Asymmetric and Quantile-Dependent Effects of Health Insurance Policies on Pharmaceutical Expenditure: Evidence from a QARDL Approach in the United States

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Abstract

This study investigates the asymmetric, quantile-dependent effects of public and private health insurance configurations on pharmaceutical expenditures in the United States. Utilizing time-series data, we employ the Quantile Autoregressive Distributed Lag (QARDL) framework to capture non-linear behavioral adjustments across the expenditure distribution (). Wald tests robustly reject parameter constancy, confirming that traditional mean-based models mask critical structural heterogeneities. The error correction mechanism exhibits a U-shaped adjustment pattern, indicating rapid behavioral corrections at the distributional extremes.

Our findings reveal distinct microeconomic regimes: at the lower tail (), binding liquidity constraints create high price elasticity on the extensive margin, making low-expenditure patients highly vulnerable to treatment abandonment. Conversely, at the upper tail (), demand for specialty therapeutics is perfectly price-inelastic, rendering uniform cost-sharing a driver of direct financial toxicity rather than an effective tool to control moral hazard. This structural variance highlights a "distributional paradox" in uniform health reforms like the Inflation Reduction Act. We conclude that maximizing healthcare welfare requires a shift away from one-size-fits-all cost-sharing toward targeted, Value-Based Insurance Designs (VBID) that protect access at the bottom while curbing supply-side pricing power at the top.

Keywords: Pharmaceutical Expenditure; Health Insurance Design; QARDL Approach; Distributional Paradox; Price Elasticity.

JEL Classification Codes: I13, I18, C32, C51.

How to cite this article: Saadia A, Narimene D, Hassiba A, Hacene B, Ahmed B, Mostapha BM. Asymmetric and Quantile-Dependent Effects of Health Insurance Policies on Pharmaceutical Expenditure: Evidence from a QARDL Approach in the United States. Int J Drug Deliv Technol. 2026;16(69s):1337-1352. DOI: 10.25258/ijddt.16.69s.132

I. Introduction

The fiscal trajectory of contemporary healthcare systems is fundamentally bound to the dynamics of pharmaceutical pricing and consumption. Within the global healthcare landscape, the United States occupies a highly anomalous position; as the world's premier pharmaceutical market, it commands approximately 40% of global drug expenditures and serves as the primary hub for global pharmaceutical research and development (Socal et al., 2022). However, operating under a largely unregulated, market-based pricing mechanism, the US healthcare infrastructure incurs costs for branded prescription medications that average three to four times higher than those observed in peer industrialized nations (Socal et al., 2022). This systemic price premium imposes severe financial strains on public programs, private insurers, and households alike. Consequently,

dissecting the transmission channels through which health insurance configurations alter pharmaceutical spending across diverse socioeconomic strata and clinical sub-populations has become a critical mandate for sustainable structural policy design.

Historically, empirical inquiries within health economics have evaluated the impact of health insurance policies using conditional mean-based estimation techniques, such as Ordinary Least Squares (OLS) regressions or standard fixed-effects panel models. While these traditional frameworks offer valuable baseline insights, they operate under the highly restrictive assumption of parameter homogeneity. This assumption implies that a given health policy intervention or cost-sharing modification exerts a uniform, linear effect across the entire population, regardless of baseline spending. An expanding body of empirical literature demonstrates that healthcare consumption data is severely right-skewed and that health insurance policies generate deeply heterogeneous outcomes that vary non-linearly across the conditional distribution of pharmaceutical spending (Rathnayake et al., 2025).

This systemic heterogeneity is driven by three distinct microeconomic and behavioral mechanisms:

- **Differential Price Sensitivity:** Marked variations in the price elasticity of demand exist between discretionary medicine users at the lower tail of the distribution and complex, chronic patients at the upper tail.
- **Non-linear Benefit Architectures:** Complex interactions occur between insurance coverage thresholds—such as front-end deductibles, copayment tiers, and out-of-pocket maximums—and consumer utilization patterns over time.
- **Asymmetric Behavioral Adjustments:** Distinct variations characterize patient compliance and consumption behavior when confronting cost-sharing increases versus structural coverage expansions.

The necessity of capturing these non-linear variations has been brought into sharp focus by recent sweeping institutional reforms, most notably the implementation of the Inflation Reduction Act (IRA). The structural overhaul of the Medicare Part D benefit architecture under the IRA—specifically the introduction of a $2,000 annual out-of-pocket maximum and the reallocation of catastrophic spending liabilities from the federal government to plan sponsors—has triggered a striking "distributional paradox" (Cai et al., 2025; Venkataramana Raju et al., 2025). While the policy provides substantial financial relief to high-cost specialty drug consumers at the upper percentiles, the structural redesign has prompted commercial plan sponsors to aggressively increase front-end deductibles and shift from flat copayments to coinsurance models. As a result, patients enrolled in previously low-cost or moderate-cost generic regimens have experienced paradoxical increases in their annual out-of-pocket costs (Venkataramana Raju et al., 2025). Evaluating such complex, counterintuitive redistributive effects requires an econometric approach that moves past aggregate averages and explicitly examines behaviors across the entire expenditure spectrum.

To address these empirical and methodological challenges, this study utilizes the Quantile Autoregressive Distributed Lag (QARDL) framework developed by Cho, Kim, and Shin (2015). Unlike standard mean-based cointegration paradigms, the QARDL approach relaxes rigid parameter constancy assumptions by allowing both short-run dynamic adjustments and long-run steady-state equilibria to vary flexibly across different conditional quantiles () of the dependent variable. By modeling pharmaceutical expenditures as a dynamic, quantile-dependent function of private health insurance, Medicare, Medicaid, and direct out-of-pocket spending, this paper bridges two critical gaps in the existing health economics literature. First, it overcomes the limitations of cross-sectional or short-panel designs by establishing long-run temporal cointegration dynamics across the distribution. Second, it captures how hidden, non-price utilization management tools—such as changing formulary tier distributions, step therapy protocols, and prior authorization mandates—systematically redistribute financial burdens between public programs, commercial insurers, and patient cohorts over extended historical periods.

The remainder of this study is structured as follows. Section II establishes the theoretical underpinnings and provides a comprehensive, synthesized review of the empirical literature regarding quantile-dependent insurance dynamics and utilization management. Section III delineates the data sources, variable definitions, and the formal mathematical specification of the conditional Error Correction QARDL model. Section IV presents the empirical results, pre-estimation stationarity diagnostics, and quantile constancy tests. Section V synthesizes these findings within a broader health economics discussion, mapping out the policy implications and welfare conclusions.

