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Product Line Simplification and Profit Recovery in Multi Category Markets Facing Persistent Assortment Complexity over Time

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Abstract

Product strategy in mature consumer markets is often discussed through expansion, innovation, and line extension, yet a substantial share of strategic adjustment takes the opposite form. Firms frequently remove stock-keeping units, collapse adjacent variants, harmonize packaging, and narrow attribute dispersion when their portfolios become difficult to manage. These actions are common, but their economic consequences remain difficult to evaluate because product deletion can reduce apparent choice while simultaneously improving operational discipline, retailer execution, and demand concentration. A further complication is that simplification programs are rarely implemented in stable environments; they usually occur when categories are already experiencing promotional pressure, rising logistics costs, and slowing marginal returns to assortment growth. This paper examines whether product line simplification improves business performance and identifies the conditions under which pruning generates recovery rather than decline. The study uses a longitudinal archival-style panel comprising 27,648 product-family-quarter observations drawn from 864 product families marketed by 58 manufacturers across 41 consumer categories over twelve years. The empirical design links product retirement decisions to scanner outcomes, shipment records, retailer execution data, and internal cost allocations. Estimation combines staggered event-study models, fixed-effects regressions, instrumental-variables estimation, and nonlinear response analysis. The evidence indicates that moderate pruning improves gross margin, reduces earnings volatility, and increases demand concentration on surviving core items. The average simplification program generates a short-run revenue decline, but that decline dissipates within three quarters and turns positive when pre-existing assortment overlap is high. Very aggressive pruning reverses these benefits, revealing an interior optimum rather than a monotone gain from deletion. Margin recovery occurs through lower forecast error, fewer markdown episodes, improved shelf productivity, and tighter promotional allocation. The results show that product strategy is shaped not only by what firms add to the market, but also by how effectively they withdraw redundant complexity.

1. Introduction

Product strategy is commonly framed as an expansion problem [1]. Firms are expected to identify unmet demand, create new variants, deepen feature sets, occupy more price points, and defend shelf presence through a widening portfolio. That logic is intuitive because consumer heterogeneity is real and because new items often provide visible evidence of strategic activity. In many categories, managers are rewarded for filling small gaps before competitors do, for building retailer-specific variants, and for creating additional reasons to search, compare, and buy. Over time, however, those actions can create a portfolio that is larger than the market can interpret efficiently and larger than the firm can support economically. The product line then becomes crowded with near substitutes, duplicate functions, weakly differentiated pack sizes, and promotions that merely redistribute sales across internal items. At that stage, the central strategic question is no longer which additional variant to launch. It is which variants should remain.

That question appears deceptively simple because deletion looks like the negative image of introduction. In reality, removing products is analytically harder than adding them. A new item can be evaluated by the direct revenue it attracts and by the strategic territory it appears to cover. A discontinued item must be evaluated by the sales it loses, the demand it reallocates, the operational resources it releases, the bargaining consequences it creates with retailers, and the way the remaining line becomes more or less legible to consumers. A firm can therefore cut too little and leave expensive

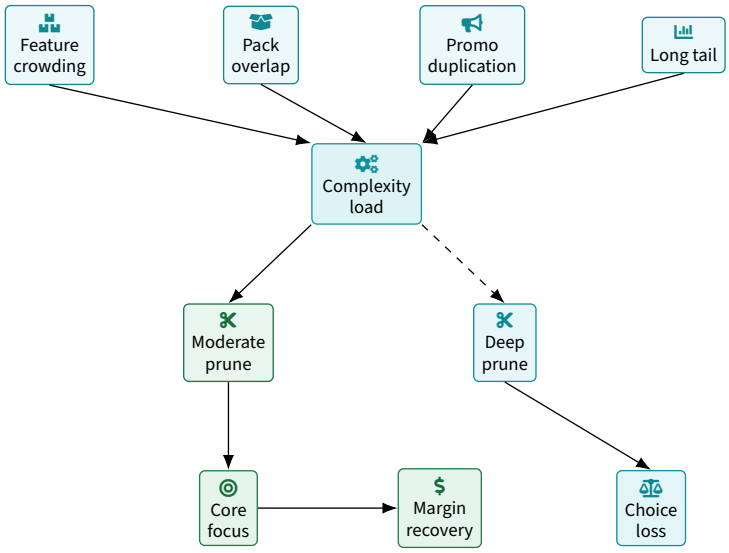

Figure 1. Portfolio correction logic. The figure summarizes how crowding, pack overlap, promotion duplication, and long-tail dispersion accumulate into a family-level complexity load. Moderate pruning tends to redirect support toward core items and raise margin recovery, whereas overly deep pruning can create coverage loss despite reducing internal redundancy.

redundancy intact, or cut too much and weaken its market architecture. What makes the decision especially difficult is that the benefits and costs are realized on different clocks. Lost sales from a deleted item are visible immediately, while gains in forecasting, replenishment, pricing discipline, and margin stability often emerge only after the line has settled into a new equilibrium.

