost level R_t, and the surplus recursion $B_{t+1} = (1 + r)B_t + u_t P_t$, with P_t premium volume and r the return on surplus. Alongside the within-period filtering of (3), the smoother holds down the variability of the rate change by adjusting the rate level toward the cost level only partially, at speed $\lambda \in (0, 1)$: $A_t - A_{t-1} = \lambda(R_t - A_{t-1})$. Under positive loss-cost drift $\delta > 0$ the cost level rises each period, and a partial adjuster tracks a rising level with a constant lag, so $\mathbb{E}[u_t^I] < 0$. The pricer adjusts fully, $\lambda = 1$, so its rate level tracks the cost level and its level gap is zero; the margin $\mu > 0$ that its objective of Section 4.3 extracts from the retention-constrained optimum then leaves $\mathbb{E}[u_t^C] = \mu > 0$.

Proposition 3. *Under loss-cost drift $\delta > 0$, the smoother runs an expected underwriting drain, $\mathbb{E}[u_t^I] = -q\delta(1 - \lambda)/\lambda < 0$, with surplus maintained by the investment term rB_t rather than by underwriting; the pricer, adjusting fully at $\lambda = 1$ and pricing at the margin $\mu > 0$ of its objective, runs a positive underwriting result, $\mathbb{E}[u_t^C] = \mu > 0$.*

This is the Allen and Gale reserve mechanism specialized: the return on the accumulated surplus funds the smoothing subsidy. It gives the third hypothesis.

Hypothesis 3. The intertemporal smoother's underwriting account drains on average and its surplus is sustained by investment income; the cross-sectional pricer's underwriting account builds.

4.7 Disintermediation and quantity migration

A low-risk policyholder pays the smoother's pooled smoothed rate a_I but is offered the pricer's segment-specific spot rate $a_C(\text{own segment})$. The intertemporal subsidy is funded by the low-risk policyholders who, in smoothing periods, pay above their current cost. A policyholder defects when $a_C(\text{segment}) < a_I$, which holds for low-risk segments and whenever the smoother prices above current cost to maintain surplus. As the pricer's local presence rises, the smoother loses exactly the policyholders whose overpayment funds the subsidy, and the subsidy becomes unfundable—the spot market unwinds the arrangement, as in Allen and Gale's Proposition 5.

To make the unwinding an equilibrium outcome rather than a comparative static, let the smoother's book carry a low-risk share θ at cost c_L and a high-risk share $1-\theta$ at cost $c_H > c_L$, pooled at the single smoothed rate a_I, so the low-risk overpay $a_I - c_L$ and the high-risk are subsidized $c_H - a_I$. The pricer builds local presence $m \in [0,1]$ at a convex cost $\Gamma(m)$, with $\Gamma' > 0$ and $\Gamma'' > 0$, which makes a fraction m of the low-risk reachable with a cost-based segment rate below a_I, each captured segment yielding the pricer a margin $\pi(a_I)$ that is positive and increasing in the pooled rate, $\pi' > 0$, because a higher pooled rate is a wider gap for the pricer to undercut. With a mass $m\theta$ of low-risk defected, the retained overpayment funds the subsidy when $(1-m)\theta(a_I - c_L) \geq (1-\theta)(c_H - a_I)$, which holds for $m \leq m^* = 1-(1-\theta)(c_H - a_I)/[\theta(a_I - c_L)]$. The presence cost satisfies $\Gamma'(0) = 0$ and $\Gamma'(m) \to \infty$ as $m \to 1$, so the pricer's best response is interior, and the funding threshold is taken to satisfy $m^* \in (0,1)$, which requires the pooled rate to lie strictly between the pool's average cost and c_H. The pricer chooses presence to maximize $m\theta\pi(a_I) - \Gamma(m)$, so its best-response presence solves $\theta\pi(a_I) = \Gamma'(m^C)$. Raising a_I moves the threshold and the best response in the same direction: it relaxes the budget, $dm^*/da_I = (1-\theta)(c_H - c_L)/[\theta(a_I - c_L)^2] > 0$, while also drawing in the pricer, $dm^C/da_I = \theta\pi'(a_I)/\Gamma''(m^C) > 0$. The rate increase is self-defeating when the second effect dominates the first,

$$\frac{\theta\,\pi'(a_I)}{\Gamma''(m^C)} > \frac{(1-\theta)(c_H - c_L)}{\theta\,(a_I - c_L)^2}, \tag{5}$$

in which case defection rises faster than the funding threshold and raising the pooled rate hastens the unwinding rather than arresting it.

Proposition 4. *In the equilibrium of the insurer interaction the smoother's quantity loss is $m^C\theta$, with m^C solving $\theta\pi(a_I) = \Gamma'(m^C)$, so it is larger the higher the pricer's per-segment margin and the lower its marginal cost of presence; and where the pricer's best-response presence exceeds the funding threshold, $m^C > m^*$, the intertemporal subsidy is not self-funding and the smoothing arrangement unwinds, the spot-market disintermediation of Allen and Gale's Proposition 5 obtaining as the equilibrium outcome. Raising the pooled rate to restore the budget is self-defeating under condition* (5)*, in which the pricer's best-response presence rises faster in a_I than the funding threshold does.*

Hypothesis 4. Net-of-rate quantity migrates from the intertemporal smoother toward the cross-sectional pricer where the pricer is established.

4.8 Testable predictions

The four hypotheses are the observable predictions of the model. Hypotheses 1 and 3 are the smoother's signatures, properties of the surplus-based optimal policy and corollaries of Allen and Gale's Propositions 2 through 4; Hypothesis 2 is the cross-sectional pricer's signature; and Hypothesis 4 is their Proposition 5 made measurable. Table 2 maps each hypothesis to its predicted sign, the Allen-Gale proposition it specializes, and the section and figure in which it is tested. Under Hypotheses 1 and 2 the single slope a linear specification reports is the average of the local slopes over the sample's indication range, so a near-equal pair of linear slopes is consistent with opposite curvatures, and the first stylized fact does not contradict the prediction.

Table 2. *The four hypotheses, their predicted signs, the Allen and Gale (1997) proposition each specializes, and the section and figure in which each is tested. The smoother is indexed I and the pricer C. "Local slope" is the derivative of the approved on the indicated rate change, $da/d\iota$, as a function of the indication. The underwriting result is the statutory underwriting gain or loss; the exposure proxy is the growth in the smoother's state private passenger automobile direct written premium net of its own approved rate change.*

	Prediction	Allen-Gale basis	Tested in
H1	Smoother pass-through convex: local slope rises with indication	Propositions 2–4 (reserve smoothing)	§7.3, Figures 3–4
H2	Pricer pass-through concave: local slope falls with indication	Proposition 1 (market equilibrium)	§7.3, Figures 3–4
H3	Smoother underwriting drains, surplus held by investment income; pricer underwriting builds	Proposition 2 (reserve mechanism)	§7.1, Figures 1–2
H4	Quantity migrates toward the pricer where the pricer is present	Proposition 5 (disintermediation)	§7.4, Figure 5

5 Data

This section identifies each source with its coverage and access date, defines every variable with its construction, reports the restrictions that take the filing-level records to the estimation sample, and closes with descriptive statistics.

5.1 Sources

The analysis draws on filing-level rate data, statutory financial statements, statutory premium records, and a set of macroeconomic series. Table 3 documents each source, its content, its coverage period, and its release or access date. Filing-level rate activity is from the public rate-filing records of the National Association of Insurance Commissioners (NAIC) System for Electronic Rate and Form Filing (SERFF; serff.com) and, for Florida, the Florida Office of Insurance Regulation (OIR) filing search (irfssearch.floir.gov); statutory financial and premium data are from the insurers' NAIC annual-statement filings; and the loss-cost-environment series are from the Energy Information Administration (EIA), the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Bureau of Labor Statistics (BLS).

Table 3. *Data sources. Each row identifies a source dataset, the content used from it, the coverage period drawn on in this paper, and the vendor release date or access basis. The rate-filing records span six regional extracts accessed 15 May 2026; the statutory financial exhibits are group-level compilations of the annual statements, accessed 13 May 2026; the Page 14 premium records are taken from the NAIC annual-statement exhibit; the market-share chronology is a countrywide private-passenger-automobile (PPA) compilation; and the loss-cost-environment series are public agency releases.*

Source	Content used	Coverage	Release / access
SERFF and Florida OIR	Filing-level PPA rate changes by state: proposed (filed), approved, and indicated change, submission and approval dates, new- and renewal-business effective dates	2021–2026	Accessed 15 May 2026
Statutory annual statements	Group statutory exhibits: balance sheet, income statement, underwriting, investment, reserve, capital adequacy, reinsurance	1996–2025	Accessed 13 May 2026
NAIC Page 14	Statutory premiums and losses by company, state, and line; PPA direct written premium	2014–2025	Annual statements
NAIC market-share tables	Countrywide PPA market share by insurer, published record	2013–2025	Accessed 5 September 2026
Market-share chronology	Countrywide PPA market share by insurer, compilation	1942–2025	Compiled; vintage not stated
EIA, FHWA, NHTSA, BLS	Retail gasoline price, vehicle miles traveled, traffic fatalities and rate, unemployment rate	2001–2025	Public releases

5.2 Variable definitions and construction

Table 4 defines each variable used in the analysis and states its construction and source. Filing-level variables are reported in percent (rate changes) or percentage points (the approved-minus-indicated gap). Statutory dollar figures are reported in the annual-statement exhibits in thousands and are converted to billions of United States dollars for presentation; they are nominal. The combined ratio is the sum of the loss-and-loss-adjustment-expense ratio, the underwriting-expense ratio, and the policyholder-dividend ratio, in percent, with values above 100 denoting an underwriting loss.

Table 4. *Variable definitions and construction. Each row gives the variable, its definition and construction step, and the source from Table 3. Rate changes are in percent; the approved-minus-indicated gap is in percentage points; statutory flows and balances are in nominal United States dollars. Private-passenger-automobile (PPA) direct written premium is constructed from the NAIC annual-statement automobile lines. "Derived" marks a variable computed from one or more source fields rather than read directly.*

Variable	Definition and construction	Source
Indicated rate change (ι)	Actuarially indicated change in the filed rate level, in percent	SERFF / Florida OIR
Filed (proposed) rate change	The rate change the insurer proposes, floored at the approved change where the recorded proposal falls below it, in percent; the pass-through outcome of Section 7	SERFF / Florida OIR (derived)
Approved rate change (a)	Rate change approved by the regulator, in percent	SERFF / Florida OIR
Approved $-$ indicated	$a - \iota$, in percentage points	SERFF / Florida OIR (derived)
Combined ratio	Loss-and-LAE ratio $+$ underwriting-expense ratio $+$ policyholder-dividend ratio, in percent; above 100 denotes an underwriting loss	Statutory financials
Policyholders' surplus	Statutory capital and surplus, in dollars	Statutory financials
Net underwriting gain (loss)	Net premiums earned less incurred loss and LAE and underwriting expense, in dollars	Statutory financials
Net investment income	Investment income net of investment expense, in dollars	Statutory financials
PPA direct written premium	Sum of NAIC annual-statement lines 19.1, 19.2, and 21.1 (private passenger auto liability and physical damage), in dollars	Page 14 (derived)
Pricer local presence	The pricer's share of the state's PPA direct written premium, in percent, taken from the statutory state-by-group premium record	Statutory annual statements (derived)
Smoother exposure proxy	Log growth in the smoother's state PPA direct written premium over 2021–2023, less the cumulative approved rate change on its filings effective in that window, in percent; the subtraction nets the price channel out of the premium change, leaving exposure	SERFF / Florida OIR and statutory statements (derived)

5.3 Sample construction

The pass-through estimation uses the filing-level data restricted to the post-pandemic loss-cost event. Table 5 reports the construction. Starting from all PPA rate filings for the two insurers in the extract, the sample is restricted to filings that carry a populated indicated rate change, then to filings whose new-business effective date falls within the 2021 through 2023 event. Filings that report an approved change without an actuarially indicated rate change are excluded throughout, because a filing with no indication cannot be placed on the indication axis; these excluded filings are smaller on average than those retained. Within the event window the exclusion is unevenly distributed: 161 of the smoother's 638 event-window filings lack an indication (25 percent) against 60 of the pricer's 862 (7 percent), and the excluded filings carry mean approved changes of 2.65 and 1.66 percent against 6.36 and 4.64 percent among those retained, so the estimation sample over-represents larger rate actions for both insurers and does so more for the smoother; the low-indication segment slopes are read with that selection in view. North Carolina is retained. The indicated rate change recorded there is the North Carolina Rate Bureau's industry-wide indication—identical across the two insurers in each year both face it (28.4 percent in 2023)—while the proposed and approved changes are the carrier's own. Because a North Carolina observation pairs the Bureau's indication with the carrier's proposed and approved change, rather than the carrier's response to its own indication as in every other state, the estimates excluding it are reported as a sensitivity check in Appendix C. Filings with an indicated rate change of exactly zero are retained as genuine observations at the origin. The estimation sample is 477 filings for the smoother, drawn from 48 states, and 802 for the pricer, drawn from 50.