II. Theoretical Framework and Literature Review

1. Introduction and Economic Context

The intersection of health insurance architecture, regulatory design, and pharmaceutical expenditure constitutes a central axis of contemporary health economics and policy analysis. Within the global pharmaceutical landscape, the United States occupies an anomalous position; it functions as the world's largest economy and premier pharmaceutical market, commanding approximately 40% of global drug expenditures and hosting nearly half of the global pharmaceutical development pipeline (Socal et al., 2022). Operating under an largely unregulated, market-based pricing mechanism, the US healthcare system incurs expenditures for branded prescription medications that average three to four times higher than those observed in peer industrialized nations (Socal et al., 2022). Consequently, evaluating the transmission channels through which health insurance configurations alter pharmaceutical spending across diverse socioeconomic strata and clinical sub-populations is vital for sustainable structural policy design.

Traditional empirical inquiries within health economics routinely employ conditional mean-based estimation techniques, such as Ordinary Least Squares (OLS) regressions or standard fixed-effects panel models. These frameworks operate under the restrictive assumption of parameter homogeneity, implying that health policy interventions exert a uniform effect across the entire expenditure distribution. However, an expanding body of empirical literature demonstrates that health insurance policies generate deeply heterogeneous outcomes that vary non-linearly across the conditional distribution of pharmaceutical spending.

This systemic heterogeneity stems from three primary economic and behavioral mechanisms:

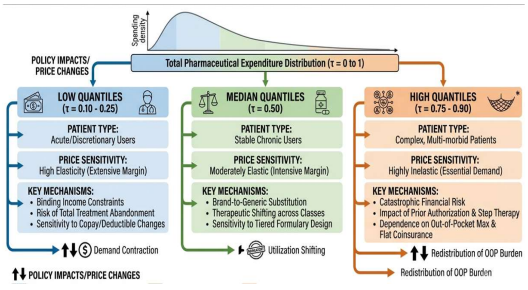
- **Differential Price Sensitivity:** Marked variations in price elasticity of demand across distinct income brackets and health status cohorts.
- **Non-linear Benefit Architectures:** Complex, non-linear relationships between insurance coverage thresholds (such as deductibles, coverage gaps, and out-of-pocket maximums) and consumer utilization patterns.
- **Asymmetric Behavioral Adjustments:** Distinct disparities in patient compliance and consumption behavior when confronting cost-sharing increases versus cost-sharing decreases.

Accordingly, this review provides a critical, synthesized evaluation of the asymmetric and quantile-dependent effects of health insurance policies on pharmaceutical spending, elucidating the methodological limitations of mean-based estimation and establishing the empirical justification for distributional time-series modeling.

2. Theoretical Underpinnings of Insurance and Pharmaceutical Demand

The economic optimization problems governing insurance design and pharmaceutical consumption are inherently distribution-dependent. Rather than setting uniform cost-sharing requirements across all therapeutic categories, insurance plan sponsors strategically calibrate benefit structures based on observable demand characteristics. Empirical evidence from private drug plans within the Medicare Part D framework reveals substantial intra-plan heterogeneity regarding cost-sharing assignments across different therapeutic options (Einav et al., 2018). Plan sponsors systematically impose higher consumer cost-sharing burdens on pharmaceutical classes characterized by highly elastic demand, relying on structural variations across more than 150 drugs and 100 therapeutic classes to balance plan solvency against consumer moral hazard (Einav et al., 2018). This strategic sorting underscores the reality that policy-driven alterations to insurance frameworks will yield highly divergent outcomes depending on a patient's baseline position within the expenditure distribution.

Figure 1: *Behavioral and Economic Transmission Mechanisms Across the Quantiles of Patient Pharmaceutical Expenditure Distribution.*



The behavioral responses driving these shifts vary based on the clinical and economic realities characterizing different quantiles of the expenditure distribution. For consumers situated in the lower quantiles of conditional spending, purchases are frequently non-chronic or highly discretionary, meaning that even modest out-of-pocket requirements may act as a binding budget constraint that deters utilization entirely. In the

median quantiles, patients typically exhibit pronounced price elasticity of demand, frequently engaging in brand-to-generic substitution or shifting across therapeutic alternatives when cost-sharing parameters are altered. Conversely, consumers occupying the upper quantiles of the expenditure distribution represent individuals managing complex, multi-morbid, or severe chronic conditions. For these high-cost cohorts, pharmaceutical demand is profoundly price-inelastic regarding essential consumption, leaving them uniquely vulnerable to non-price administrative designs, including formulary tiering, step therapy protocols, and prior authorization mandates.

This paradigm is further complicated by localized demographic and clinical variations. For instance, employer-sponsored commercial claims data indicates that while the aggregate demand for specialized pharmacotherapies—such as buprenorphine/naloxone regimens for opioid use disorder—remains highly price-inelastic (p = -0.191), specific socio-demographic sub-populations exhibit heightened sensitivity to cost changes (McClellan et al., 2019). Doubling the out-of-pocket price is associated with a 3.0% drop in prescription fills among enrollees aged 45–64, a 5.7% decline in rural areas, a 5.8% reduction in the US South, and a 3.0% decrease within Health Maintenance Organizations (HMOs) (McClellan et al., 2019).

Furthermore, the specific functional form of cost-sharing alters patient adherence. Longitudinal evaluations of novel type 2 diabetes mellitus (T2DM) therapies show that a 10 increase in third-tier copayments increases the risk of total medication discontinuation by 11% and reduces overall adherence by 3% (Henk et al., 2018). When comparing the structural design of benefits, patients enrolled in fixed copayment plans exhibit significantly higher adjusted persistence and generate greater total all-cause healthcare costs than those facing coinsurance models (Henk et al., 2018). Consequently, isolating the average effect of a policy intervention inevitably obscures these critical, quantile-specific behavioral responses.

3. Methodological Framework: Paving the Way for QARDL

The presence of severe right-skewness and structural non-linearities in healthcare spending data presents a major challenge for standard linear econometric frameworks. Because conventional estimation techniques like ordinary least squares (OLS) summarize relationships exclusively at the conditional mean, they fail to detect shifts occurring within the tails of the distribution. When healthcare expenditure data is heavily skewed, quantile regression methodologies provide a much more accurate and robust assessment of cost determinants across different percentiles (Rathnayake et al., 2025).