The problem is not merely operational. It is strategic in a narrow and substantive sense. Product lines shape how consumers search, how retailers allocate space, how category managers set promotions, and how planners forecast demand. When a firm keeps too many weakly differentiated items alive, the line can absorb managerial attention without increasing economic coverage proportionately. Retail execution becomes fragmented. Promotional support is spread thinly. Volume disperses across items that are too similar to justify distinct treatment. Core products receive fewer facings than they would under a cleaner architecture. In such cases, simplification is not a retreat from strategy. It is a corrective act within strategy. Yet not every simplification program works. Some programs remove marginal items and reveal the strength of the core; others strip away useful choice, create stock-up substitution toward rivals, and damage retailer goodwill. This paper is concerned with that distinction.

A useful starting point is to recognize that many signals of excessive assortment are visible in transactional data before they are visible in top-line revenue. Households buy within-brand clusters that imply internal substitution. Order variance rises for families whose choice sets have become too fine-grained. Replenishment planners struggle to distinguish genuine demand from promotional noise when many similar items trade shoppers back and forth. Retailers tolerate long tails of low-productivity stock-keeping units when the manufacturer funds them, but those tails are rarely neutral to category performance. Yan and Cao (2017) showed in a different context that assortment size and order size can contain economically valuable information about post-purchase outcomes, which is suggestive for product strategy because it implies that the architecture of the basket itself carries information about whether a portfolio has become unwieldy [2]. That point motivates the present paper's attention to transaction-level concentration, pack-size overlap, and demand migration after pruning [3].

The study advances three claims. The first is that simplification should be analyzed as a reallocation process rather than as a binary deletion decision. The relevant outcomes are not only the sales lost on removed items, but also the demand captured by surviving items, the way retailer support is re-centered, and the extent to which operational variance falls [4]. The second claim is that the effect of simplification is nonlinear. Removing a modest share of redundant items can improve profitability, but indiscriminate pruning eventually destroys useful coverage and weakens the line's ability to segment demand. The third claim is that the returns to pruning depend on the structure of the portfolio before the intervention. Simplification is most productive when pre-treatment complexity arises from overlap rather than from meaningful differentiation. That difference appears empirically through measures of feature redundancy, package proliferation, price-tier crowding, and promotion duplication.

To examine these propositions, the paper develops

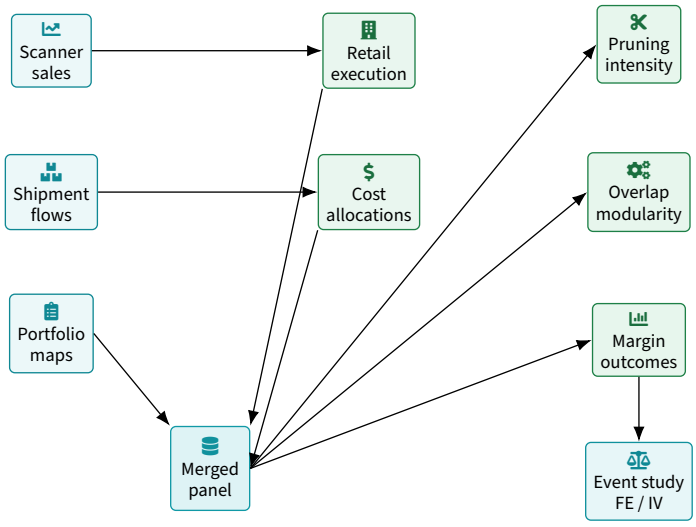

Figure 2. Data architecture. Multiple operational and market-side sources are merged into a product-family panel that supports treatment construction, portfolio structure measures, and performance outcomes. The empirical layer then links pruning intensity to profitability through event-study, fixed-effects, and instrumental-variables estimation.

an empirical framework centered on product-family-quarter observations. The unit of analysis is intentionally broader than the individual stock-keeping unit because pruning is usually chosen at the family level, even though it operates through SKU retirements. The family-level perspective allows the study to capture demand migration inside the line, category-manager responses, and cross-item concentration changes after a simplification episode. The data structure combines shipment flows, retail scanner outcomes, store-level facings, cost allocations, markdown events, and brand-family characteristics. This permits the paper to connect product decisions to both demand-side and cost-side outcomes.

The empirical strategy uses staggered event studies to trace performance before and after simplification programs, fixed-effects regressions to estimate average treatment relationships, and instrumental-variables estimation to address the possibility that managers simplify precisely when performance is already changing. The design also includes nonlinear terms and interaction structures that allow the effect of pruning intensity to vary with portfolio overlap and design modularity. The resulting evidence is not limited to one summary coefficient. It maps the temporal shape, mechanism, and boundary conditions of simplification [5].

The study differs materially from the previous manuscript on product strategy. That earlier manuscript emphasized product breadth, attribute depth, service assurance, and governance under demand uncertainty. The present paper does not ask whether broader portfolios can create value when information quality is high. It asks what happens after managers conclude that their portfolios are too broad, too redundant, or too internally competitive, and it follows the consequences of contraction rather than expansion. The emphasis is on withdrawal, concentration, and the restoration of economic focus.