Table 5. *Sample construction for the pass-through estimation. Each row applies one restriction to the filing-level rate data and reports the surviving count for the smoother (State Farm) and the pricer (Progressive). The populated-indication restriction excludes filings that report an approved change without an actuarially indicated rate change, which cannot be placed on the indication axis; the event restriction keeps filings whose new-business effective date falls in 2021 through 2023. Filings with an indicated rate change of exactly zero are retained. The final row is the estimation sample; it retains North Carolina, where the recorded indicated change is the Rate Bureau's industry-wide indication rather than the carrier's own, with the estimates excluding it reported as a sensitivity check in Appendix C.*

Restriction	Smoother	Pricer
All PPA rate filings in the extract	1,071	1,304
With a populated indicated rate change	878	1,236
Effective within the 2021–2023 event (estimation sample)	477	802

5.4 Descriptive statistics

Table 6 reports descriptive statistics. Panel A covers the filing-level estimation sample over the 2021 through 2023 event; Panel B covers the statutory financial series over 2001 through 2025, the window used for the underwriting-account comparison. In the filing-level panel the smoother's indicated rate change is higher on average than the pricer's (a mean of 13.92 against 7.51 percent), and both insurers file and approve less than they indicate: the mean approved-minus-indicated gap is -7.56 percentage points for the smoother and -2.87 for the pricer. In the statutory panel

the smoother's mean combined ratio is 106.65 against the pricer's 92.04, its mean net underwriting result is negative (−$2.53 billion a year) against the pricer's positive $2.09 billion, and its surplus is larger and, in dollar terms, more variable, with a mean of $84.65 billion against $10.22 billion.

Table 6. *Descriptive statistics. Panel A reports the filing-level estimation sample (Table 5) over the 2021–2023 event: the indicated and approved rate changes in percent and their difference in percentage points, by insurer. Panel B reports the statutory financial series over 2001–2025, annual observations, by insurer: the combined ratio in percent, policyholders' surplus, the net underwriting gain or loss, and net investment income, the final three in billions of nominal United States dollars. N is the number of observations; SD is the sample standard deviation; P25 and P75 are the 25th and 75th percentiles. Sources and definitions are in Tables 3 and 4.*

Variable	N	Mean	SD	Min	P25	Median	P75	Max
Panel A. Filing-level rate data, 2021–2023								
Smoother (State Farm)								
Indicated rate change (%)	477	13.92	9.41	−12.2	8.10	13.00	18.80	56.7
Filed (proposed) rate change (%)	477	6.45	6.29	−10.0	2.30	5.20	9.10	45.3
Approved rate change (%)	477	6.36	6.22	−10.0	2.20	5.20	9.00	45.3
Approved − indicated (pp)	477	−7.56	6.68	−38.7	−12.90	−5.70	−2.50	12.9
Pricer (Progressive)								
Indicated rate change (%)	802	7.51	7.48	−10.3	3.23	7.30	11.10	48.6
Filed (proposed) rate change (%)	802	4.78	4.98	−15.8	0.80	4.91	7.90	24.85
Approved rate change (%)	802	4.64	4.89	−15.8	0.80	4.90	7.80	21.1
Approved − indicated (pp)	802	−2.87	4.92	−31.2	−3.90	−1.70	−0.30	9.97
Panel B. Statutory financial series, 2001–2025 (annual)								
Smoother (State Farm)								
Combined ratio (%)	25	106.65	8.01	94.27	101.56	106.28	110.30	127.56
Policyholders' surplus ($bn)	25	84.65	38.88	31.60	58.03	75.68	116.16	170.00
Net underwriting g/(l) ($bn)	25	−2.53	3.76	−13.33	−4.21	−2.07	−0.59	4.41
Net investment income ($bn)	25	2.94	0.56	2.07	2.70	2.81	3.16	4.50
Pricer (Progressive)								
Combined ratio (%)	25	92.04	3.23	85.87	88.58	92.82	94.72	96.92
Policyholders' surplus ($bn)	25	10.22	7.20	2.99	5.15	6.87	14.04	28.22
Net underwriting g/(l) ($bn)	25	2.09	2.20	0.20	0.96	1.40	1.86	9.83
Net investment income ($bn)	25	0.79	0.72	0.37	0.41	0.47	0.81	3.27

6 Empirical Specification and Identification

This section states the pass-through specification, the source of identification for the curvature contrast, and the alternative explanations the design must rule out.

6.1 Specification

The pass-through predictions concern the shape of the conditional mean of the insurer's filed change given the indication, $\mathbb{E}[a \mid \iota]$. The filed (proposed) change is the insurer's own decision and is the empirical counterpart of the policy $a_I(\cdot)$ the model assigns to each type, so it is the primary measure of the pass-through technology; the approved change is the rate the regulator grants, equal to the filed change up to censoring, and is the operative rate carried into the underwriting and migration tests of Hypotheses 3 and 4. The estimand is the local slope $da/d\iota$ as a function of ι: rising for the smoother under Hypothesis 1, falling for the pricer under Hypothesis 2. It is recovered in three steps. A single-slope ordinary-least-squares regression of a on ι gives the linear summary. A locally weighted scatterplot smoother (LOWESS)[25] displays the conditional mean without imposing a functional form. A changepoint estimate then allows the slope to change at an estimated threshold τ in the indication, fitted under inverse-variance weights to control the heteroskedastic tail of large indications; the changepoint and leverage-control method is set out in Appendix B. The same fit is run on the approved change as a check on regulatory censoring: where the approved fit nearly coincides with the filed fit, the curvature is the insurer's own rather than the regulator's. The underwriting-asymmetry prediction of Hypothesis 3 is read from the statutory underwriting result and surplus accounts over 2001 through 2025. The migration prediction of Hypothesis 4 is read from the cross-state association between the pricer's local presence and the smoother's exposure growth net of its own approved rate.

6.2 Identification

Identification of the type contrast rests on one industry-wide loss-cost shock, the post-pandemic severity and inflation surge of 2021 through 2023, which holds the loss-cost environment fixed across the two insurers; this is the event of the event study. Because both insurers face the same shock, the difference between their responses within the event window is a difference in conduct rather than in environment. The pass-through curvature is identified from variation in the indication within the event window, in which both the approved and the indicated change are recorded; it carries no pre-event benchmark, the indication being recorded from 2021, so its contrast is between insurers within the window rather than before and after it. The migration prediction is measured from cross-state variation in the pricer's local presence; the association is contemporaneous, and Section 8 states what it does not identify.

6.3 Alternative explanations

Because the evidence rests on two insurers, the specification addresses explanations other than the type contrast. Three are addressable with the data in hand. A difference in expense ratios or in distribution channel would shift the level of pass-through but not its curvature, and the predictions concern curvature; both insurers file below indication, so a level difference alone does not generate opposite curvatures. A difference in regulatory stringency across the states in which the

[25] William S. Cleveland, "Robust Locally Weighted Regression and Smoothing Scatterplots," *Journal of the American Statistical Association* 74, no. 368 (1979): 829–836.

two insurers operate is addressed by re-estimating the migration association excluding the prior-approval states of California, New York, and New Jersey, where the association retains its sign. A difference in the mix of states is addressed by the within-state paired timing comparison, in which the smoother is slower in 42 of 44 states. A fourth explanation bears on the measured curvature in a direction that does not threaten the finding. The indication ι_t of (1) is an internal actuarial calculation the insurer files, not an external observable; were the smoother to dampen its filed indication by a uniform proportional factor, the indication axis would be rescaled and the estimated convexity would understate the true convexity, leaving the sign intact. A dampening that varies with the size of the shock is not signed by this argument: a nonlinear transformation of the indication axis can itself induce curvature in the estimated relation, so the lower-bound reading holds under the proportional form and the explanation is offered under that restriction. Three explanations cannot be separated with two insurers: a difference in reserve redundancy between them, any unobserved firm attribute correlated with both pass-through curvature and underwriting outcomes, and the endogenous allocation of the pricer's local presence. The pricer writes personal automobile business nationwide, so the cross-state variation in its presence m_t is variation in the intensity of presence rather than in the discrete decision to be present; the concern is the endogeneity of that intensity rather than selection in entry. A segmented pricer's technology is most rewarding where risk heterogeneity is greatest, and those are plausibly the same states in which a pooled incumbent's low-risk policyholders overpay by the most relative to a cost-based rate, so the pricer's presence and the size of the contestable low-risk pool share a common determinant in the state's risk composition. The migration association is consistent with that common determinant and with the disintermediation mechanism alike; the two-insurer cross-state design identifies the association but not its direction, and the negative correlation of -0.27 is read as the association the mechanism predicts rather than as a causal effect of presence on migration. The pricer's presence is measured at the end of the sample, after the event window over which the exposure proxy is formed, so the association is a contemporaneous one and the ordering of presence and migration is not identified by it. A common determinant of this kind is consistent with the theoretical reading, in that the pricer's presence is heaviest where the Allen-Gale arrangement leaves the largest low-risk overpayment, while leaving the strict causal claim outside the reach of a two-insurer design. Separating these would require the cross-firm design discussed in Section 8.

7 Results

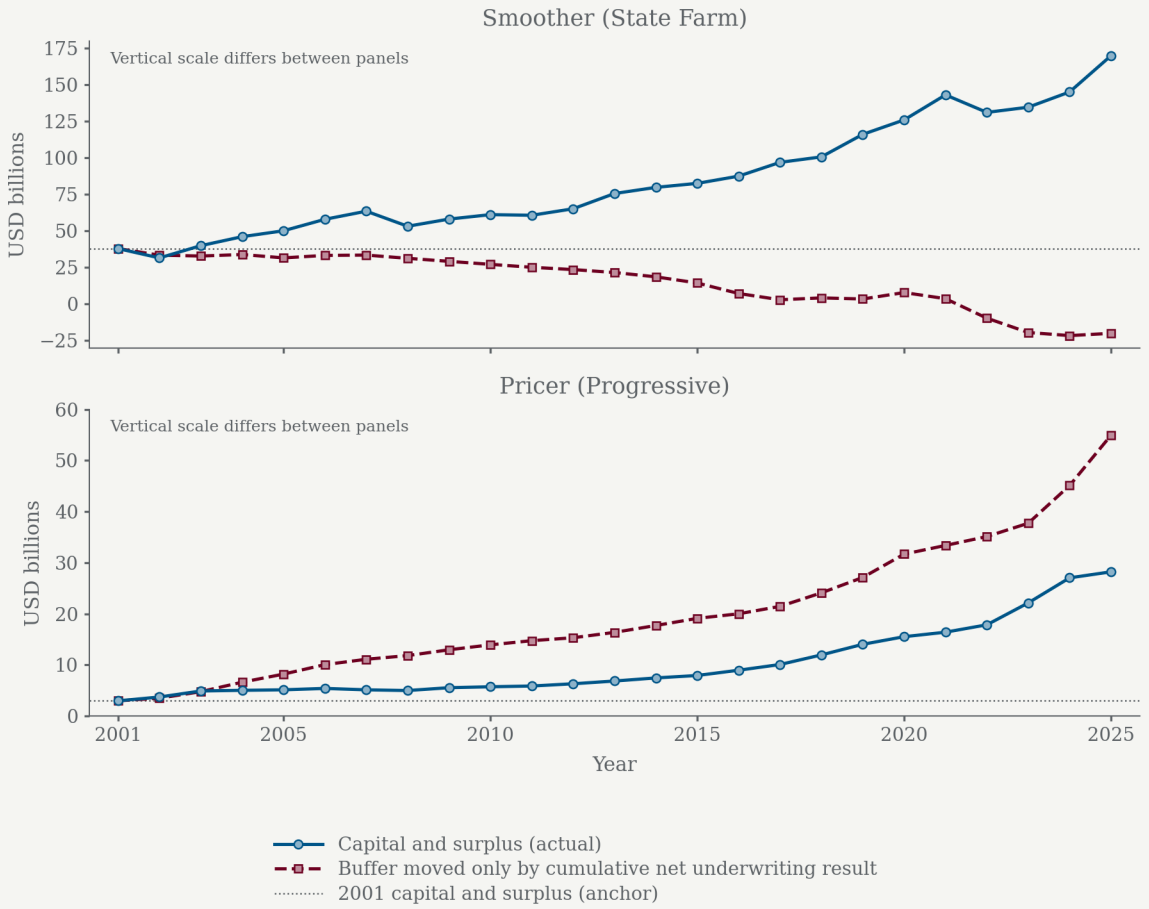
This section reports the underwriting-account asymmetry between the two insurers, the event in the underwriting account, the pass-through estimates and the tests of their curvature, and the quantity migration, in that order.

7.1 The underwriting-account asymmetry

Over 2001 through 2025 the smoother's underwriting account drained while its surplus rose; investment income funded the drain, and the level of surplus rose principally on unrealized capital changes (Table 7). The smoother recorded a net underwriting loss in 19 of 25 years, a cumulative net underwriting loss of $63.328 billion, and a mean combined ratio of 106.65; over the same span its surplus rose from $43.691 billion at year-end 2000 to $169.997 billion, with affiliated investments accounting for 38.8 percent of 2025 surplus. The pricer recorded no underwriting-loss years over the same span, a cumulative underwriting gain of $52.132 billion, and a mean combined ratio of 92.04, and it paid $41.856 billion in dividends to its parent, with affiliated investments accounting for 3.5 percent of surplus. Figure 1 shows surplus against the buffer path that moves only with the underwriting account. The pattern is the one in Proposition 3: the smoother's underwriting account drains while the pricer's builds. Table 7 decomposes the change in surplus over 2001 through 2025 into its statutory components. For the smoother, net investment income of $73.410 billion and realized capital gains of $12.803 billion fund the cumulative underwriting loss of $63.328 billion, so investment income alone exceeds the drain; the remainder of the $126.306 billion surplus increase, $97.821 billion, is unrealized capital and other surplus changes, the mark on holdings that include the affiliated investments carrying 38.8 percent of 2025 surplus. For the pricer the underwriting gain itself is the largest component, and $41.856 billion of the resulting net income left as dividends to the parent. The investment account funds the smoother's drain; the unrealized mark on its holdings drives the level of its surplus.