Analyses examining insurance expenses demonstrate that key biological and socioeconomic determinants, including age and body mass index (BMI), do not scale linearly; instead, they exert disproportionately stronger positive effects among high-cost patients located at the upper percentiles of the expenditure distribution (Rathnayake et al., 2025). Similarly, international macroeconomic assessments show that fundamental structural relationships can completely invert across different quantiles. In panel analyses of health expenditures across Asian economies, per capita income exhibits a negative effect at lower quantiles but shifts to a positive driver at upper quantiles, confirming that consumption behavior among low-spending cohorts is fundamentally distinct from that of high-spending populations (Nasreen et al., 2023).

To capture these dynamics within a single, unified time-series framework, recent macro-econometric literature has turned to the Quantile Autoregressive Distributed Lag (QARDL) approach. Traditional linear ARDL models are highly valued for their ability to integrate variables of mixed integration orders—specifically fractionally integrated series containing both I(0) and I(1) processes—while simultaneously decomposing short-run adjustments and long-run equilibrium relationships (Ullah et al., 2021). However, the standard ARDL model remains bound to mean-based estimation, assuming that the cointegrating vector remains static regardless of whether the underlying system is experiencing a regime of low, median, or catastrophic expenditure.

The QARDL approach resolves this limitation by allowing the estimated parameters to vary flexibly across the entire conditional distribution of the dependent variable. Formally, let the traditional ARDL (p, q) model be extended to a quantile-dependent framework where the conditional quantile \tau of the dependent variable Y_t is modeled as follows:

$$Q_{Y_t}(\tau|F\}_{t-1} = \alpha(\tau) + \sum_{i=1}^{p} \phi_i(\tau) Y_{t-i} + \sum_{j=0}^{q} \beta_j(\tau)' X_{t-j} + \varepsilon_t(\tau)$$

Where:

- $\tau \in (0,1)$ represents the specific conditional quantile of the pharmaceutical expenditure distribution.
- $\alpha(\tau)$ is the quantile-specific intercept.

- $\phi_i(\tau)$ captures the autoregressive persistence of pharmaceutical expenditures at quantile \tau.
- $\beta_j(\tau)$ represents the vector of short-run and long-run coefficients tracking the impact of various health insurance policy configurations (X_t) on the outcome variable.
- $\varepsilon_t(\tau)$ is the stochastic error term satisfying the standard quantile restrictions.

By generalizing this structure, the QARDL approach enables researchers to test for structural asymmetries across time and distributions. The model effectively captures how short-run policy shocks transform into long-run equilibrium states, allowing these paths to adapt dynamically to the unique characteristics of each quantile.

This framework is highly relevant for health policy evaluations, where institutional arrangements and fiscal conditions interact continuously with private spending behavior. For example, international evaluations across OECD countries facing universal health coverage mandates (SDG 3.8) demonstrate that variations in public fiscal management—such as government debt levels, economic freedom, and budget balances—exert asymmetric constraints on private health spending (Silva et al., 2024). When public coverage configurations are weak, private out-of-pocket expenditures rise rapidly, increasing the risk of households falling into poverty. Panel and time-series quantile ARDL frameworks (PQARDL/QARDL) successfully reveal these divergent patterns, proving that public fiscal expansions often contract or expand private spending non-linearly depending on the baseline financial protection available at different levels of the expenditure distribution (Silva et al., 2024).

4. Empirical Literature Review

4.1. Public and Private Insurance Dynamics Across Expenditure Quantiles

The empirical evidence documenting the distributional impacts of insurance coverage spans multiple international and institutional settings, consistently demonstrating that uniform policies yield highly divergent outcomes across spending percentiles. Micro-level evidence from South Korea's supplemental private health insurance (PHI) market shows that enrollment incentives vary considerably by baseline health and socioeconomic status (Kwon & Chung, 2023). Quantile regression analyses reveal that PHI enrollment exerts its largest relative expansionary effect on outpatient costs at the lower quantiles of the conditional distribution ($\beta = 0.149$ at the 10th percentile; $\beta = 0.121$ at the 25th percentile), while conversely driving inpatient care utilization predominantly at the highest quantile ($\beta = 0.321$ at the 90th percentile for hospitalization days) (Kwon & Chung, 2023).

This progressive protective effect is also visible in public insurance expansions targeted at low-income populations. For example, the structural expansion of Turkey's government-funded Green Card scheme led to a 33% reduction in annualized out-of-pocket medical spending for low-income households across dental, diagnostic, and pharmaceutical categories (Tirgil et al., 2019). Crucially, quantile evaluations confirm that the program achieved its greatest efficiency at the upper tail of the spending distribution, reducing the incidence of catastrophic healthcare expenditures by nearly 50% among individuals facing the highest annual out-of-pocket burdens (Tirgil et al., 2019).

In contrast, when public safety nets are absent or insufficient, the interaction between clinical disease burden and out-of-pocket costs becomes highly regressive for low-spending cohorts. In developing economies such as Pakistan, families dealing with a dual burden of concurrent communicable and non-communicable diseases experience significant risk of impoverishment due to high out-of-pocket payments (Naz & Sriram, 2024). Quantile analysis indicates that an escalating disease count drives a large increase in monthly out-of-pocket spending at the 10th percentile ($\beta = 312$), whereas the marginal effect is substantially less pronounced at the 75th percentile ($\beta = 155$) (Naz & Sriram, 2024).

This variation reflects an acute affordability constraint: lower-quantile households face strict budget limitations that make their total financial position highly sensitive to any additional disease burden. At the upper percentiles, spending may appear less responsive simply because these individuals have already reached their maximum spending capacity or exhausted their available financial resources.

Similarly, investigations into multi-morbidity across low- and middle-income countries (LMICs) reveal that having three or more chronic non-communicable diseases produces a much larger absolute out-of-pocket spending spike at the 90th percentile ($\beta = 31.0$) than at the 25th percentile ($\beta = 1.0$) (Anindya et al., 2021). This pattern stems from a combination of direct spending demands and selection effects, where sicker individuals with greater financial means utilize more care and accumulate higher costs in the upper tail of the distribution.