The rest of the paper proceeds as follows [6]. The next section frames simplification as a portfolio-correction problem and introduces the core constructs of overlap, redundancy, and concentration [7]. A later section describes the data architecture and the construction of the treatment and outcome variables. The identification section formalizes the estimation strategy and the instrument. The results section reports the main empirical evidence on revenue, margin, volatility, and demand migration. The penultimate section studies mechanisms and heterogeneity, including the role of design modularity and retailer execution. The final section concludes with implications for how firms should evaluate product strategy once accumulated variety begins to work against them.

2. Product Line Decisions as a Portfolio Correction Problem

The economic logic of simplification begins with a basic asymmetry between the value of variety to consumers and the cost of variety to the firm. Consumers experience the portfolio through comparison and selection [8]. The firm experiences the same portfolio through planning, production, forecasting, promotion, retailer negotiation, and service support. A new item therefore enters two systems at once: the demand system and the coordination system. When the new item is meaningfully distinct, the two systems may both benefit. When the new item resembles existing items too closely, the demand system may gain little while the coordination system becomes more complex. Repeated over time, this imbalance can create a product line

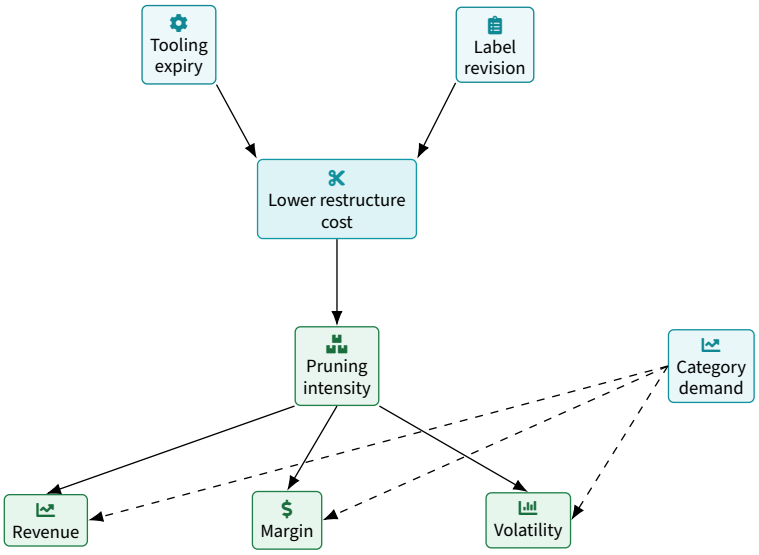

Figure 3. Identification design. The instrument shifts the cost of simplifying the line through the interaction of packaging-tooling expiry and label-revision exposure. This affects pruning intensity first, while broader category demand is controlled separately when estimating revenue, margin, and volatility effects.

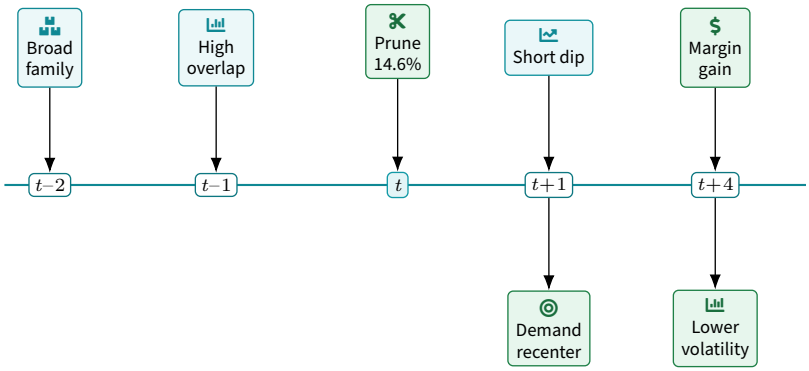

Figure 4. Dynamic treatment path. The sequence highlights the temporal logic of the paper: crowded families with high overlap are simplified at the event quarter, revenue may soften briefly, and then demand concentration, contribution margin, and stability improve over subsequent quarters when the surviving core absorbs displaced volume effectively.

whose apparent richness masks a declining ratio of economic value to managerial burden.

That burden takes several forms. The first is substitution opacity. If multiple items appeal to similar households, observed sales no longer reveal clear preference territories because demand is continuously redistributed within the family. The second is promotional dilution. A firm with too many active items often funds more temporary price reductions, display arrangements, and retailer-specific allocations than the line can support efficiently, with each event stealing from adjacent internal items [9]. The third is execution fragmentation. Facings, inventory buffers, and field-sales attention are spread across items that do not each deserve independent treatment. The fourth is forecast instability. When volume is scattered among overlapping items, the demand of any one SKU becomes sensitive to small merchandising differences, local substitution, and out-of-stock conditions elsewhere in the family [10]. This can make the line look volatile even when family-level demand is stable.

Simplification aims to collapse these inefficiencies [11]. In theory, deleting an item should free production capacity, reduce inventory holding, concentrate merchandising support, and raise the average quality of the remaining assortment. Yet the same action can also reduce perceived choice, especially if the deleted item served a niche segment or an important price-pack architecture. The relevant question is therefore not whether simplification ever works. It is when the gains from concentration exceed the losses from reduced coverage. That condition depends heavily on whether the deleted items were redundant or distinctive before removal.