Table 7. *Surplus reconciliation, 2001 through 2025, in billions of dollars. Each column reports the cumulative statutory component over the 25 years: net underwriting result (UW), net investment income (NII), net realized capital gains, income tax, net income, dividends to stockholders, the change in policyholders' surplus from year-end 2000 to year-end 2025, and the residual of unrealized capital and other surplus changes (the change in surplus less net income plus dividends). Net income also carries other income and expense items not shown, a net charge of $0.346 billion for the smoother and a net credit of $3.782 billion for the pricer, so the listed components do not sum to it. Every column therefore spans the same 25 years. Components are group-level property-and-casualty statutory figures. The pricer's year-end 2000 surplus is not reported in the financial highlights exhibit and is taken from the beginning-of-period capital and surplus for 2001 in the income statement exhibit, a row that reproduces the year-end series for the smoother in the same year. Sources: statutory annual statements (NAIC filings), accessed 13 May 2026; author's calculations.*

	UW	NII	Realized	Tax	Net income	Dividends	ΔSurplus	Unrealized & other
Smoother	−63.328	73.410	12.803	−5.946	28.485	0.000	126.306	97.821
Pricer	52.132	19.711	2.253	20.527	57.351	41.856	25.428	9.933

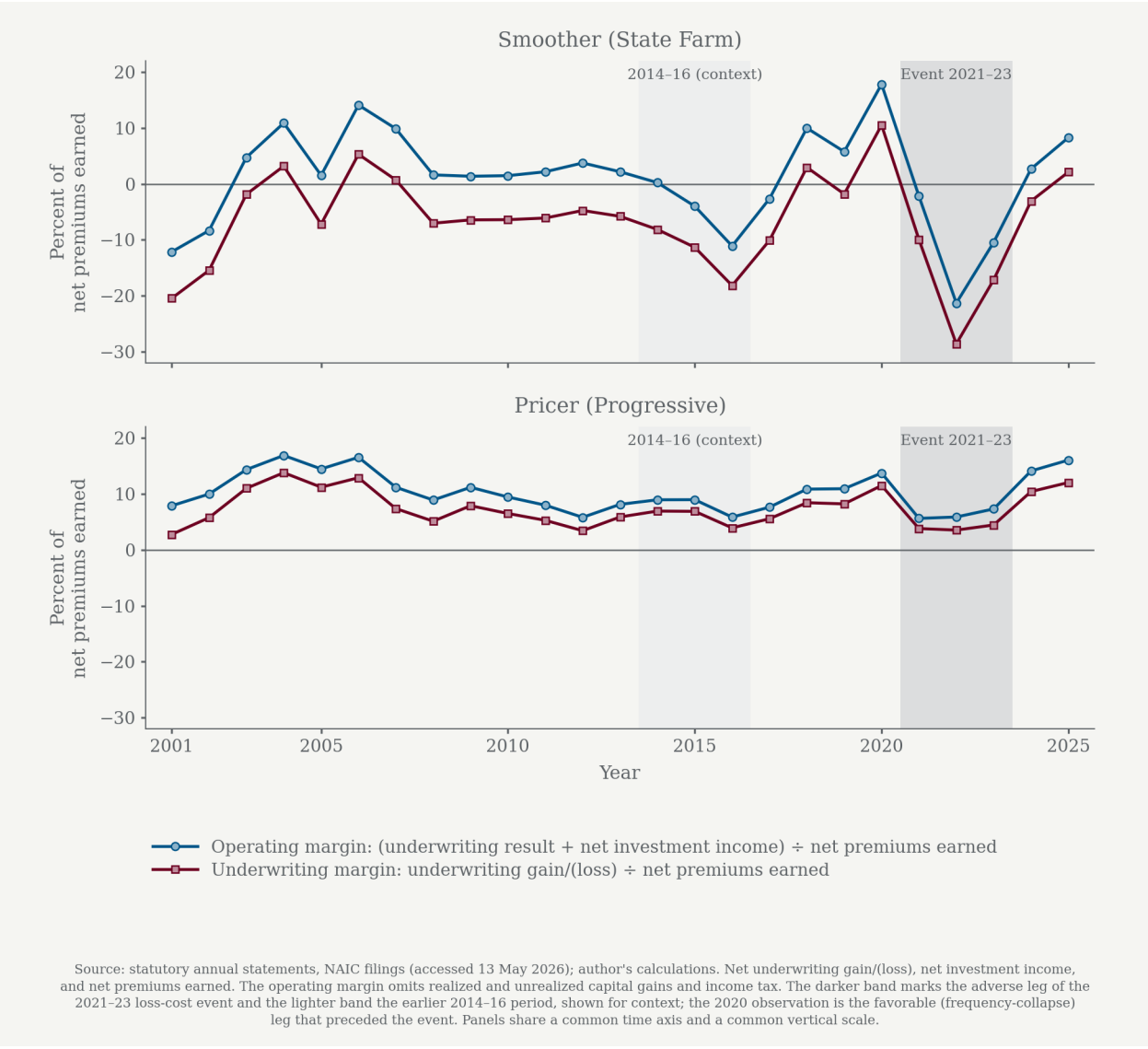


Source: statutory annual statements, NAIC filings (accessed 13 May 2026); author's calculations. Capital and surplus and net underwriting gain/(loss), in billions of dollars (reported in the statements in thousands). The maroon line anchors each carrier at its 2001 capital and surplus and moves it only by the cumulative net underwriting gain/(loss) from 2002 onward; the gap to the blue line is cumulative non-underwriting accretion (net investment income, realized and unrealized gains, affiliate equity), less distributions. The smoother's 2022 net underwriting loss, $13.330 bn, is the largest of the 2001–2025 record. Panels share a common time axis; the vertical scales differ between panels and are not comparable across them.

Figure 1. *Capital and surplus against an underwriting-only buffer path, 2001–2025, one panel per insurer, the smoother (State Farm) above the pricer (Progressive). The horizontal axis is the calendar year, common to both panels; the vertical axis is in billions of United States dollars on an independent scale per panel, the two insurers differing by an order of magnitude in size. The solid blue line with circular markers is actual statutory policyholders' capital and surplus. The dashed maroon line with square markers is a counterfactual buffer that starts at the insurer's 2001 capital and surplus and moves only by the cumulative net underwriting gain or loss from 2002 onward; the gap between the two lines is cumulative non-underwriting accretion—net investment income, realized and unrealized gains, and affiliate equity—net of distributions. The dotted line marks the 2001 capital and surplus. The smoother's 2022 net underwriting loss, $13.330 billion, is the largest of the 2001–2025 record. Source: statutory annual statements (NAIC filings), accessed 13 May 2026; author's calculations. The smoother's surplus rises while its underwriting-only buffer falls below the 2001 anchor; the pricer's surplus and buffer both rise.*

7.2 The event in the underwriting account

Within the event the two insurers diverged: the smoother's combined ratio moved from 110.30 to 127.56 to 115.90 over 2021 through 2023 while the pricer's held at 95.30, 95.78, and 94.72. Figure 2 places the event against the full record, with the earlier loss-cost period of 2014 through 2016 shaded for context, in which the smoother's combined ratio rose from 107.71 to 111.04 to 117.62 while the pricer's remained below 100. The smoother absorbed the shock into its underwriting account and the pricer priced through it, the contrast that the type distinction predicts.



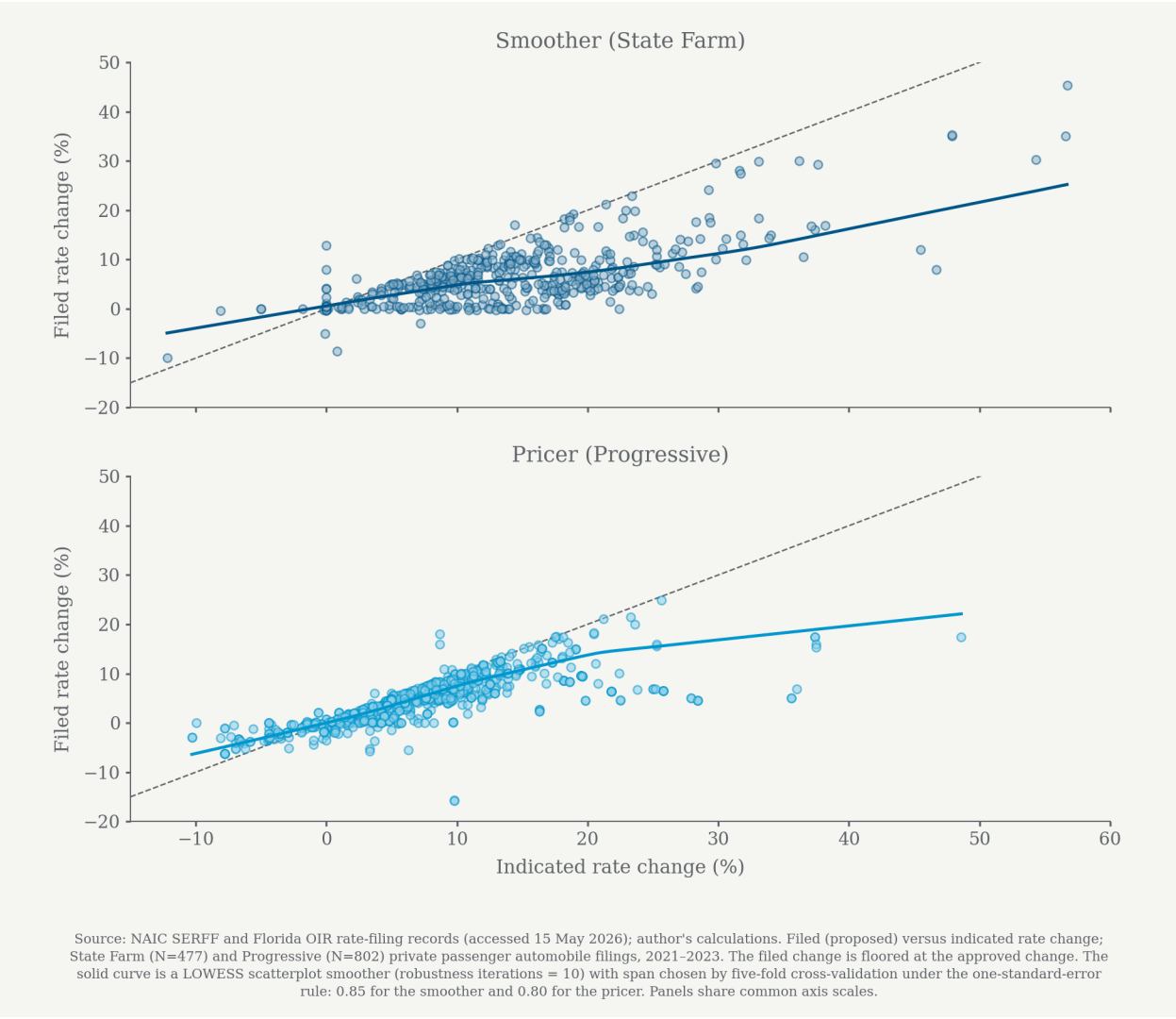
Source: statutory annual statements, NAIC filings (accessed 13 May 2026); author's calculations. Net underwriting gain/(loss), net investment income, and net premiums earned. The operating margin omits realized and unrealized capital gains and income tax. The darker band marks the adverse leg of the 2021–23 loss-cost event and the lighter band the earlier 2014–16 period, shown for context; the 2020 observation is the favorable (frequency-collapse) leg that preceded the event. Panels share a common time axis and a common vertical scale.

Figure 2. *Underwriting and operating margins, 2001–2025, for the two insurers, with the loss-cost event and the earlier loss-cost period shaded. The horizontal axis is the calendar year; the vertical axis is in percent of net premiums earned, with the zero line marked. The solid blue line with circular markers is the operating margin and the solid maroon line with square markers is the underwriting margin. The underwriting margin is the statutory underwriting gain or loss divided by net premiums earned, the complement of the combined ratio, so a combined ratio above 100 corresponds to a negative underwriting margin; the operating margin adds net investment income and omits realized and unrealized capital gains and income tax. The darker band marks the adverse leg of the 2021–2023 loss-cost event, the window of the study; the lighter band marks the earlier 2014–2016 loss-cost period, shown for context and not studied, both bands labeled directly within the plot area; the 2020 observation is the favorable frequency-collapse leg that preceded the event. Source: statutory annual statements (NAIC filings), accessed 13 May 2026; author's calculations. In each adverse band the smoother's underwriting margin falls below zero while the pricer's remains positive.*