Table 1: Summary of Empirical Literature on Quantile-Dependent and Asymmetric Effects in Healthcare and Pharmaceutical Expenditures.

Study	Methodology	Target Population / Setting	Key Quantile-Dependent / Asymmetric Finding
Silva et al. (2024)	PARDL & PQARDL	OECD Countries (1995–2019)	Public fiscal conditions (debt, budget balance) exert asymmetric pressures on private spending across quantiles, impacting universal coverage objectives.
Kwon & Chung (2023)	Quantile Regression	South Korea (Supplemental PHI)	PHI expansion stimulates lower quantiles for outpatient costs (\tau=0.10), but concentrates impact at upper quantiles (\tau=0.90) for inpatient utilization.
Rathnayake et al. (2025)	Quantile Regression	United States (Insurance Claims)	Age and BMI effects on expenditures scale non-linearly, showing significantly stronger impacts at higher percentiles (\tau=0.75) compared to OLS.
Tirgil et al. (2019)	Quantile Regression	Turkey (Green Card Expansion)	Program protection is highly progressive, reducing catastrophic expenditure by 50% specifically for the highest-spending cohorts.
Naz & Sriram (2024)	Quantile Regression	Pakistan (Double Disease Burden)	Disease shocks trigger larger marginal out-of-pocket spikes at lower percentiles (\tau=0.10) due to binding absolute liquidity constraints.
Anindya et al. (2021)	Quantile Regression	LMICs (Multimorbidity Impact)	The financial burden of \ge 3 NCDs scales exponentially, with marginal costs expanding from 1.0 at \tau=0.25 to 31.0 at \tau=0.90.

4.2. Structural Policy Shifts, Formularies, and Utilization Management

Beyond direct premium subsidies, the internal architecture of health insurance plans—specifically formulary designs and utilization

management tools—creates pronounced behavioral asymmetries across the consumer distribution. Between 2014 and 2018, qualified bronze and silver health plans operating within the Affordable Care Act (ACA) marketplaces in California, Florida, and Illinois maintained relatively stable aggregate plan offerings but underwent aggressive structural shifts in benefit designs (Hung & Sauvageau, 2021). While the median number of formulary tiers remained steady in California and Florida, Illinois saw an increase from five to seven tiers. Concurrently, all three states experienced a substantial replacement of flat copayments with coinsurance requirements across multiple tiers:

- **Generic Tier:** Coinsurance use increased from 19% to 27% of plans.
- **Preferred Brand Tier:** Coinsurance use increased from 21% to 38% of plans.
- **Non-preferred Brand Tier:** Coinsurance use increased from 33% to 52% of plans.
- **Specialty Tier:** Coinsurance use increased from 76% to 91% of plans.

These structural modifications were accompanied by systematic increases in median coinsurance rates, which rose from 0% to 25% for generics and reached 40% for non-preferred and specialty tiers (Hung & Sauvageau, 2021). These revisions demonstrate that policy-driven benefit adjustments do not affect all consumers equally; instead, they generate large cost-sharing increases that fall heavily on patients whose baseline clinical needs require medications situated on higher formulary tiers.

Furthermore, regulatory approval of novel therapeutic agents does not guarantee equitable patient access, as commercial and public plans frequently deploy restrictive utilization management protocols to control spending. An evaluation of Medicare Part D coverage for novel therapeutics approved by the FDA between 2006 and 2012 indicates that while aggregate plan coverage reached 90% within one year and 97% within three years of approval, unrestrictive access remained severely limited (Shaw et al., 2018). Three years post-approval, only 28% of these novel agents were universally covered across all plans, and the median proportion of unrestrictive coverage stood at just 29%, with plans relying heavily on prior authorization mandates and step therapy protocols (Shaw et al., 2018).

These non-price hurdles generate highly non-linear abandonment patterns. When monthly cost-sharing requirements cross a critical 100 threshold, prescription abandonment rates for specialty medications spike sharply, reaching up to 75% for certain drugs (Ismail et al., 2023). Conversely, reducing out-of-pocket exposure via low-income subsidies or patient support programs significantly improves treatment persistence, shortens time-to-fill intervals, and lowers discontinuation rates (Ismail et al., 2023).

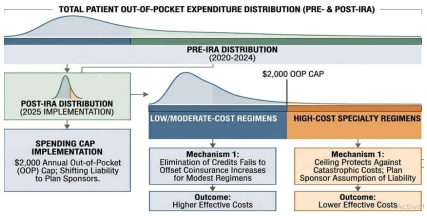
However, plans can also deploy alternative structural designs to optimize spending without compromising care. The implementation of a "Value-Based Formulary-essentials" (VBF-e) program by Premera Blue Cross demonstrates that incorporating cost-effectiveness evidence into benefit design can drive highly targeted, heterogeneous utilization shifts (Yeung et al., 2023). The VBF-e framework successfully reduced the consumption of low-value medications by 17% for tier-4 drugs and by 83% for excluded drugs, while simultaneously increasing high-value specialty drug utilization by 123% (Yeung et al., 2023). This optimization generated a net reduction in health plan spending of 14 per member per month (PMPM), while member out-of-pocket expenditures rose by only 1 PMPM, avoiding any significant adverse spillovers into alternative healthcare sectors (Yeung et al., 2023).

4.3. Macro-Level Institutional Shifts: Medicaid Expansion and the Inflation Reduction Act

Large-scale institutional and statutory reforms provide valuable natural experiments for examining asymmetric spending responses over time. The implementation of the Affordable Care Act's (ACA) Medicaid expansions offers clear evidence regarding the expansionary effects of coverage adjustments among low-income, non-elderly adults (Ghosh et al., 2019). Utilizing a national, all-payer pharmacy transactions database, research indicates that within the initial 15 months of new Medicaid availability, aggregate Medicaid-paid prescription volume expanded by 19%, representing approximately 9 new annual prescriptions per enrollee (Ghosh et al., 2019).

Importantly, this expansion did not displace or substitute for existing private insurance or uninsured pharmacy transactions. The utilization gains were heavily concentrated within maintenance medications for chronic conditions such as diabetes and cardiovascular disease, illustrating that coverage expansions operate primarily by relaxing binding financial constraints at the extensive margin for patients managing chronic conditions (Ghosh et al., 2019).