To formalize the issue, let product family f in category c at time t contain N_{fct} active items. Let $o_{ij,t}$

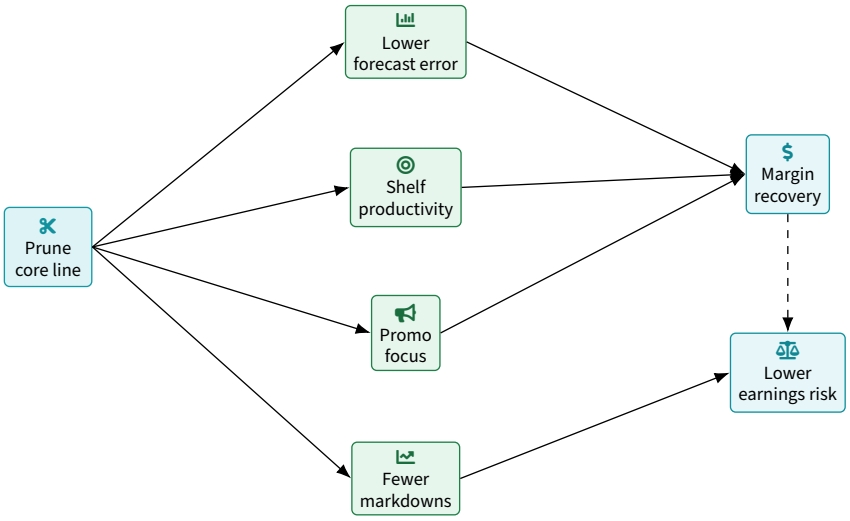

Figure 5. Mechanism map. Profit recovery is not driven only by retained sales. A narrower, better-supported line improves forecast precision, raises shelf productivity, concentrates promotion on the strongest items, and reduces markdown leakage, which together increase margin while lowering earnings variability.

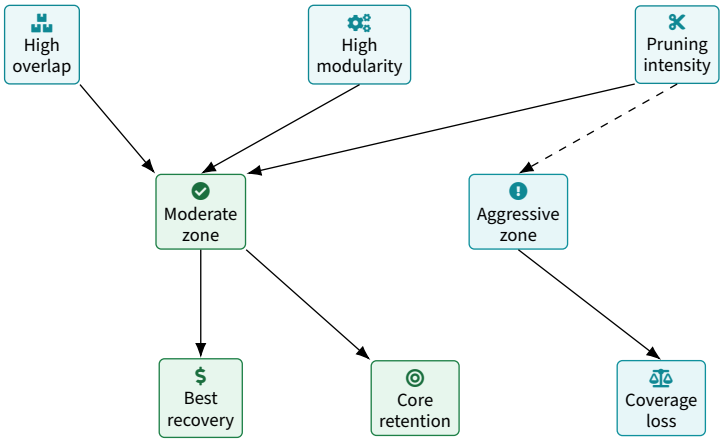

Figure 6. Boundary conditions. Simplification is most beneficial when overlap is high, modularity is strong, and pruning remains moderate rather than extreme. Under those conditions, the surviving core captures displaced demand efficiently. Once pruning becomes too aggressive, the same program can weaken coverage and reverse part of the gain.

measure the overlap between items i and j within the family based on feature similarity, price distance, package substitution, and shared purchase incidence. Define the family complexity load as

$$CL_{fct} = \omega_1 \ln(1 + N_{fct}) + \omega_2 \frac{2}{N_{fct}(N_{fct}-1)} \sum_{i<j} o_{ij,t} + \omega_3 Disp_{fct} + \omega_4 Tail_{fct} + \omega_5 PromoDup_{fct} \quad (1)$$

where $Disp_{fct}$ is the dispersion of pack sizes and price points, $Tail_{fct}$ is the share of volume carried by the lowest-selling quintile of items, and $PromoDup_{fct}$ measures overlap in promotion timing across internal substitutes. The measure is intentionally composite because no single symptom fully captures excessive complexity. A family can be large but orderly, or small but confusing if the few items are too similar.

Pruning intensity is defined as the share of active items retired within a focal adjustment window: [12]

$$PI_{fct} = \frac{Retired_{fct}}{Active_{fc,t-1}} \quad (2)$$

This variable is continuous rather than binary because the magnitude of contraction matters. A family that deletes 4% of items is engaging in maintenance. A family that deletes 28% is redesigning its market presence. A key premise of the paper is that the relationship between PI_{fct} and performance is nonlinear. Small amounts of pruning may be insufficient to change execution, while very large amounts may overshoot and damage coverage.