7.3 Pass-through curvature

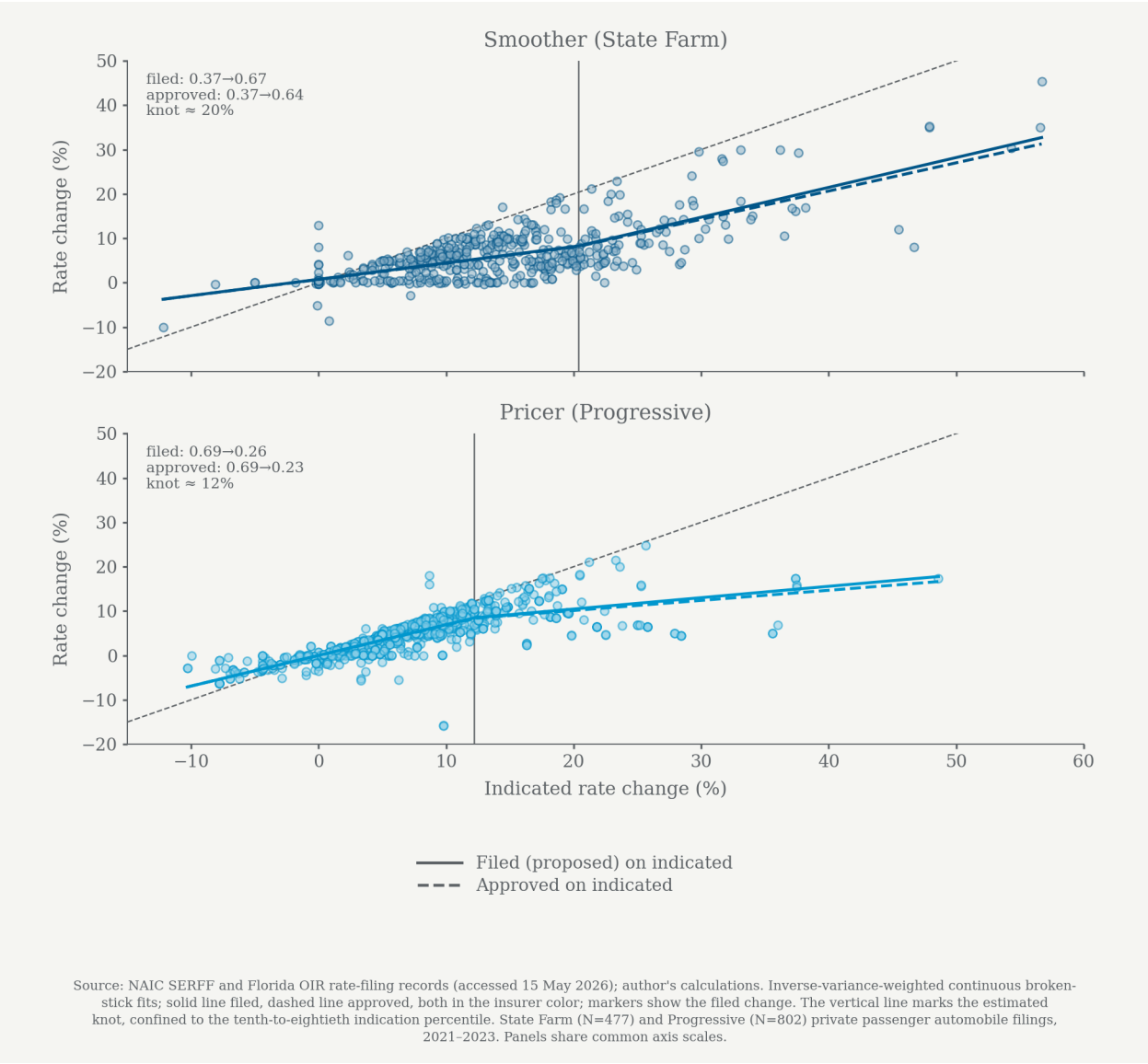
A single-slope regression of the filed change on the indicated rate change returns slopes near one-half for the two insurers: 0.478 for the smoother and 0.512 for the pricer. Both file below their indication—the median filed change falls short of the indicated change by 5.7 percentage points for the smoother, which files below indication in 92 percent of cases, and by 1.6 percentage points for the pricer, which files below indication in 82 percent of cases. On the linear reading the two insurers look alike, distinguished only by level.

The linear reading is the summary a single slope makes of two opposite curvatures; the ordinary-least-squares coefficient weights the local slopes by the local variance of the indication, so it is a distribution-weighted summary rather than an arithmetic average of the segment slopes. Figure 3 shows the filing-level data with a locally weighted scatterplot smoother: the pricer's curve bends downward at high indication while the smoother's is closer to a straight line. The bend is a slope change, and resolving it requires the leverage control set out in Appendix B, because the variance of the filed change around the linear fit is 6.1 times larger in the top indication quartile than in the bottom for the smoother and 12.3 times larger for the pricer, so the few large-indication filings act as leverage points. Figure 4 shows the leverage-controlled fit on the insurers' own filed changes with the approved fit overlaid, the sparse high-indication tail downweighted in the feasible generalized-least-squares estimation.



Source: NAIC SERFF and Florida OIR rate-filing records (accessed 15 May 2026); author's calculations. Filed (proposed) versus indicated rate change; State Farm (N=477) and Progressive (N=802) private passenger automobile filings, 2021–2023. The filed change is floored at the approved change. The solid curve is a LOWESS scatterplot smoother (robustness iterations = 10) with span chosen by five-fold cross-validation under the one-standard-error rule: 0.85 for the smoother and 0.80 for the pricer. Panels share common axis scales.

Figure 3. *Filed versus indicated rate change at the filing level, 2021–2023, one panel per insurer. The horizontal axis is the indicated rate change in percent; the vertical axis is the filed (proposed) rate change in percent; the dashed line is the 45-degree identity. The solid curve is a LOWESS scatterplot smoother (Cleveland 1979) with robustness iterations set to ten and span selected by five-fold cross-validation under the one-standard-error rule (Hastie, Tibshirani, and Friedman 2009), span 0.85 for the smoother and 0.80 for the pricer. State Farm* $N = 477$*, Progressive* $N = 802$*. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations. The scatterplot smoother bends downward at high indication for the pricer and is closer to linear for the smoother.*



Source: NAIC SERFF and Florida OIR rate-filing records (accessed 15 May 2026); author's calculations. Inverse-variance-weighted continuous broken-stick fits; solid line filed, dashed line approved, both in the insurer color; markers show the filed change. The vertical line marks the estimated knot, confined to the tenth-to-eightieth indication percentile. State Farm (N=477) and Progressive (N=802) private passenger automobile filings, 2021–2023. Panels share common axis scales.

Figure 4. *Leverage-controlled pass-through on the insurers' own filed (proposed) changes, with the approved fit overlaid; inverse-variance-weighted continuous broken-stick fits, 2021–2023, one panel per insurer. The horizontal axis is the actuarially indicated rate change in percent and the vertical axis the rate change in percent; the dashed gray line is the 45-degree identity and the vertical line marks the estimated knot. Both fits are drawn in the insurer's color, matching Figure 3: the solid line is the fit to the filed change and the dashed line the fit to the approved change. Markers show the filed change. The fit is feasible generalized least squares with weights set to the inverse of a locally estimated variance from a robust LOWESS mean, so the sparse, high-variance high-indication filings are downweighted in estimation (Appendix B); the knot is confined to the tenth-through-eightieth indication percentile. The filed change is floored at the approved change for the small share of filings that record a proposed below the approved. State Farm* $N = 477$*, Progressive* $N = 802$*. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations.*

Under the leverage control the two insurers separate on their own filed changes, and they do so under both the broken-stick and the independent-segment specifications when the two are placed on equal footing. The smoother's pass-through is convex: its local slope rises from about 0.37 below an indication near 20 percent to about 0.67 above, and the independent-segment fit at the same weighting gives 0.39 rising to 0.79. The pricer's pass-through is concave: its local slope falls from about 0.69 below an indication near 12 percent to about 0.26 above, and the independent-segment fit gives 0.67 falling to 0.08. Both knots are the upper bound of the admitted knot support, the eightieth indication percentile of each insurer, at which the weighted criterion is smallest; Appendix B sets out that boundary solution and the estimates under narrower and wider supports. The approved rate tracks the filed rate closely: the regulator approves as filed in 90 percent of the smoother's filings and 92 percent of the pricer's, and the approved fit nearly coincides with the filed fit, rising from about 0.37 to about 0.64 for the smoother and falling from about 0.69 to about 0.23 for the pricer. The two part only in the high-indication tail, where the regulator's censoring trims a few points from the largest filings of both insurers, raising the measured concavity of the pricer slightly and reducing the measured convexity of the smoother slightly; the censoring moves both in the same direction and so is not what separates them. The convexity matches Hypothesis 1 and the concavity Hypothesis 2, the concavity resting on the pricer's high-indication filings (Appendix B); the filed local slopes average to the linear slopes near one-half, 0.478 and 0.512, that a single regression reports. The sign of the curvature, not the count of breaks, is the reported finding. A sensitivity analysis that frees the number of breaks, reported in Appendix B and Figure B.2, leaves the convex pass-through of the smoother and the concave pass-through of the pricer in place. Excluding North Carolina leaves the curvature unchanged: the smoother's filed pass-through is 0.371 below and 0.690 above the knot and the pricer's 0.691 and 0.294, against the full-sample 0.369/0.672 and 0.692/0.256; Appendix C reports the excluded-sample fits and figures in full.

A timing difference reinforces the type distinction. The smoother's median interval from submission to effect is 66.5 days; the pricer's is one day, with 58 percent of its filings effective within a day of submission under a use-and-file posture and 89 percent of the smoother's effective at least 30 days out. Within states with at least five filings each, the smoother is slower in 42 of 44, by a median of 57 days, so the difference is in conduct rather than in the mix of states.

7.4 Quantity migration

Across states, the pricer's local presence is negatively associated with the smoother's exposure growth net of its own approved rate. The pricer's presence is its share of the state's private passenger automobile direct written premium; the smoother's exposure proxy is the log growth of its state private passenger automobile direct written premium over the 2021 through 2023 event less the cumulative approved rate change it obtained on filings effective in that window, so the proxy nets the price channel out of the premium change. Over the 46 states in which both insurers write and the smoother files, the cross-state correlation between presence and the exposure proxy is -0.27 with a t-statistic of -1.9; the partial coefficient controlling for the smoother's approved-rate level is -0.31 with a t-statistic of -2.2. The same correlation computed against the smoother's raw premium growth, which does not net out rate, is -0.20, so netting the approved rate strengthens

the association rather than weakening it: what the presence of the pricer is associated with is exposure rather than price. The sign is stable across the nine estimation windows that contain the whole event, from 2019–2023 through 2021–2025, over which the correlation ranges from -0.34 through -0.26; a window lying outside the event does not carry it (2024–2025, 0.16), the design's placebo window. It survives the exclusion of the prior-approval states of California, New York, and New Jersey at -0.19, where the smaller sample carries a t-statistic of -1.2. The association carries the sign the mechanism predicts, and it is not strong at conventional significance levels; the weight of Hypothesis 4 rests on the national share trajectory, and the cross-state association is read as corroboration rather than as the test. At the national level the pricer's private passenger automobile share rose from 7.3 percent in 2004, in the compilation, to 18.60 percent in 2025 in the NAIC market-share report, converging on the smoother's 18.64 percent; on the published record from 2013 the smoother's share stayed within a band of 16.0 through 18.9 percent, its low falling in 2021, and the compilation places it between 17.8 and 18.6 percent over 2004 through 2012. Figure 5 shows the two trajectories. The pattern matches Hypothesis 4: quantity migrates toward the pricer where the pricer is established.

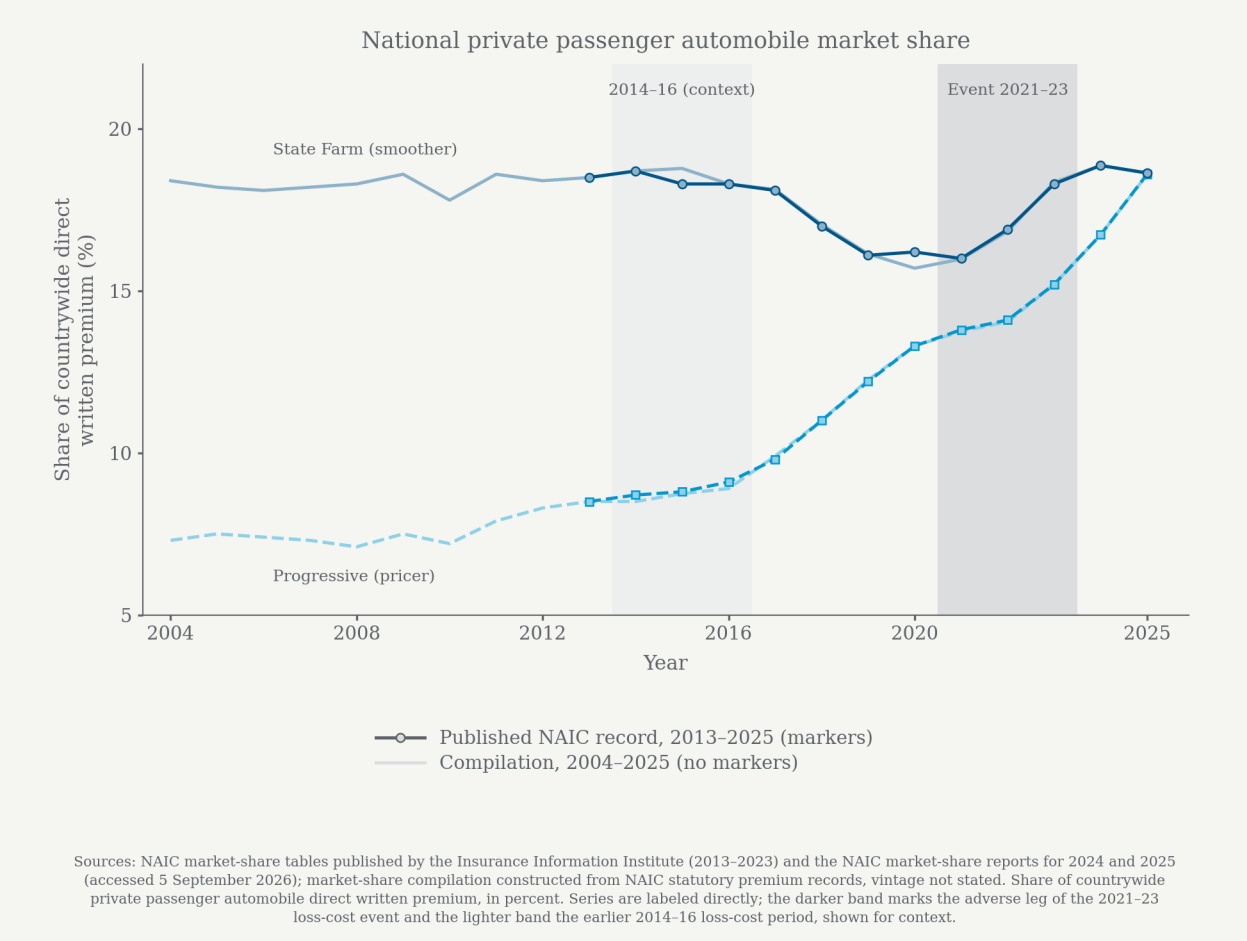


Figure 5. *National private passenger automobile market share, 2004–2025, for the two insurers, with the loss-cost event and the earlier loss-cost period shaded. The horizontal axis is the calendar year; the vertical axis is the share of countrywide private passenger automobile direct written premium in percent. The solid deep-blue line with circular markers is the smoother (State Farm) and the dashed bright-blue line with square markers is the pricer (Progressive) on the published NAIC record, 2013–2025, which the figure uses where it exists; the lighter lines of the same hues without markers are a compilation constructed from NAIC statutory premium records over 2004–2025, which states no vintage or access date, drawn over its whole span so that its agreement with the published record is visible. The two insurers are labeled directly within the plot area; the legend below the chart distinguishes the two series. The darker band marks the adverse leg of the 2021–2023 loss-cost event and the lighter band the earlier 2014–2016 loss-cost period, shown for context, both labeled directly within the plot area. Sources: NAIC market-share tables published by the Insurance Information Institute for 2013 through 2023 and the NAIC market-share reports for 2024 and 2025, accessed 5 September 2026; the compilation as supplied. The compilation agrees with the published record within 0.2 percentage points in 24 of the 26 insurer-years and reproduces 2013, 2014, and 2024 exactly; the smoother's 2015 and 2020 values differ by 0.48 and 0.50 points. The pricer's share rises toward the smoother's over the period.*