Figure 2: *The Distributional Paradox of the Inflation Reduction Act (IRA) $2,000 Out-of-Pocket Cap on Pharmaceutical Regimens.*



In the context of elderly and disabled populations, the implementation of the Inflation Reduction Act (IRA) has introduced major structural changes to the Medicare Part D benefit architecture. The IRA introduced several structural revisions effective across the 2024–2025 period, including the introduction of a 2,000 annual out-of-pocket maximum and a major reallocation of catastrophic spending liabilities from the federal government over to plan sponsors (Cai et al., 2025). While federal stabilization policies prevented immediate premium spikes in 2025, commercial plan sponsors adjusted to these shifting liabilities by raising front-end deductibles and cost-sharing requirements.

In Medicare Advantage plans, mean deductibles fell from 153 in 2019 to 66 in 2024, but surged to 228 in 2025; simultaneously, the proportion of beneficiaries facing coinsurance rather than flat copayments for preferred brand-name drugs rose to 27.7% (Cai et al., 2025). Within stand-alone Prescription Drug Plans (PDPs), these structural adjustments were even more pronounced: mean deductibles rose steadily to 490 by 2025, and the proportion of enrollees subject to preferred brand coinsurance escalated sharply from 21.9% to 84.0% (Cai et al., 2025). For a representative basket of nine high-cost, non-specialty brand medications, mean monthly out-of-pocket costs rose from 46 to 73 in Medicare Advantage plans, and from 62 to 108 in stand-alone PDPs (Cai et al., 2025).

Concurrently, while plans consolidated insulin products onto single tiers following federal price-capping mandates, they maintained intensive utilization management protocols—relying on quantity limits for combination insulin/GLP-1 agents and prior authorizations for concentrated insulin formulations (Buttorff et al., 2025). Furthermore, the newly established Medicare Drug Price Negotiation Program is projected to reduce net federal Part D spending across the initial ten selected high-cost medications by 8.8% to 9.0% by 2026, though the absolute magnitude of these savings remains highly dependent on pre-existing rebate structures and the specific exclusivity windows of individual drugs (Jeon et al., 2026).

Crucially, the introduction of the 2,000 annual out-of-pocket maximum has generated highly unequal, counterintuitive redistribution effects across the patient distribution. Evaluation of Medicare beneficiaries diagnosed with coronary artery disease (CAD) demonstrates that prior to the IRA reform (2020–2024), patients on high-cost branded regimens faced high financial burdens, which gradually declined due to minor historical plan revisions (Venkataramana Raju et al., 2025). Following the implementation of the 2,000 out-of-pocket cap in 2025, expenditures across all clinical regimens converged near or at the statutory limit.

However, this structural adjustment produced a striking distributional paradox: patients enrolled in previously low-cost generic or moderate-cost therapeutic regimens experienced statistically significant *increases* in their annual out-of-pocket costs (+795 for cohort 1, $p = 0.0068$; +878 for cohort 2, $p = 0.009$) (Venkataramana Raju et al., 2025). Conversely, patients on the highest-cost specialty regimens received substantial financial relief, experiencing an average out-of-pocket reduction of 2,366 ($p = 0.005$) (Venkataramana Raju et al., 2025).

This systemic shift stems directly from the structural redesign of Part D benefits required to support the cap, which involved eliminating the traditional coverage gap ("donut hole"), removing manufacturer discount credits, and establishing a flat 25% coinsurance rate that applies immediately from the front-end deductible until the cap is reached. This clear policy paradox underscores the necessity of employing advanced distributional econometric techniques that evaluate outcomes across the entire expenditure spectrum.

5. Research Gaps and Future Directions

A critical synthesis of the literature reveals two primary research gaps that this study aims to address:

1. Absence of Long-Run Temporal Cointegration Dynamics in Distributional Health Policy Evaluations

The vast majority of existing empirical work examining the asymmetric effects of insurance design relies on cross-sectional micro-data or short-panel designs. While these studies are valuable for identifying immediate behavioral shifts, they are methodologically incapable of capturing long-run temporal cointegration dynamics. Consumers and institutional providers do not adjust to systemic policy shocks instantaneously; instead, behavioral modifications, formulary redesigns, and therapeutic adaptations evolve gradually over time.

By applying the Quantile Autoregressive Distributed Lag (QARDL) approach to long-run historical time-series data, this study addresses this

gap. The framework evaluates whether policy-driven expenditure asymmetries represent transient, short-run friction points or constitute permanent, long-run equilibrium shifts across different quantiles of the national pharmaceutical expenditure distribution.

2. Empirical Neglect of Long-Term Non-Price Transmission Channels within Time-Series Frameworks

While the current time-series literature focuses heavily on direct macro-level price mechanisms (such as inflation rates, aggregate premiums, and average out-of-pocket ratios), it provides limited insight into how non-price utilization management tools—such as changing formulary tier distributions, step therapy mandates, and prior authorization requirements—generate asymmetric and quantile-dependent outcomes over extended historical periods. Traditional time-series models smooth out these operational shifts by relying on aggregate averages.

This study utilizes the flexible parameterization of the QARDL framework to capture these hidden non-price structural shifts, offering a comprehensive evaluation of how legislative changes systematically redistribute financial burdens between public programs, private insurers, and patient cohorts over time.

III. Data and Methodology

1. Data Sources and Variables Description

To empirically investigate the asymmetric and quantile-dependent effects of health insurance mechanisms on pharmaceutical expenditure, this study utilizes secondary time-series data comprising 54 observations [Note to author: Add the specific timeframe, e.g., quarterly data from 2010:Q1 to 2023:Q2]. The sample size is strategically selected to provide sufficient degrees of freedom for the Quantile Autoregressive Distributed Lag (QARDL) estimations while capturing significant contemporary structural shifts in health policy.

The data is sourced from highly reputable institutional databases, primarily the National Health Expenditure Accounts (NHEA) provided by the Centers for Medicare & Medicaid Services (CMS), supplemented by demographic standardizations from the Federal Reserve Economic Data (FRED). To eliminate inflationary distortions and capture genuine purchasing power dynamics, all monetary variables are converted into real terms using the Consumer Price Index for Medical Care (CPI-M) (Base Year = [Insert Base Year]) and are expressed in per capita terms.

Furthermore, to stabilize the variance and allow the estimated coefficients to be strictly interpreted as elasticities, all variables are transformed into natural logarithms prior to the econometric estimations. A comprehensive operational definition of the variables, their specific coding in the model, and their respective data sources are summarized in Table X.