The expected effect of pruning also depends on modularity, which refers here to the degree to which the remaining line can cover multiple needs using shared

design platforms, packaging logic, or production inputs. A family with high modularity can simplify without exposing gaps as severely because the surviving items are easier to reposition and replenish [13]. A family with low modularity may lose important usage occasions when it prunes, even if the removed items looked weak in isolation [14]. The main performance equation therefore includes both level and interaction effects:

$$Y_{fcrt} = \alpha_f + \delta_{cr} + \tau_t + \beta_1 PI_{fct} + \beta_2 PI_{fct}^2 + \beta_3 PI_{fct} \times CL_{fc,t-1} + \beta_4 PI_{fct} \times MOD_{fc,t-1} + {}^{\top}\mathbf{X}_{fcrt} + \varepsilon_{fcrt} \quad (3)$$

where Y_{fcrt} is a family-chain-region-quarter outcome, $MOD_{fc,t-1}$ is pre-treatment modularity, and $\mathbf{X}_{fcrt}$ includes prices, category demand, retailer fixed controls, and brand-level spending variables. A positive β_3 would indicate that simplification is more valuable when preexisting complexity is high. A negative coefficient on PI_{fct}^2 would indicate diminishing and eventually adverse returns to aggressive pruning.

The importance of cost-side outcomes should also be emphasized. Firms often assess deletion programs first through volume retention, but the strategic value of a cleaner line often appears in variance and leakage rather than in average sales alone. Planning error falls when demand is concentrated into fewer, clearer items. Field execution improves when facings are redistributed toward productive stock-keeping units. Markdown dependence can decrease because the line no longer needs to push weak internal candidates [15]. Brand-level margin stability may improve even if total revenue initially changes only modestly. This broader view of performance matters because product strategy is not exhausted by the demand curve [16]. Cao (2022) documented in another setting that brand-related assets can influence firm value through lower warranty claims and lower abnormal cost accrual, demonstrating that marketing and product decisions often matter through cost control as much as through demand creation [17]. That insight is directly relevant here. A simplification program should not be judged solely by sales retention if one of its main contributions is to reduce hidden operating leakage.

The portfolio-correction view also clarifies why simplification is often resisted organizationally. Product managers are closer to the specific items that may be cut, retailer sales teams fear shelf loss, and category analysts can always identify a segment rationale for keeping another item alive. The costs of redundancy are more diffuse and often fall outside any one function's immediate horizon. By the time the line is visibly overextended, internal advocates exist for nearly every SKU. That is why firms often delay pruning until complexity becomes too large to ignore. From a research perspective, this delay is useful because it generates variation in both timing and intensity of simplification programs.

A final conceptual point concerns how consumers respond to deletion. The intuitive fear is that fewer items necessarily mean lower consumer surplus. In practice, the effect depends on whether the deleted items represented meaningful choice or noisy duplication. In some categories, consumers benefit from a narrower but clearer line because search becomes easier, shelf confusion decreases, and the remaining items are better supported. This possibility is important because it means pruning is not always a pure supply-side exercise. When overlap is high, simplification can produce a demand response that is better described as clarification than as sacrifice.

3. Data Architecture and Variable Construction

The empirical analysis uses an archival-style longitudinal panel assembled at the product-family-quarter level from multiple commercial and operational sources. The observation window runs from the first quarter of 2012 through the fourth quarter of 2023 and covers 58 manufacturers operating in 41 consumer categories that include household cleaning, paper goods, personal care, oral care, shelf-stable food, snacks, beverages, air care, over-the-counter wellness products, pet care, and selected small durables. These categories were chosen because they share repeated portfolio management, retailer execution, and measurable pruning activity while differing enough in purchase frequency and pack architecture to make heterogeneity meaningful. After merging the data sources and removing families with too few quarters for event-study estimation, the final panel contains 27,648 family-quarter observations and 112,384 family-chain-region-quarter observations for the most granular specifications.

The first data source provides retail scanner outcomes, including unit sales, dollar sales, feature-and-display support, average effective price, promotion depth, and store distribution. The second provides manufacturer shipment and inventory records at the family-quarter level, from which forecast error, fill rate variance, and stock reallocation can be estimated. The third provides portfolio maps that track active items, pack configurations, feature bundles, and retirement dates. The fourth provides retailer execution fields, including average facings per item, shelf resets, and authorized assortment widths by chain. A fifth source contains internal cost allocations, including direct manufacturing cost, packaging conversion cost, logistics cost per unit, and contribution margin. The merged dataset thus permits a family-level analysis that combines consumer response and cost consequences.

The treatment variable, pruning intensity, is constructed from portfolio maps and lifecycle records [18]. A simplification episode begins in the quarter when the