8 Discussion

The four findings correspond to the four hypotheses, and the hypotheses are specializations of the Allen and Gale mechanism under the auxiliary assumptions stated in Section 4: the signal-extraction structure behind Hypothesis 1, the retention and segmentation costs behind Hypothesis 2, the partial adjustment, drift, and margin behind Hypothesis 3, and the presence-cost stage game behind Hypothesis 4. The smoother absorbs the transitory part of a loss-cost shock into its underwriting account and surplus, passing through only the persistent part, which produces the convex pass-through of Hypothesis 1 and, under secular loss-cost drift, the one-directional underwriting drain of Hypothesis 3 funded by investment income; the pricer tracks current cost, capping the headline increase at high indication in favor of segmentation, which produces the concave pass-through of Hypothesis 2 and the underwriting build; and where the pricer is established, the policyholders whose overpayment funds the smoother's intertemporal subsidy defect, which produces the quantity migration of Hypothesis 4, the empirical counterpart of Allen and Gale's disintermediation result. The near-equal linear pass-through slopes are not evidence of similar conduct; they are the averages of opposite curvatures.

The case-study design narrows but does not eliminate the alternatives to the type contrast. As Section 6 sets out, a level difference in pass-through from expense or channel does not produce the opposite curvatures; a difference in regulatory stringency is addressed by the survival of the migration association's sign when the prior-approval states are excluded; and a difference in the mix of states is addressed by the within-state paired timing comparison. What two insurers cannot separate is an unobserved firm attribute correlated with both the curvature and the underwriting outcome, a difference in reserve redundancy between the two, or the endogenous intensity of the pricer's presence: the pricer writes nationwide, so its presence varies across states in degree rather than in existence, heaviest where risk heterogeneity makes segmentation most rewarding and a pooled incumbent's low-risk overpayment largest; the final of these is consistent with the disintermediation reading while leaving the strict causal claim outside the reach of the design, as Section 6.3 sets out.

Five limitations bound the reading. First, the curvature is reported by its sign rather than by a count of breaks. With every bootstrap drawing its signs by state, the unsigned supremum-F test rejects the linear model for the smoother and leaves the pricer outside the five percent level, while the directional supremum-t tests of the stated hypotheses reject for both insurers and jointly; a sensitivity analysis that frees the number of breaks puts negligible mass on the linear model for either insurer, and the difference between the two slope changes rejects equality. The convexity of the smoother and the concavity of the pricer are the findings, the between-insurer contrast carries the sharpest rejection, and the count of breaks is not asserted. Second, the high-indication tail is thin for both insurers, so the slope-above estimates rest on relatively few filings, which the leverage control downweights but cannot replace, and the knot at which the slope changes is the upper bound of the admitted support rather than a bend located within it (Appendix B). Third, the evidence is observational; the event is a common shock rather than an assigned treatment, and the cross-state migration association is not an experiment. That association carries the predicted sign but is not strong at conventional significance levels, and the pricer's presence is measured after

the event window over which the exposure proxy is formed, so the migration prediction rests principally on the national share trajectory, with the cross-state association as corroboration. Fourth, the insurer interaction is solved as the equilibrium of a stage game—the pricer's best-response presence against the smoother's funding threshold, with disintermediation obtaining when the former exceeds the latter—but not as the full dynamic stochastic game in which the surplus and the pricer's presence evolve jointly under the regulator's approval rule; that Markov-perfect treatment, whose equilibrium objects two insurers cannot identify, is left to a cross-firm extension. Fifth, two insurers identify a contrast, not a population; extending the pass-through estimation to the full set of national insurers, with the smoother-pricer character treated as a measured firm attribute rather than a label, would convert the contrast into a cross-firm relationship. The findings are consistent with the mechanism; they do not establish it against every alternative.

9 Conclusion

Specializing the Allen and Gale framework to personal automobile rate-setting turns their welfare results into testable conduct predictions and turns their disintermediation result into a measurable market-structure prediction. On filing-level, statutory, and premium data for the two insurers that occupy the intermediary and spot-market roles, the predictions hold: convex pass-through and a surplus-funded underwriting drain for the smoother, concave pass-through, the less settled of the two curvature readings, and an underwriting build for the pricer, and quantity migration toward the pricer where it is established. The smoother's conduct is the rate-setting form of building surplus in good states and drawing it down in bad; the pricer's is the rate-setting form of pricing to current cost; and the convergence of their shares is the rate-setting form of the constraint that competition from a spot market places on intertemporal smoothing. The evidence is an event study on the two insurers that occupy the polar roles; the next step is to treat the smoother-pricer character as a measured firm attribute and estimate the pass-through curvature across the full set of national insurers, which would convert the two-insurer contrast into a cross-firm relationship.

A Proofs

This appendix proves the four propositions of Section 4, each proof self-contained and stating the condition under which its result holds.

A.1 Proof of Proposition 1

Under (1)–(2), the posterior mean is $a_I(\iota) = \psi(\iota)\,\mathbb{E}[g \mid \iota, \text{slab}]$ since $\mathbb{E}[g \mid \iota, \text{spike}] = 0$, and the within-slab conditional mean is the Gaussian shrinkage $\delta + \sigma_g^2(\sigma_g^2+\sigma_\varepsilon^2)^{-1}(\iota-\delta)$, which gives (3). The signal probability $\psi(\iota)$ is a logistic function of a quadratic in ι,

$$\psi(\iota) = \Big[1 + \tfrac{1-q}{q}\sqrt{\tfrac{\sigma_g^2+\sigma_\varepsilon^2}{\sigma_\varepsilon^2}}\,\exp\!\big(\tfrac{(\iota-\delta)^2}{2(\sigma_g^2+\sigma_\varepsilon^2)} - \tfrac{\iota^2}{2\sigma_\varepsilon^2}\big)\Big]^{-1},$$

whose exponent is a quadratic in ι with leading coefficient $-c_2$, where $c_2 = \sigma_g^2/\big(2\sigma_\varepsilon^2(\sigma_g^2+\sigma_\varepsilon^2)\big) > 0$ since $\sigma_\varepsilon^2 < \sigma_g^2+\sigma_\varepsilon^2$, so the log-odds of the persistent state—the negative of that exponent up to a constant—is a convex quadratic with leading coefficient c_2. The log-odds of the persistent state therefore attain a minimum at $\iota^* = -\delta\sigma_\varepsilon^2/\sigma_g^2 \le 0$ and increase in ι for all $\iota > \iota^*$, so $\psi'(\iota) > 0$ over the positive indications that dominate the data: a small indication is read as noise and discounted, a large one is better explained by the diffuse persistent state and is passed through.

Write $m(\iota) = \delta + k(\iota-\delta)$ with $k = \sigma_g^2(\sigma_g^2+\sigma_\varepsilon^2)^{-1} \in (0,1)$, so that $a_I = \psi m$ and

$$a_I'(\iota) = \psi'(\iota)\,m(\iota) + \psi(\iota)\,k, \qquad a_I''(\iota) = \psi''(\iota)\,m(\iota) + 2\psi'(\iota)\,k.$$

The condition $\psi(0) \le \tfrac{1}{2}$ does the work at the origin: with $\sigma(\cdot)$ the logistic function, $\psi'' = \sigma'(L)\big[L'' + (L')^2(1-2\psi)\big]$, and while $\psi \le \tfrac{1}{2}$ both bracketed terms are non-negative—$L'' = 2c_2 > 0$ from the convex log-odds quadratic above—so $\psi'' > 0$; with $m(\iota) = \delta(1-k) + k\iota > 0$ for $\iota \ge 0$ and $\delta \ge 0$, it follows that $a_I'' = \psi'' m + 2\psi' k > 0$ at least until ψ crosses one-half, so the pass-through steepens from the origin. Without the condition the proposition fails: where the prior weight q is large, the slab is barely more diffuse than the noise (σ_g small relative to σ_ε), and the drift is moderate relative to σ_ε, $\psi(0)$ exceeds one-half and $a_I''(0) < 0$ is attainable ($q = 0.95$, $\delta = 1$, $\sigma_g = 0.1$, $\sigma_\varepsilon = 1$ gives $\psi(0) = 0.92$ with $a_I''(0) < 0$), so the restriction excludes that region rather than being a convenience. As ι grows, $\psi \to 1$ and $\psi' \to 0$ at a Gaussian rate while m grows linearly, so ψ'' turns negative at saturation and a_I'' changes sign. Let $\bar\iota$ be the first such sign change; a_I is strictly convex on $(0,\bar\iota)$ and a_I' is increasing there, which is the statement of the proposition. Beyond $\bar\iota$ the slope declines. Its limit is the ceiling k, and the approach is from above: $a_I'(\iota) - k = \psi'(\iota)m(\iota) - \big(1-\psi(\iota)\big)k$, and with $1-\psi \approx e^{-L(\iota)}$ and $\psi' \approx L'(\iota)e^{-L(\iota)}$, where L is the log-odds, the difference has the sign of $L'(\iota)m(\iota) - k$, which is positive for large ι because L' grows linearly and m grows linearly. The local slope therefore overshoots k before returning to it, and the convexity claim is confined to $(0,\bar\iota)$. The estimation sample lies in that interval, where the local slope is increasing; Hypothesis 1 is the statement that it does so. □

A.2 Proof of Proposition 2

The pricer chooses the headline change a and segmentation s to meet required revenue $\rho(\iota) = a + \phi s$ at minimum cost $L(a) + \kappa K(s)$, where L is the retention cost and K the segmentation cost. The retention cost is assumed to satisfy $L' > 0$, $L'' > 0$, and $L''' > 0$, the final of which is the form the rising-elasticity condition $\eta'(a) > 0$ is taken to have; the segmentation cost is taken quadratic, so that $K'' > 0$ is constant. The first-order condition equates the marginal cost of the two channels, $L'(a) = (\kappa/\phi)\, K'\big((\rho(\iota) - a)/\phi\big)$. Differentiating with respect to ι gives $da/d\iota = \rho'(\iota)\left[1 + \phi^2 L''/(\kappa K'')\right]^{-1} \in (0, 1)$; with the normalization $\rho'(\iota) = 1$ of Section 4.5, this is (4) with $\mathcal{E} = \phi^2 L''/(\kappa K'')$. Because $L''' > 0$ raises L'' as a grows while the quadratic K holds K'' constant, $\mathcal{E}$ is increasing in ι along the optimal path, so $da/d\iota$ is decreasing in ι and $a_C''(\iota) < 0$. With $L''' = 0$ the pass-through would be linear, so the strict inequality carries the concavity. □

A.3 Propositions 3 and 4

Proposition 3 follows from the smoother's partial adjustment of the rate level toward the cost level, $A_t - A_{t-1} = \lambda(R_t - A_{t-1})$ with $\lambda \in (0, 1)$. Writing $G_t = R_t - A_{t-1}$ and using $\mathbb{E}[\Delta R_t] = q\delta$, the gap evolves in expectation as $G_{t+1} = q\delta + (1 - \lambda)G_t$, converging to $G^* = q\delta/\lambda$, so the level shortfall $R_t - A_t = (1 - \lambda)G_t$ converges to $q\delta(1 - \lambda)/\lambda$ and the underwriting result $u_t^I = A_t - R_t$ converges to $-q\delta(1 - \lambda)/\lambda < 0$. The drain rises with the drift $q\delta$ and with the degree of smoothing $1 - \lambda$; the per-period change $a_t - \iota_t$ averages zero, the rate and cost levels growing at the same rate, while the level gap is a persistent shortfall. The pricer adjusts fully, $\lambda = 1$, so its level gap is zero and $a_C(\iota_t)$ tracks ι_t to first order; full adjustment alone would give $\mathbb{E}[u_t^C] = 0$; the margin $\mu > 0$ is carried by the pricer's objective of Section 4.3, which maximizes the per-period underwriting result, and gives $\mathbb{E}[u_t^C] = \mu > 0$. The underwriting build of the pricer is that margin, an assumption of its objective rather than a result of Proposition 2. The investment term sustains the smoother's surplus where $rB_t \geq -u_t P_t$; in the data this holds in expectation, mean net investment income of \$2.94 billion per year against a mean underwriting result of $-\$2.53$ billion. The surplus recursion $B_{t+1} = (1 + r)B_t + u_t P_t$ sustains the smoother's surplus through the investment return rB_t, which funds the steady shortfall. Proposition 4 follows from the funding budget and the pricer's optimization. The retained low-risk overpayment $(1 - m)\theta(a_I - c_L)$ covers the subsidy $(1 - \theta)(c_H - a_I)$ if and only if $m \leq m^* = 1 - (1 - \theta)(c_H - a_I)/[\theta(a_I - c_L)]$. Differentiating the threshold gives $dm^*/da_I = (1 - \theta)(c_H - c_L)/[\theta(a_I - c_L)^2] > 0$, so a higher pooled rate relaxes the budget taken by itself. The pricer maximizes $m\theta\pi(a_I) - \Gamma(m)$, with first-order condition $\theta\pi(a_I) = \Gamma'(m^C)$ and $\Gamma'' > 0$ ensuring a maximum, so $m^C = (\Gamma')^{-1}(\theta\pi(a_I))$ rises in $\theta\pi$ and falls in the marginal cost of presence, and $dm^C/da_I = \theta\pi'(a_I)/\Gamma''(m^C) > 0$. Raising a_I is therefore self-defeating if and only if condition (5) holds, in which case the best-response presence rises faster than the threshold it must stay below. The equilibrium quantity loss is $m^C\theta$; where $m^C > m^*$ the budget fails at the pricer's best response and the smoothed pool unwinds, the disintermediation of Allen and Gale's Proposition 5. □

B Changepoint and Leverage-Control Methodology

The pass-through curvature is a question about the slope of the filed change on the indicated rate change as a function of the indication. It is carried by a continuous broken-stick model in which a break changes the slope alone, with a single shared error variance. The break τ is placed by minimizing the weighted residual sum of squares over a grid spanning the tenth through the eightieth indication percentile, with a minimum of fifteen filings on each side of the break.