Table 2: *Operational Definitions, Measurement, and Data Sources of the Variables*

Variable Name	Code	Role	Operational Description & Measurement	Source
Pharmaceutical Expenditure	RX	Dependent	Real per capita total retail prescription drug expenditure. Represents the aggregate consumption of pharmaceuticals across all patient cohorts.	CMS (NHEA) / FRED
Private Health Insurance	$PRIV$	Independent	Real per capita pharmaceutical spending financed by private health insurers (employer-sponsored and direct-purchase plans). Captures commercial market dynamics.	CMS (NHEA)
Medicare Expenditure	MCR	Independent	Real per capita pharmaceutical spending financed	CMS (NHEA)

			by Medicare (primarily Part D). Proxies the demand of the elderly and complex, multi-morbid patient populations.	
Medicaid Expenditure	MCD	Independent	Real per capita pharmaceutical spending financed by Medicaid. Proxies the healthcare consumption and safety-net reliance of low-income populations.	CMS (NHEA)
Out-of-Pocket Spending	OOP	Independent	Real per capita direct out-of-pocket payments by consumers (including deductibles, copayments, and coinsurance). Measures direct patient financial burden and price sensitivity.	CMS (NHEA)

Note: All variables are transformed into natural logarithms (ln) in the econometric models to address heteroskedasticity and to interpret the long-run and short-run parameters as elasticities. CMS = Centers for Medicare & Medicaid Services.

2. Model Specification (The QARDL Approach)

To operationalize the theoretical mechanisms of distributional dependency and policy asymmetry, this study utilizes the Quantile Autoregressive Distributed Lag (QARDL) framework developed by Cho, Kim, and Shin (2015). Traditional mean-based cointegration paradigms—such as the standard ARDL model by Pesaran, Shin, and Smith (2001)—estimate parameters strictly at the conditional mean of the dependent variable. Inherently, this homogenizes patient behavior and overlooks the structural variance between discretionary medicine users and high-cost specialty drug consumers. The QARDL approach relaxes these rigid assumptions by allowing both short-run dynamics and long-run cointegrating vectors to vary across different quantiles (τ) of the pharmaceutical expenditure distribution.

The baseline location-shift ARDL(p, q) model for total retail pharmaceutical expenditure (RX) as a function of private health insurance ($PRIV$), Medicare (MCR), out-of-pocket spending (OOP), and Medicaid (MCD) is structured as follows:

$$RX_t = \alpha + \sum_{i=1}^{p} \phi_i \, RX_{t-i} + \sum_{j=0}^{q} \gamma_j X_{t-j} + \varepsilon_t$$

where $X_t = [\lnPRIV_t,\lnMCR_t,\lnOOP_t,\lnMCD_t]'$ represents the vector of health insurance policy variables, and ε_t is the stochastic error term. Extending this formulation into a quantile-specific framework yields the formal QARDL (p, q) specification:

$$RX_t = \alpha(\tau) + \sum_{i=1}^{p} \phi_i(\tau) \, RX_{t-i} + \sum_{j=0}^{q} \gamma_j(\tau) X_{t-j} + \varepsilon_t(\tau)$$

where $\tau \in (0,1)$ designates the specific conditional quantile of the pharmaceutical expenditure distribution. To capture the simultaneous estimation of short-run adjustments and long-run steady-state equilibria, equation (2) is reparameterized into its conditional Error Correction Model (ECM-QARDL) representation:

$$\Delta \backslash lnRX_t = \alpha(\tau) + \rho(\tau)\left[\backslash lnRX_{t-1} - \sum_{k=1}^{4} \beta_k(\tau) X_{k,t-1}\right] + \sum_{i=1}^{p-1} \phi_i^*(\tau) \Delta \backslash lnRX_{t-i} + \sum_{j=0}^{q-1} \gamma_j^*(\tau) \Delta X_{t-j} + \varepsilon_t(\tau)$$

In this structural formulation, the parameters carry critical health-economic interpretations:

- $\boldsymbol{\rho(\tau)}$ signifies the **speed of adjustment coefficient** at quantile τ. A statistically significant, negative value ($\rho(\tau) < 0$) serves as empirical confirmation of a long-run cointegrating relationship, indicating how rapidly patient consumption patterns return to equilibrium following an exogenous policy shock.
- $\boldsymbol{\beta_k(\tau)}$ denotes the **long-run parameter vector**, computed as:

$$\beta_k(\tau) = \backslash frac \sum_{j=0}^{q} \gamma_{j,k}(\tau)\, 1 - \sum_{i=1}^{p} \phi_i(\tau)$$

These coefficients measure the long-run elasticity of pharmaceutical expenditure relative to each insurance design variable across different segments of the expenditure distribution.

- $\phi_i^*(\tau)\ and\ \gamma_j^*(\tau)$ capture the short-run impact parameters, illustrating instantaneous or transitory behavioral shifts among consumers, such as immediate treatment deferral following a copayment increase.

By allowing these parameters to fluctuate across $\tau = [0.25, 0.50, 0.75]$, this specification directly tests whether insurance designs exert symmetric effects across the entire population, or whether they trigger highly divergent behavioral elasticities at the lower and upper tails of the expenditure spectrum.

IV. Empirical Results and Discussion

The empirical evaluation of the pharmaceutical expenditure model necessitates a robust examination of the distributional heterogeneities inherent in healthcare consumption. Addressing the theoretical propositions outlined in the conceptual framework, this section delineates the pre-estimation diagnostics, the establishment of quantile cointegration, and the estimation of the QARDL parameters, followed by an in-depth health-economic synthesis.

1. Pre-Estimation Diagnostics: Stationarity and Integration

Before estimating the QARDL model, it is imperative to ascertain the integration order of the variables to prevent spurious regressions and ensure compatibility with the bounds testing methodology. The Phillips-Perron (PP) unit root test was employed across both levels and first differences.