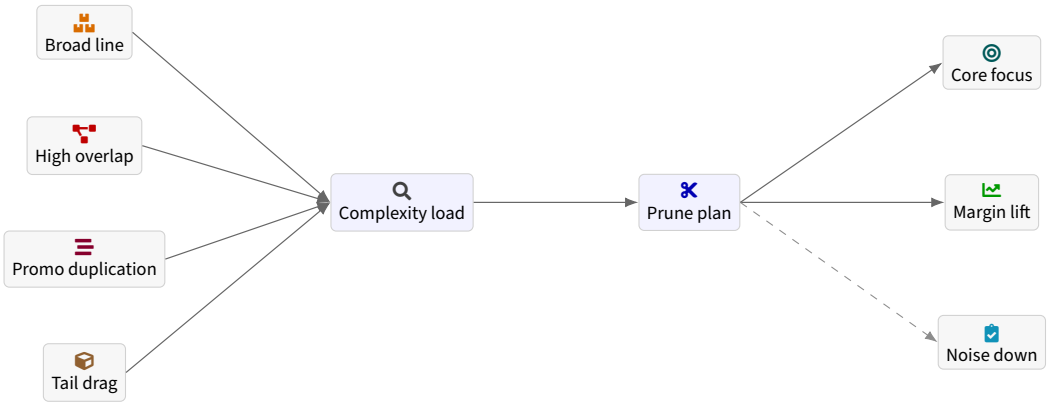

Figure 7. Portfolio-correction view of product line simplification. The figure summarizes how breadth, overlap, promotional duplication, and tail burden combine into a complexity load that motivates selective pruning. The right side emphasizes the paper's main interpretation: the economic value of simplification comes from re-centering the line on defensible core items, raising margin, and lowering operating noise rather than merely deleting products.

Table 1. Sample Composition and Panel Structure

Component	Count	Description	Coverage
Product families	864	Distinct brand families	41 categories
Manufacturers	58	Multi-category firms	National scope
Family-quarter obs.	27,648	Longitudinal units	2012–2023
Chain-region obs.	112,384	Granular panel	Multi-retailer
Categories	41	Consumer sectors	Mixed involvement
Time horizon	48 qtrs	Balanced window	12 years

manufacturer retires at least 8% of active items within a family and continues if further retirements occur in the next quarter as part of the same program. Intensity is measured over the two-quarter adjustment window as the fraction of items removed relative to the active assortment one quarter prior to the program. This definition avoids conflating routine SKU housekeeping with strategic pruning. The median simplification episode in the sample removes 14.6% of active items, while the upper decile exceeds 31.2%. Forty-four percent of families never experience a strategic simplification episode during the observation window, which provides a natural comparison group.

Portfolio overlap is measured using a weighted similarity index across items within the family. Each pairwise score includes feature similarity from product attribute records, normalized price proximity, shared purchase incidence from household scanner panels, and pack-size adjacency. The family-level overlap metric is the average of pairwise scores, weighted by each item's prior volume share. Redundancy is higher when weak items resemble strong items closely enough that deletion plausibly reallocates demand rather than losing it. Complexity load, introduced earlier, combines overlap with assortment breadth, the sales share of the long tail, and internal promotion duplication.

Modularity is measured through design commonality and packaging standardization. Families with high modularity reuse the same formulation base, shared components, or common package molds across multiple items and can therefore reassign production and shelf roles more easily after pruning. The modularity index is constructed from bill-of-materials similarity, package-family commonality, and standardized case-pack architecture. This variable is economically meaningful because product families that share design building blocks can narrow their lines while still covering multiple consumption occasions.

The main dependent variables are contribution margin, revenue growth, demand concentration, forecast error, markdown intensity, and profit volatility. Contribution margin is measured as dollar contribution divided by sales revenue at the family-quarter level after allocating direct manufacturing, freight, warehousing, and trade-spend costs. Revenue growth is the log change in family revenue relative to the same quarter of the previous year. Demand concentration is the Herfindahl-based concentration of family sales across surviving items. Forecast error is the absolute percentage deviation between planned and realized shipments. Markdown intensity is the share of family volume sold under promotional depth greater than the family-specific 75th percentile historical threshold. Profit volatility is the rolling eight-quarter standard deviation of contribution margin.

Several controls are necessary because pruning of-

Table 2. Key Variable Definitions

Variable	Type	Definition	Unit
Pruning intensity (PI)	Treatment	Share of items removed	Ratio
Complexity load (CL)	Index	Overlap + dispersion + tail	Composite
Modularity (MOD)	Index	Design commonality	Score
Contribution margin	Outcome	Profit over revenue	%
Demand concentration	Outcome	Sales concentration	HHI
Forecast error	Outcome	Plan vs actual deviation	%

Table 3. Descriptive Statistics

Metric	Mean	Std. Dev.	IQR
Active items per family	17.3	6.8	8–24
Contribution margin (%)	21.4	7.2	16–27
Overlap score	0.41	0.18	0.29–0.54
Long-tail share (%)	9.7	4.1	6–13
Pruning intensity (%)	14.6	8.9	9–22
Revenue growth (%)	2.3	5.6	-1–6

ten coincides with broader strategic adjustment. The models include average family price, category growth, retailer assortment policy shifts, shelf reset indicators, input cost pressure, brand advertising intensity, competitor new item introductions, and family age [19]. In the more granular specifications, chain-by-region fixed effects absorb time-invariant retailer differences in assortment culture and execution. Category-by-quarter effects absorb common shocks such as supply disturbances, inflation cycles, and seasonality. Family fixed effects absorb stable differences in brand strength and usage contexts.