The data are heteroskedastic. Taking the residual of the filed change around the single-slope linear fit, its variance in the top indication quartile is 6.1 times its variance in the bottom quartile for the smoother and 12.3 times for the pricer, and the squared residual is correlated with the indication at 0.49 for the smoother and 0.34 for the pricer. The sparse, high-variance tail of large indications therefore exerts leverage on the slope and on break placement. The control is feasible generalized least squares: weights are the inverse of a locally estimated variance, taken from a LOWESS scatterplot smoother of the squared residuals around a robust LOWESS mean so that a bend in the mean does not contaminate the variance estimate. Both smoothers run at a span of 0.55; the mean smoother uses ten robustness iterations and the variance smoother three; the variance estimate is floored at its fifth percentile, and the largest weight is 51 times the smallest for the smoother and 37 times for the pricer. The knot grid carries sixty equally spaced points between the tenth and eightieth indication percentiles, and the break is confined to the tenth-through-eightieth indication percentile so that it does not rest on the tail.

The knot is a boundary solution. For both insurers, on the filed and the approved change alike, the weighted residual sum of squares declines across the whole support and is smallest at its upper bound, so the knot reported, 20.38 percent for the smoother and 12.20 for the pricer, is the bound of the admitted support rather than a minimum located within it, and the slope above it is the slope over the top quintile of each insurer's indications; the position of the bend inside the support is not identified by the criterion. The sign of the curvature does not depend on the bound. With the support narrowed to the seventieth percentile the smoother's filed slopes are 0.371 below and 0.558 above a knot of 17.62 percent and the pricer's 0.691 and 0.410 about 10.11; widened to the ninetieth, they are 0.381 and 0.852 about 24.94 for the smoother and 0.683 and -0.113 about 16.68 for the pricer, the knot at the bound in every case, the smoother's pass-through convex and the pricer's concave throughout. One exception is reported: on the sample excluding North Carolina with the support narrowed to the seventieth percentile, the pricer's weighted criterion is smallest at an interior knot of -0.18 percent, where the fit is 0.446 below and 0.704 above, a convex reading. The pricer's concavity therefore rests on a support that reaches its high-indication filings, which is where the bend the mechanism predicts lies, and on the tail whose thinness the second limitation of Section 8 states; the reversible-jump sampler below shares the eightieth-percentile support. The fixed constants of the weighting were each halved and multiplied by one and a half. The smoother's convex fit holds under every variation and without the floor, its slopes within 0.355 through 0.376 below the knot and 0.665 through 0.723 above it. The pricer's concave fit holds under every variation but one: with the span widened to 0.825 the weighted criterion is smallest at an interior knot of -0.15 percent, where the fit is 0.433 below and 0.705 above, the near-zero competitor of the North Carolina-excluded case; the unweighted broken-stick reported above is

concave. A state-cluster bootstrap of the filings, states drawn with replacement with the weights held at their sample values, over 9,999 replications from a fixed seed, places the knot at the upper bound of the eightieth-percentile support in 81 percent of replications for the smoother and 63 percent for the pricer, at median knots of 20.20 and 11.96 percent; the slope change keeps its sample sign in 87 percent of the smoother's replications and 66 percent of the pricer's, and on the ninetieth-percentile support the knot sits at the bound in 31 and 28 percent of replications with the sign kept in 92 and 77. Re-estimating the variance weights within every replication moves these shares up rather than down, to 85 and 63 percent at the bound and 91 and 68 percent keeping the sign on the eightieth-percentile support. The pricer's concavity is the less settled of the two readings, consistent with its larger p-values above; the gap closes as the support widens (Figure B.3). Figure B.1 draws the weighted criterion against the candidate knot on the full sample and on the sample excluding North Carolina over the tenth-through-ninetieth percentile: the smoother's criterion declines through the bound to the edge of the wider support, and the pricer's carries the competing minimum near zero indication before declining through the bound.

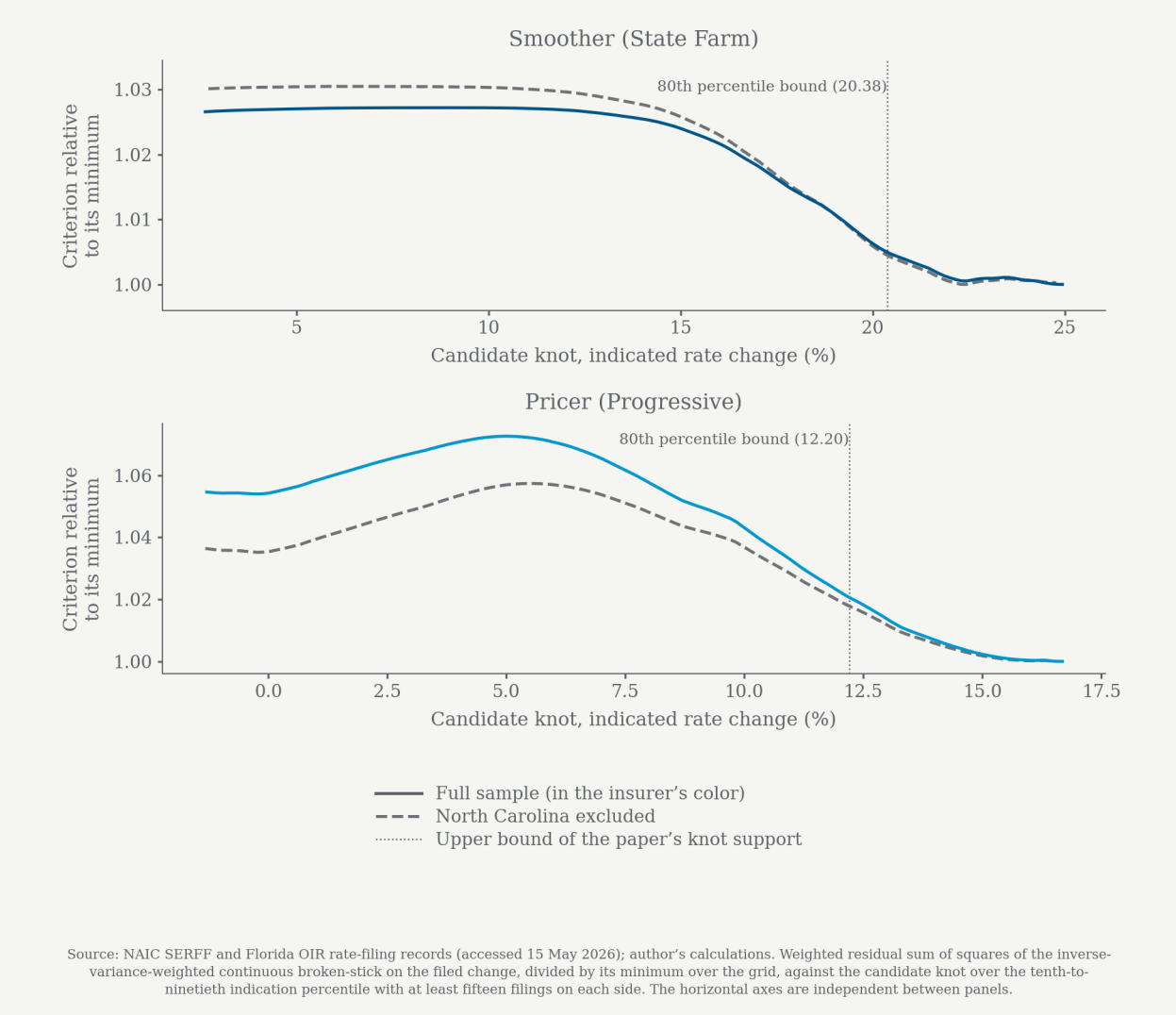


Figure B.1. *Criterion profile of the broken-stick knot search, filed change, 2021–2023, one panel per insurer, the smoother (State Farm) above the pricer (Progressive). The horizontal axis is the candidate knot in percent of indicated rate change, on an independent scale per panel; the vertical axis is the weighted residual sum of squares of the inverse-variance-weighted continuous broken-stick at that knot, divided by its minimum over the grid. The solid line in the insurer's color is the full sample and the dashed gray line the sample excluding North Carolina; the dotted vertical line marks the upper bound of the paper's knot support, the eightieth indication percentile of the full sample, and the grid runs from the tenth through the ninetieth percentile with at least fifteen filings on each side. State Farm $N = 477$ and 475, Progressive $N = 802$ and 799. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations. The criterion is still declining at the bound in every case; the pricer's profile carries a second, local minimum near zero indication.*

The slope change is supported against the linear null by a weighted wild-bootstrap supremum-F test, which takes the maximum F-statistic for the slope-change term over the break grid and simulates its null distribution by resampling the weighted residuals of the linear fit with random

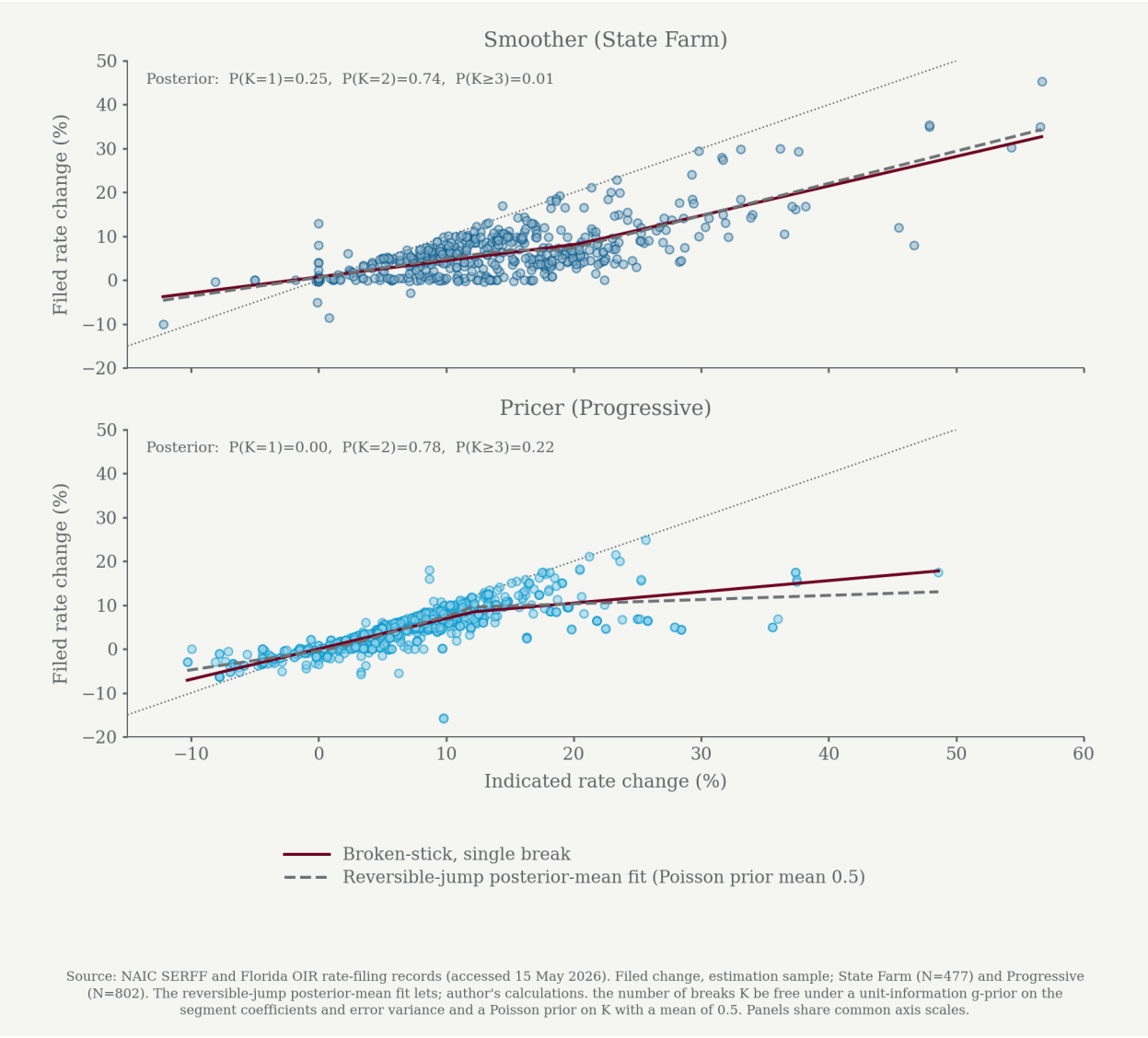
signs drawn by state, over 4,999 replications from a fixed seed, repeating the knot-grid search in every replication while holding the variance weights at their sample estimates: under that algorithm the test rejects the linear null at $p = 0.046$ for the smoother and reaches $p = 0.069$ for the pricer. Every bootstrap in this paper draws its signs by state, because a filing is one of several the same insurer makes in the same state and the within-state correlation is what the clustering accommodates; drawing signs independently by filing treats those filings as independent observations and moves the two p-values to 0.044 and 0.0002, the pricer's by a factor of more than three hundred, because its high-indication filings concentrate in a few states. Re-estimating the variance weights within every replication moves the smoother's p-value to 0.108 and the pricer's to 0.117, so neither insurer's single-break rejection is robust to the treatment of the estimated weights. The curvature inference does not rest on that test alone. A state-clustered wild bootstrap over 9,999 replications, studentized by the cluster-robust standard error and computed with the knot held at its sample value, places the smoother's slope change of 0.304 at a 95 percent interval of $[0.056, 0.552]$ and the pricer's change of -0.437 at $[-0.767, -0.110]$. Testing each against zero under the same clustering, with the linear null imposed on the resampling, gives $p = 0.026$ for the smoother and $p = 0.086$ for the pricer: the two procedures agree for the smoother and diverge for the pricer, whose restricted residuals carry the large break the null denies and so inflate its null distribution. Hypotheses 1 and 2 are directional—the smoother's local slope rises, the pricer's falls—so each admits a one-sided test in the stated direction: from the same null draws, $p = 0.013$ for the smoother and $p = 0.043$ for the pricer. A directional supremum-t statistic—the maximum over the knot grid of the signed t-statistic of the slope-change term, with the grid re-searched in every replication and the signs drawn by state, over 9,999 replications—rejects the linear model in the stated direction at $p = 0.022$ for the smoother and $p = 0.036$ for the pricer; and the theory's joint prediction, a convex smoother and a concave pricer, rejects by intersection–union at $p = 0.036$, the maximum of the two one-sided values, a bound valid under any dependence between the two samples. The difference in slope changes between the two insurers, 0.740 with a cluster-robust standard error of 0.172, gives $z = 4.31$ and rejects equality at $p = 0.002$ under the same clustered, studentized test with a common slope change imposed. The contrast carries the sharpest rejection, and on the paper's support the directional tests place each insurer's curvature on its own footing at the five percent level; Figure B.3 below traces both across the support bound. The contrast survives within-state identification: pooling the two insurers with a state fixed effect, an insurer-specific linear slope, and an insurer-specific slope change at each insurer's sample knot, with one bootstrap sign per state shared across both insurers' filings in that state, the difference in slope changes is 0.613 with a cluster-robust standard error of 0.178 ($z = 3.44$), a 95 percent studentized interval of $[0.213, 1.008]$, and a null-imposed $p = 0.009$ over 9,999 replications. The state fixed effects absorb every state-level condition—the regulatory regime, the loss-cost environment, the filing law—so the difference is identified from within-state variation in the two insurers' responses to the same indications rather than from where the two insurers file; 48 of the 50 sample states carry filings from both. Tests of the curvature sign that do not locate the bend have little power against it, because the knot sits at the upper bound of its support, the eightieth percentile of each insurer's indication distribution: a quadratic in the indication carries the predicted sign for both insurers but does not resolve it ($p = 0.43$ and 0.42), and a slope change fixed at the weighted median indication misses the bend entirely. Locating the slope change is what the knot grid provides, and the cost of that