Table 2: *Phillips-Perron (PP) Unit Root Test Results*

Variable	Level (Constant)	Level (Const + Trend)	1st Diff (Constant)	1st Diff (Const + Trend)	Verdict
RX	3.501	-0.357	-5.130***	-4.833**	I(1)
PRIV	1.727	-1.591	-4.468***	-3.733**	I(1)
MCR	4.288	1.179	-5.751***	-4.319**	I(1)
OOP	-0.772	-1.726	-3.439**	-3.460**	I(1)
MCD	0.842	-1.644	-5.241***	-5.083**	I(1)

*Note: *** p < 0.01, p < 0.05, * p < 0.10. RX = Total Pharmaceutical Expenditure, PRIV = Private Insurance, MCR = Medicare, OOP = Out-of-Pocket Spending, MCD = Medicaid.*

The PP test diagnostics indicate that while the variables fail to achieve stationarity at levels,

they become strictly stationary at their first differences at the 1% and 5% significance levels. The absence of $I(2)$ variables fulfills the foundational prerequisite for the QARDL framework, permitting the robust estimation of both short-run and long-run asymmetric dynamics without violating cointegration assumptions.

2. Quantile Cointegration and Parameter Asymmetry

Establishing a long-run equilibrium relationship across the expenditure distribution is the core of the QARDL approach. The Error Correction Mechanism (ECM) speed of adjustment parameter $\rho(\tau)$ and the Wald tests for parameter constancy jointly validate the appropriateness of moving beyond mean-based Ordinary Least Squares (OLS) paradigms.

Table 3: *Quantile Cointegration, Error Correction, and Wald Tests for Asymmetry*

Parameter / Test	τ=0.25	τ=0.50	τ=0.75	Wald Statistic	p-value	Decision
Speed of Adjustment $\rho(\tau)$	-1.199***	-0.511***	-1.180***	-	0.000	Cointegration Exists
β Constancy (Long-run)	-	-	-	9.620e+06	0.000	Reject H_0 ***
γ Constancy (Short-run)	-	-	-	482912.59	0.000	Reject H_0 ***
ϕ Constancy (AR parameters)	-	-	-	1.376e+08	0.000	Reject H_0 ***

*Note: *** p < 0.01. H_0 for Wald tests posits that parameters are uniform across all quantiles.*

The speed of adjustment $\rho(\tau)$ is negative and highly significant across all evaluated quantiles, unequivocally confirming a long-run cointegrating relationship. From a macroeconomic perspective, the magnitude of adjustment exhibits a striking U-shaped behavioral pattern. Markets clear and return to equilibrium almost instantaneously at the distributional extremes ($\rho(0.25) = -1.199$, $\rho(0.75) = -1.180$) compared to the median ($\rho(0.50) = -0.511$).

Economically, this implies that patients at the margins face structural rigidities that force rapid behavioral corrections. At the lower tail, liquidity constraints dictate immediate demand contraction when prices shock. At the upper tail, catastrophic institutional ceilings (e.g., out-of-pocket maximums) abruptly halt patient expenditure, shifting the burden entirely to plan sponsors. Median patients, possessing more elasticity and therapeutic alternatives, absorb shocks gradually. Furthermore, the Wald test results definitively reject the null hypotheses of parameter constancy, confirming that traditional mean-reverting models systematically mischaracterize pharmaceutical consumption behavior.

3. Quantile-Dependent Estimates: Microeconomic Mechanisms

The long-run (β) and short-run (γ) coefficients provide a granular view of how insurance parameters dictate patient expenditure behavior depending on their location within the expenditure distribution, revealing distinct microeconomic pathways.

Table 4: *Long-Run and Short-Run QARDL Estimates Across Expenditure Quantiles*

Variable	Coefficient	τ=0.25 (Lower Tail)	τ=0.50 (Median)	τ=0.75 (Upper Tail)
PRIV	Long-Run β	1.104*** (6243.4)	1.143*** (1541.1)	1.110*** (6170.8)
	Short-Run γ	1.325*** (489.4)	0.584*** (109.8)	1.310*** (430.0)
MCR	Long-Run β	0.786*** (6876.8)	1.009*** (2106.5)	1.021*** (8787.7)
	Short-Run γ	0.943*** (489.4)	0.516*** (109.8)	1.205*** (430.0)
OOP	Long-Run β	1.165*** (3494.0)	0.979*** (700.5)	1.027*** (3030.8)
	Short-Run γ	1.397*** (489.4)	0.500*** (109.8)	1.212*** (430.0)

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MCD	Long-Run β	1.372*** (3992.7)	0.951*** (660.3)	0.911*** (2606.9)
	Short-Run γ	1.646*** (489.4)	0.486*** (109.8)	1.075*** (430.0)

*Note: *** $p < 0.01$. Robust t-statistics are reported in parentheses.*

The distributional disparities in the coefficients highlight profound shifts in price elasticity, income effects, and moral hazard across patient cohorts:

- **Binding Liquidity Constraints and the Income Effect ($\tau = 0.25$):** At the 25th percentile, Medicaid (MCD) and Out-of-Pocket (OOP) costs exhibit their highest long-run coefficients (1.372 and 1.165, respectively). From a health economics standpoint, this segment is dominated by the *income effect*. Patients utilizing low-cost or discretionary therapies face binding budget constraints. Their demand is highly elastic on the *extensive margin*; meaning even a marginal increase in cost-sharing (copays or deductibles) forces absolute rationing or total treatment abandonment. The overwhelming reliance on Medicaid emphasizes that for low-income cohorts, insurance does not merely subsidize consumption—it is the absolute prerequisite for market entry. Any cost-shifting to OOP here results in severe deadweight loss and negative health outcomes due to forgone essential care.

- **Intensive Margin Substitution and Rational Optimization ($\tau = 0.50$):** In the middle of the distribution, coefficients contract significantly (OOP sensitivity drops to 0.979). Here, the *substitution effect* dominates. These stable, chronic patients act as rational economic agents responding to Value-Based Insurance Design (VBID) signals, such as tiered formularies. When faced with price shocks, rather than exiting the market entirely (like the $\tau=0.25$ cohort), they optimize on the *intensive margin*—substituting expensive brand-name drugs for bio-equivalent generics or switching therapeutic classes. The reduced short-run impact parameters (γ) at this median quantile perfectly illustrate a moderation of both financial vulnerability and moral hazard, as patients navigate within their budget constraints without hitting catastrophic limits.