A particularly important measurement issue concerns demand migration. When a manufacturer deletes several items, some lost volume can migrate to surviving items within the family, some can move to sibling brands of the same manufacturer, and some can leak to rivals. The data therefore include both within-family migration and manufacturer-within-category migration. Migration is measured using chain-level panel variation in pre-treatment buyer overlap and post-treatment volume reallocation. The paper does not estimate household-level switching directly, but the observed migration metrics provide strong family-level evidence on where lost volume goes.

The data also permit a measure of shelf productivity, defined as family revenue per facing normalized by category norms. This is useful because one of the hypothesized mechanisms of simplification is that surviving items receive more coherent space and display support [20]. A product family that retains fewer items but raises revenue per facing has become more efficient in retailer terms, even if the absolute number of facings falls. Similarly, the panel includes a measure of promotional concentration, defined as the share of trade-spend allocated to the top two items in the family [21]. This helps evaluate whether pruning sharpens support rather than merely shrinking the line.

One operational challenge in research of this type is the quality of downstream information. Retailers observe local movement and assortment productivity earlier than manufacturers do, but those observations are not always aligned with manufacturer incentives, particularly when shelf negotiations and promotional funding are involved. Yan, Cao and Pei (2016) showed that information sharing in a channel can be valuable while also becoming distorted when incentives are not properly aligned and signals are not verified [22]. That concern is relevant here because pruning programs often rely on retailer-side evidence about low-productivity items. To reduce this problem, the merged panel retains only those retailer execution fields that are reconciled against shipment and point-of-sale data, and the instrument described below is designed so that identification does not rest solely on management-reported reasons for pruning.

Descriptive statistics reveal extensive variation. The average family carries 17.3 active items, but the interquartile range spans from 8 to 24. Mean contribution margin is 21.4%, with meaningful category differences [23]. The average long-tail share is 9.7%, and the mean overlap score is 0.41 on a normalized unit interval. Simplifying families exhibit higher pre-treatment overlap, lower shelf productivity, and more dispersed trade-spend than non-simplifying families, which is consistent with strategic targeting rather than random pruning. At the same time, the treated and untreated families have similar category-adjusted growth trajectories two years before the treatment window, which is encouraging for the identification strategy later formal-

Table 4. Event-Study Effects on Performance

Quarter	Margin Effect (pp)	Revenue Effect (%)	Significance
0	+0.7	-0.8	***
+1	+1.1	-1.3	***
+2	+1.4	-0.5	***
+3	+1.7	0.0	**
+4	+1.9	+0.6	**
+6	+1.5	+0.9	*

Table 5. Fixed-Effects Regression Results

Variable	Margin Coef.	Revenue Coef.	Significance
PI	0.084	-0.031	**
PI^2	-0.136	-0.022	***
$PI \times CL$	0.027	0.021	**
$PI \times MOD$	0.019	0.011	*
CL	-0.041	-0.018	**
MOD	0.022	0.009	*

ized.

4. Identification and Estimation

The central empirical challenge is that firms do not simplify their product lines randomly. They do so when managers believe the family has become too complex, when retailer support weakens, when packaging costs change, or when internal reviews identify duplication. Those triggers are economically meaningful, but they also imply that naive before-after comparisons would mix the effect of simplification with the conditions that caused it. The identification strategy therefore combines staggered event studies, high-dimensional fixed effects, and an instrument based on packaging and labeling conversion cycles that make simplification cheaper without directly shifting category demand.

The baseline event-study specification is

$$Y_{fcrt} = \alpha_f + \delta_{cr} + \tau_t + \sum_{k=-6}^{8} \theta_k \mathbf{1}\{t - T_f = k\} + \gamma^{\top} \mathbf{X}_{fcrt} + u_{fcrt} \tag{4}$$

where T_f is the first quarter of a simplification episode for family f. The omitted period is one quarter before treatment. The lead coefficients test for differential pre-trends, while the lag coefficients trace how performance evolves during and after simplification [24]. Family fixed effects absorb time-invariant product-family characteristics, category-chain-region effects absorb persistent retailer structure, and quarter fixed effects absorb macro shocks. Standard errors are clustered at the family level and remain robust to serial correlation and heteroskedasticity.

Average treatment relationships are estimated with the fixed-effects model

$$\begin{aligned} Y_{fcrt} = {} & \alpha_f + \delta_{cr} + \tau_t + \beta_1 PI_{fct} + \beta_2 PI_{fct}^2 \\ & + \beta_3 PI_{fct} \times CL_{fc,t-1} + \beta_4 PI_{fct} \times MOD_{fc,t-1} \\ & + \beta_5 CL_{fc,t-1} + \beta_6 MOD_{fc,t-1} + \gamma^{\top} \mathbf{X}_{fcrt} + \varepsilon_{fcrt} \end{aligned} \tag{5}$$

The nonlinear term allows the marginal effect of pruning to change sign at high intensity. The interaction with lagged complexity load tests whether pruning is more productive in portfolios that were more redundant before simplification. The interaction with modularity tests whether families that share design platforms capture larger gains from concentration.