search is priced into the supremum-F null distribution by repeating it in every replication. The contrast survives the weighting and the support: the unweighted broken-stick gives $0.336 \to 0.713$ for the smoother and $0.733 \to 0.145$ for the pricer, so the opposite curvatures are not an artifact of the variance weights, and re-estimating on the common indication support $[-10.3, 48.6]$, which retains 473 of 477 and all 802 filings, gives $0.351 \to 0.666$ and an unchanged pricer fit.

As a sensitivity analysis, the single break of the broken-stick is relaxed. A continuous reversible-jump sampler[26] lets the number of breaks be free, with the segment coefficients, conditional on the error variance, under a unit-information g-prior with $g = n$, the error variance under a Jeffreys prior, both integrated out analytically, knot locations the order statistics of draws uniform on the tenth-through-eightieth percentile grid with at least fifteen observations per segment[27] and a Poisson prior on the number of breaks. The sampler is unweighted, so relative to the feasible generalized-least-squares fit it varies the variance treatment together with the break count; the unweighted broken-stick of Section 7 carries the same opposite curvatures, which is what makes the two comparable. The posterior places less than 0.005 mass on the no-break linear model for either insurer, and the posterior-mean fit preserves the convex pass-through of the smoother and the concave pass-through of the pricer. The curvature is not sensitive to the prior on the number of breaks: across Poisson prior means of 0.25, 0.5, 1, and 2 the break-count posterior shifts toward more breaks as the prior mean rises, while the posterior-mean fit's local slope stays within 0.381 through 0.407 below the smoother's knot and 0.728 through 0.744 above it, and within 0.627 through 0.632 and 0.076 through 0.099 for the pricer. Figure B.2 shows the posterior-mean fit at a Poisson prior mean of one-half against the broken-stick. The sign of the curvature, not the count of breaks, is the reported finding.

[26] Peter J. Green, "Reversible Jump Markov Chain Monte Carlo Computation and Bayesian Model Determination," *Biometrika* 82, no. 4 (1995): 711–732.

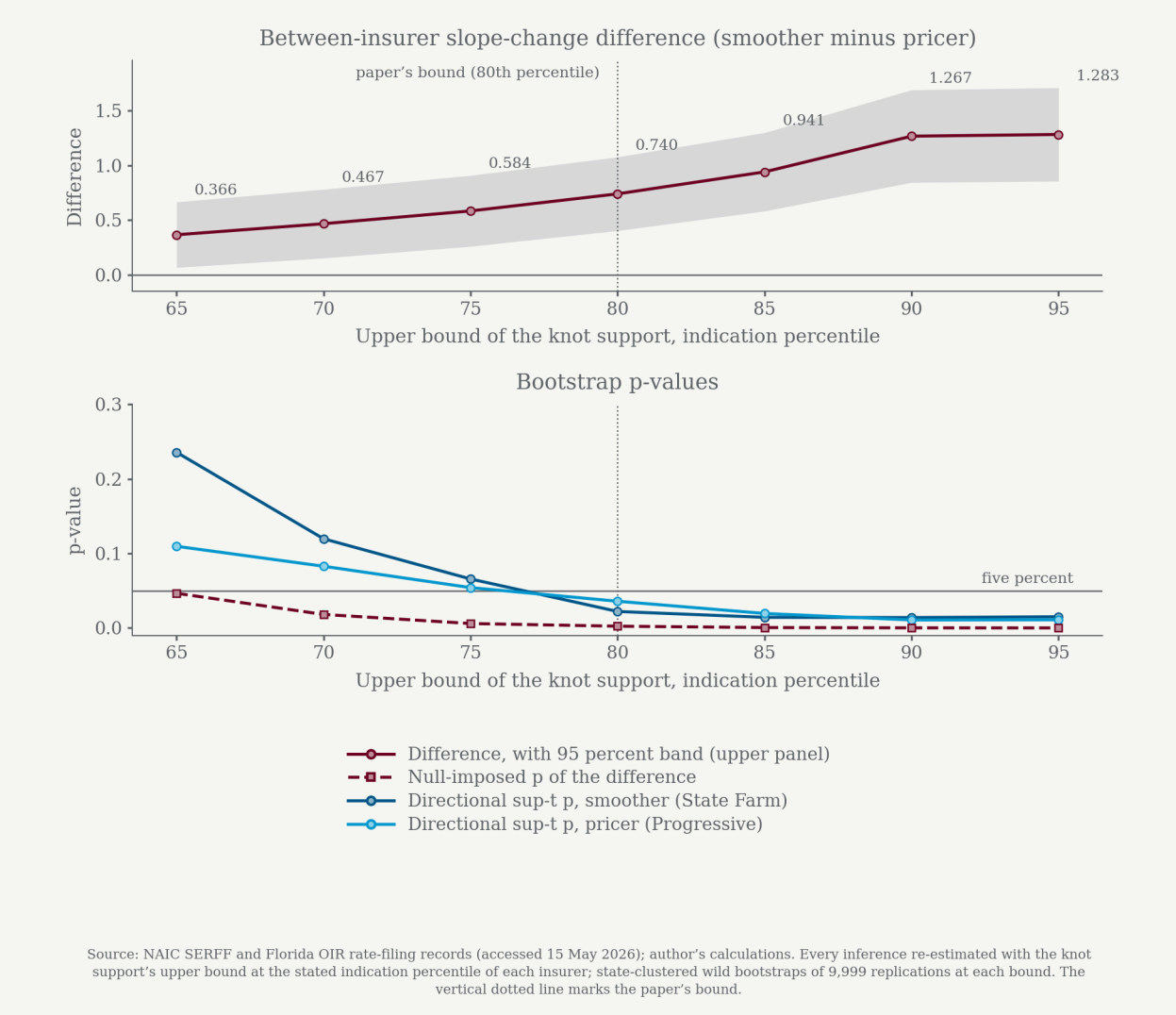
[27] Arnold Zellner, "On Assessing Prior Distributions and Bayesian Regression Analysis with g-Prior Distributions," in *Bayesian Inference and Decision Techniques: Essays in Honor of Bruno de Finetti*, ed. Prem K. Goel and Arnold Zellner (Amsterdam: North-Holland, 1986), 233–243; Robert E. Kass and Larry Wasserman, "A Reference Bayesian Test for Nested Hypotheses and Its Relationship to the Schwarz Criterion," *Journal of the American Statistical Association* 90, no. 431 (1995): 928–934.



Source: NAIC SERFF and Florida OIR rate-filing records (accessed 15 May 2026). Filed change, estimation sample; State Farm (N=477) and Progressive (N=802). The reversible-jump posterior-mean fit lets; author's calculations. the number of breaks K be free under a unit-information g-prior on the segment coefficients and error variance and a Poisson prior on K with a mean of 0.5. Panels share common axis scales.

Figure B.2. *Sensitivity of the pass-through curvature to freeing the number of breaks, filed change, 2021–2023, one panel per insurer, the smoother (State Farm) above the pricer (Progressive). The horizontal axis is the indicated rate change in percent and the vertical axis the filed rate change in percent, on scales common to both panels; the dotted line is the 45-degree identity. Points are filings in the insurer's color. The solid line is the inverse-variance-weighted broken-stick fit with a single break, the primary specification of Figure 4; the dashed line is the posterior-mean fit of a reversible-jump sampler that lets the number of breaks K be free, under a unit-information g-prior on the segment coefficients and error variance and a Poisson prior on K with a mean of one-half. Knot locations are supported on the tenth-through-eightieth indication percentile, at most four breaks are entertained, and each segment is required to hold at least fifteen filings; the chain is run for 80,000 draws from a fixed seed, of which the first 20,000 are discarded. The annotation in each panel reports the posterior probability of K breaks. State Farm $N = 477$, Progressive $N = 802$. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations. The posterior-mean fit tracks the broken-stick and preserves the convex pass-through of the smoother and the concave pass-through of the pricer.*

The upper bound of the knot support is the one tuning choice of the estimation that the data do not fix, and Figure B.3 traces the inference across it, every test re-estimated with the bound at the sixty-fifth through the ninety-fifth indication percentile of each insurer. The between-insurer difference rises with the bound, from 0.366 (cluster-robust standard error 0.153, $z = 2.40$) at the sixty-fifth percentile through the 0.740 of the paper's eightieth to 1.283 ($z = 5.89$) at the ninety-fifth, and levels off beyond the ninetieth; its null-imposed p-value is 0.047 at the sixty-fifth percentile and below 0.05 at every bound, one replication of 9,999 reaching the observed statistic at the ninetieth and none at the ninety-fifth. The individual insurers' directional tests cross the five percent level between the seventy-fifth and the eightieth percentile, at $p = 0.066$ for the smoother and 0.054 for the pricer at the seventy-fifth, and from the eighty-fifth the two insurers' directional p-values lie within a hundredth of each other. The paper's bound is therefore the narrowest at which each insurer's curvature stands on its own, while the contrast between the two stands at every bound.



Source: NAIC SERFF and Florida OIR rate-filing records (accessed 15 May 2026); author's calculations. Every inference re-estimated with the knot support's upper bound at the stated indication percentile of each insurer; state-clustered wild bootstraps of 9,999 replications at each bound. The vertical dotted line marks the paper's bound.

Figure B.3. *The between-insurer inference across the upper bound of the knot support, filed change, 2021–2023. The horizontal axis of both panels is the upper bound of the knot support as an indication percentile of each insurer's sample, from the sixty-fifth through the ninety-fifth; the dotted vertical line marks the paper's eightieth. The upper panel plots the difference in slope changes, smoother minus pricer, at the knot each bound selects, with its 95 percent band from the cluster-robust standard error, and labels each value. The lower panel plots three bootstrap p-values against the five percent line: the null-imposed p-value of the difference (maroon, dashed), and the directional supremum-t p-values of the smoother (State Farm, deep blue) and the pricer (Progressive, bright blue), each from a state-clustered wild bootstrap of 9,999 replications at that bound. State Farm $N = 477$, Progressive $N = 802$. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations. The difference rises with the bound and rejects at every bound; the directional tests cross five percent between the seventy-fifth and the eightieth percentile.*

The difference is also tested against a null that rests on no resampling of residuals. Under the null that the insurer label carries no information about a filing's pass-through curvature, the labels

are exchangeable within a state, so the two samples are pooled and the labels permuted among the filings of each state, each state's counts of smoother and pricer filings held fixed; for each permuted insurer the variance weights are re-estimated and the knot re-searched as in the sample fit, and the difference in slope changes and its cluster-robust studentized form are recomputed, over 9,999 permutations from a fixed seed. Four of the 9,999 permutations reach the observed difference of 0.740 (the largest permuted value is 0.837), so $p = 0.0005$ with the observed configuration counted, and 82 reach the observed z of 4.31, $p = 0.008$. The permuted difference is centered at 0.127 rather than at zero, with a standard deviation of 0.108, a property of a permutation that holds each state's insurer counts fixed; the p-values are computed on the absolute permuted statistic without recentering. The replication counts reported here and in Section 7 are 4,999 for the supremum-F tests and 9,999 for the clustered bootstraps, the knot bootstrap, and the permutations.