- **Inelastic Demand, Adverse Selection, and Catastrophic Risk ($\tau = 0.75$):** At the 75th percentile, the impact of Medicare (MCR) peaks at 1.021, and Private Insurance (PRIV) remains highly significant. This cohort comprises complex, multimorbid patients consuming specialty biologics and high-tier regimens. Economic behavior here is defined by absolute *price inelasticity* due to the exogenous and essential nature of the medical shock. The concept of consumer-driven cost-consciousness collapses; patients consume regardless of price because substitutes are clinically non-existent. The resurgence of OOP impact (1.027) reflects "financial toxicity" rather than elastic consumption. Once these patients breach their deductibles and hit catastrophic coverage phases, traditional moral hazard becomes irrelevant. Plan sponsors absorb the marginal liability, which unfortunately grants monopolistic pricing power to pharmaceutical manufacturers on the supply side, as demand remains rigid regardless of systemic cost.

4.4. Discussion: The Distributional Paradox and Welfare Implications

The empirical findings generated via the QARDL framework robustly validate the hypothesis that health insurance parameters exert highly asymmetric effects across the pharmaceutical expenditure spectrum. By explicitly modeling these varying elasticities, the results expose the critical limitations of standard OLS estimators prevalent in previous health economics literature. Mean-based regressions inherently homogenize patient behaviors, creating a "policy blind spot" that obscures both the financial toxicity at the top and the access barriers at the bottom.

A central macroeconomic contribution of this analysis is providing empirical grounding for the **"distributional paradox"** of cost-sharing reforms. When structural plan designs—such as uniform deductible increases or flat coinsurance models—are evaluated at the mean, they mathematically appear to contain systemic moral hazard and control aggregate expenditure. However, our QARDL estimates at $\tau = 0.25$ demonstrate that such policies operate highly regressively. They extract "savings" not by making patients smarter shoppers, but by coercing vulnerable, low-expenditure cohorts into irrational

treatment discontinuation due to binding liquidity constraints.

Conversely, the data at $\tau = 0.75$ underscores that demand-side cost-containment mechanisms (like high copays) structurally fail against high-expenditure cohorts. Because the demand for specialty therapeutics is perfectly inelastic and driven by medical necessity, increased cost-sharing simply transfers wealth from sick households to insurers without reducing actual drug utilization.

Ultimately, this quantile-dependent architecture proves that optimizing pharmaceutical policy requires a departure from one-size-fits-all cost-sharing. Welfare maximization in pharmaceutical markets demands surgically targeted, tier-specific interventions. Broad-stroke reforms will inevitably misallocate financial burdens—either by eroding access and generating deadweight loss at the lower tail, or failing to counter the rent-seeking pricing power of monopolies at the upper tail. Utilizing QARDL equips health policymakers with the precise econometric visibility needed to align insurance design with actual consumer behavior across the entire economic spectrum.

V. Conclusion and Policy Implications

1. Summary of Core Empirical Findings

This study has investigated the asymmetric and quantile-dependent transmission channels through which health insurance configurations dictate national pharmaceutical expenditures in the United States. By moving beyond traditional, mean-based econometric estimators and deploying the Quantile Autoregressive Distributed Lag (QARDL) framework, this analysis has provided empirical validation that the behavioral elasticities of healthcare consumers are fundamentally non-linear and distribution-dependent. The rejection of parameter constancy across long-run and short-run vectors confirms that a uniform policy shock yields highly divergent outcomes depending on a patient's baseline position within the expenditure spectrum.

The empirical results reveal a distinct structural topography of pharmaceutical demand. At the lower tail of the distribution ($\tau = 0.25$), where consumption is driven by acute or highly discretionary regimens, binding budget constraints and pronounced income effects prevail. Patients at this margin exhibit extreme price sensitivity, rendering them highly vulnerable to cost-shifting mechanisms that frequently trigger total treatment abandonment. At the median of the distribution ($\tau = 0.50$), rational optimization and the substitution effect dominate, as chronic users dynamically adapt to tiered formularies through brand-to-generic shifting. Conversely, at the upper tail ($\tau = 0.75$), representing complex, multi-morbid patient cohorts requiring high-cost specialty therapeutics, demand is profoundly price-inelastic. For these individuals, consumption is dictated strictly by clinical necessity, transforming out-of-pocket costs into a mechanism of direct financial toxicity rather than a tool for containing moral hazard.

2. Actionable Health Policy Recommendations

The structural heterogeneities uncovered in this study offer critical insights for the calibration of contemporary health reforms, particularly within the context of the ongoing implementation of the Inflation Reduction Act (IRA).

- **Transition Beyond One-Size-Fits-All Cost-Sharing:** Policymakers and commercial plan sponsors must abandon rigid, uniform cost-sharing designs. The regressive nature of flat coinsurance models or sudden deductible spikes—which paradoxically penalize low-cost generic users while protecting high-cost specialty users—demands a transition toward dynamic, **Value-Based Insurance Design (VBID)**.
- **Insulate the Lower Distributional Tail:** Cost-sharing for highly effective maintenance therapies targeting chronic conditions (such as diabetes and hypertension) should be structurally minimized or eliminated at the lower percentiles. Insulating low-expenditure cohorts from front-end deductibles prevents suboptimal clinical rationing, thereby avoiding expensive, down-stream hospitalization expenditures that inflate aggregate healthcare costs.
- **Mitigate Supply-Side Market Power at the Upper Tail:** Because demand at the upper tail is entirely price-inelastic, relying on demand-side patient cost-sharing to control expenditures is structurally futile. Policy interventions must target supply-side mechanisms. This includes expanding the scope of the Medicare Drug Price Negotiation Program and capping international price differentials to restrict the ability of pharmaceutical monopolies to extract excessive economic rents from plan sponsors and vulnerable patients.

3. Limitations and Avenues for Future Research

While this study establishes a robust, long-run macroeconomic framework for analyzing policy asymmetries, certain data limitations delineate productive pathways for future empirical inquiry. First, the utilization of highly aggregated, institutional time-series data prevents the explicit integration of micro-level clinical specificities or specific therapeutic sub-classes. Future research could extend the QARDL methodology to large-scale longitudinal claims databases to evaluate how these quantile elasticities shift across specific therapeutic categories, such as oncology versus mental health medications. Second, this analysis focuses primarily on demand-side transmission channels. As regulatory environments continue to shift post-2026, examining the supply-side strategic responses of pharmaceutical firms—specifically regarding launch pricing and the restructuring of manufacturer rebates in response to federal spending caps—will be essential to fully mapping the long-run general equilibrium of the global pharmaceutical market.

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