The primary dependent variable is the insurer's filed (proposed) change, which the filing record reports separately from the approved change. The two coincide for most filings—the regulator approves as filed in 90 percent of the smoother's filings and 92 percent of the pricer's—and where they differ, the approved change is below the filed change, a censoring haircut, for 4.4 percent of the smoother's filings at a median of 1.2 percentage points and for 4.6 percent of the pricer's at a median of 2.5 points. About five percent of filings record a proposed change below the approved change, which is internally inconsistent for a single filing; these are floored at the approved change, and the sign of the curvature is unchanged across the as-filed, floored, and dropped treatments of them.

C North Carolina Sensitivity

The estimation sample retains North Carolina. The indicated rate change recorded there is the North Carolina Rate Bureau's industry-wide indication—identical across the two insurers in each year both face it—while the proposed and approved changes are the carrier's own, so a North Carolina observation pairs the Bureau's indication with the carrier's response rather than the carrier's response to its own indication. This appendix re-estimates the pass-through on the sample that excludes North Carolina and sets the estimates beside the full-sample estimates. The check is distinct from the changepoint sensitivity of Appendix B: that analysis frees the number of breaks on the full sample, while the check here holds the single-break specification fixed and removes one state from the sample.

Excluding North Carolina leaves 475 filings for the smoother, drawn from 47 states, and 799 for the pricer, drawn from 49. On the excluded sample the smoother's filed pass-through rises from 0.371 below an indication near 20 percent to 0.690 above, and the pricer's falls from 0.691 below an indication near 12 percent to 0.294 above, against the full-sample 0.369 and 0.672 for the smoother and 0.692 and 0.256 for the pricer. The approved fits move with the filed fits: the smoother from 0.367 to 0.653 and the pricer from 0.684 to 0.288, against the full-sample 0.366 and 0.636 for the smoother and 0.686 and 0.228 for the pricer. The single-slope linear fits on the excluded sample are 0.482 for the smoother and 0.528 for the pricer on the filed change and 0.471 and 0.512 on the approved change, against 0.478 and 0.512 on the filed change and 0.467 and 0.497 on the approved change in the full sample. Table C.1 sets the broken-stick estimates side by side.

Table C.1. *Pass-through slope estimates on the full sample and on the sample excluding North Carolina. Each row is one insurer and one dependent variable, the filed change (the proposed change floored at the approved change) or the approved change. "Below" and "Above" are the local pass-through slopes below and above the estimated knot from the inverse-variance-weighted continuous broken-stick fit by feasible generalized least squares (Appendix B); "Knot" is the knot location in percent of indicated rate change. The full sample retains North Carolina (State Farm $N = 477$, Progressive $N = 802$); the excluded sample drops it (State Farm $N = 475$, Progressive $N = 799$). In every row the knot is the upper bound of the admitted support, the eightieth indication percentile of the sample (Appendix B). Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations.*

		Full sample			Excluding North Carolina		
Insurer	Dependent	Below	Above	Knot	Below	Above	Knot
State Farm	Filed	0.369	0.672	20.38	0.371	0.690	20.32
State Farm	Approved	0.366	0.636	20.38	0.367	0.653	20.32
Progressive	Filed	0.692	0.256	12.20	0.691	0.294	12.20
Progressive	Approved	0.686	0.228	12.20	0.684	0.288	12.20

The sign of the curvature is unchanged: the smoother's pass-through is convex and the pricer's concave on the excluded sample, as on the full sample. Excluding North Carolina raises the pricer's high-indication filed slope from 0.256 to 0.294, consistent with the North Carolina filings sitting at a high indication against a lower carrier outcome, and does not reverse the concavity. Figures C.1

and C.2 reproduce the locally weighted fit of Figure 3 and the leverage-controlled fit of Figure 4 on the excluded sample.

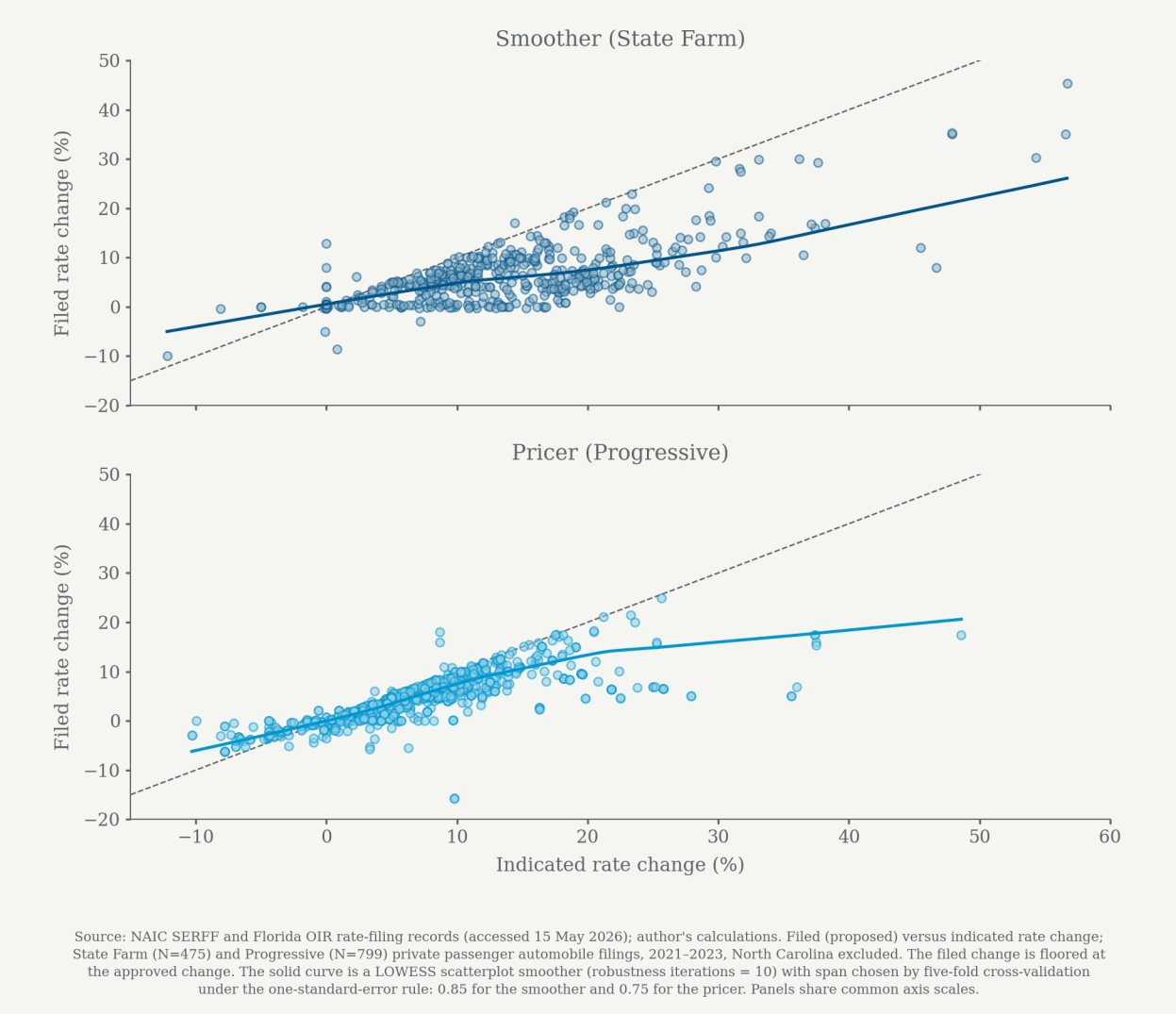
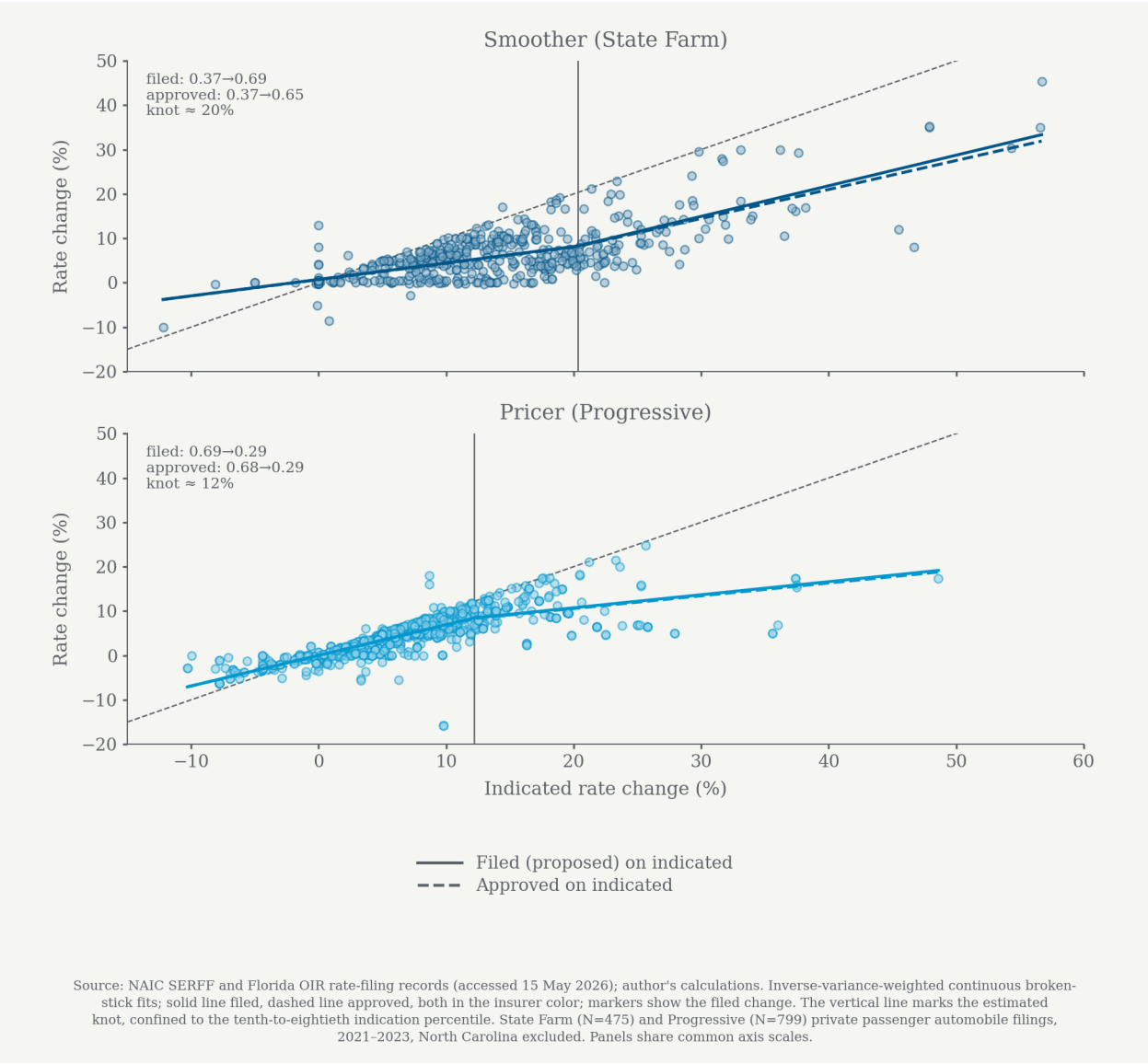


Figure C.1. *Filed versus indicated rate change at the filing level on the sample excluding North Carolina, 2021–2023, one panel per insurer. The horizontal axis is the indicated rate change in percent; the vertical axis is the filed (proposed) rate change in percent; the dashed line is the 45-degree identity. The solid curve is a LOWESS scatterplot smoother (Cleveland 1979) with robustness iterations set to ten and span selected by five-fold cross-validation under the one-standard-error rule (Hastie, Tibshirani, and Friedman 2009), span 0.85 for the smoother and 0.75 for the pricer. State Farm* $N = 475$*, Progressive* $N = 799$*; North Carolina excluded. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations. The scatterplot smoother bends downward at high indication for the pricer and is closer to linear for the smoother, as in Figure 3.*



Source: NAIC SERFF and Florida OIR rate-filing records (accessed 15 May 2026); author's calculations. Inverse-variance-weighted continuous broken-stick fits; solid line filed, dashed line approved, both in the insurer color; markers show the filed change. The vertical line marks the estimated knot, confined to the tenth-to-eightieth indication percentile. State Farm (N=475) and Progressive (N=799) private passenger automobile filings, 2021–2023, North Carolina excluded. Panels share common axis scales.

Figure C.2. *Leverage-controlled pass-through on the insurers' own filed (proposed) changes, with the approved fit overlaid, on the sample excluding North Carolina; inverse-variance-weighted continuous broken-stick fits, 2021–2023, one panel per insurer. The horizontal axis is the indicated rate change in percent and the vertical axis the rate change in percent; the dashed gray line is the 45-degree identity and the vertical line marks the estimated knot. Both fits are drawn in the insurer's color: the solid line is the fit to the filed change and the dashed line the fit to the approved change; markers show the filed change. The estimator and the tenth-through-eightieth-percentile knot restriction match Figure 4. State Farm $N = 475$, Progressive $N = 799$; North Carolina excluded. Source: SERFF and Florida OIR (accessed 15 May 2026); author's calculations.*

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