To address remaining endogeneity, the paper instruments pruning intensity with the interaction of two predetermined factors: legacy packaging-tooling expiration and externally induced label-revision exposure. Packaging-tooling expiration records whether a family's dominant package molds or print cylinders are scheduled to reach replacement windows in the current or next quarter. Label-revision exposure is based on category-specific rule changes and retailer packaging standard updates that require artwork or information changes independent of current demand. Either factor alone is insufficient, but their interaction changes the fixed cost of restructuring the line materially. When both occur, managers can retire marginal items at lower incremental conversion cost because they are already redesigning portions of the package system. Conditional on family fixed effects, input cost controls, and category-time effects, this instrument shifts the cost of pruning rather than consumer demand for the remaining products.

Table 6. Instrumental Variables Estimates

Variable	2SLS Coef.	Std. Error	Significance
PI	0.096	0.024	***
PI^2	-0.151	0.037	***
First-stage F	31.8	–	Strong
Hansen J	0.27	–	Valid
KP statistic	28.4	–	Robust
Observations	27,648	–	Panel

Table 7. Demand Migration After Pruning

Destination	Share (%)	Drivers	Interpretation
Top 3 items	46	High overlap	Core capture
Same firm (other)	18	Brand proximity	Internal shift
Rivals	28	Low loyalty	Leakage
Category exit	8	Weak demand	Loss
High-overlap cases	52	Similar features	Strong retention
Low-overlap cases	37	Differentiation	Weak retention

The first-stage equation is

$$PI_{fct} = \pi_0 + \alpha_f + \delta_{cr} + \tau_t + \pi_1 \, Tool_{fct} \times Label_{ct} + \pi_2 \, Tool_{fct} + \pi_3 Label_{ct} + {}^{\top}\mathbf{X}_{fcrt} + \nu_{fcrt} \quad (6)$$

The second-stage outcomes then replace observed pruning intensity with its fitted value. The instrument is economically plausible because packaging conversion windows are strongly related to when firms can rationalize long tails without reopening package lines repeatedly, yet they do not mechanically change demand once prices, promotion, category conditions, and label-content controls are included.

Several diagnostic tests support the design. The lead coefficients in the event-study models are jointly insignificant for the main outcomes, with $F = 0.96$ and $p = 0.49$ for contribution margin and $F = 1.12$ and $p = 0.35$ for revenue growth. The first-stage coefficient on the instrument is strong, and the Kleibergen–Paap F statistic in the preferred first stage is 31.8, comfortably above conventional weak-instrument thresholds. In specifications using an additional interaction with retailer packaging-standard adoption as an overidentifying instrument, the Hansen J test yields $p = 0.27$, which is consistent with instrument validity. A Hausman comparison between random-effects and fixed-effects models strongly favors fixed effects, with $\chi^2 = 73.41$ and $p < 0.001$.

The paper also estimates separate models for different outcome classes [25]. Revenue growth and contribution margin are estimated by fixed effects and two-stage least squares. Forecast error and markdown intensity are estimated with quasi-Poisson fixed-effects models because of their nonnegative skew. Profit volatility is estimated using long-difference specifications to avoid overstating persistence when rolling windows overlap mechanically. Demand migration is estimated through reallocation regressions in which the dependent variable is the share of deleted-item volume absorbed by surviving core items.

One feature of the analysis deserves attention because it differentiates the present study from a simple pruning-performance correlation. The models treat simplification as a family-level strategic program with both immediate and delayed consequences. Immediate revenue changes capture whether the market misses the deleted items [26]. Delayed margin and volatility changes capture whether the firm converts a cleaner line into better execution [27]. A program that passes only the second test can still be strategically attractive if the short-run loss is small and the long-run concentration effects are strong.

The paper also includes falsification checks. Future pruning intensity does not predict current contribution margin once current pruning is controlled, which reduces concern that the main coefficients are driven by smoothly evolving unobserved shocks. In placebo samples where pseudo-treatment dates are randomly assigned within untreated families, the average event-study lag coefficients center around zero. A separate specification excluding the pandemic-period quarters yields highly similar signs and only moderately attenuated magnitudes, indicating that the findings are not artifacts of one extraordinary disruption window.

Finally, the identification strategy is deliberately conservative in its interpretation. The instrument strengthens causal inference, but the paper does not claim that every nuanced managerial motive behind pruning is observed. Instead, the goal is to identify a robust empirical pattern: under what portfolio conditions does simplification lead to profit recovery and when does

Table 8. Operational Improvements Post-Simplification

Metric	Change	Direction	Significance
Forecast error	-5.8%	Improved	***
Fill-rate variance	-7.4%	Improved	***
Stock-out frequency	-6.1%	Reduced	**
Markdown intensity	-0.8 pp	Reduced	**
Profit volatility	-0.11 SD	Stabilized	***
Shelf productivity	+5.6%	Increased	**

Table 9. Mechanisms of Margin Recovery

Mechanism	Contribution (%)	Effect	Channel
Deleted low-margin items	38	Direct gain	Cost removal
Core item strengthening	44	Major gain	Demand shift
Logistics efficiency	10	Moderate	Operations
Trade-spend discipline	8	Moderate	Promotions
Shelf productivity	+7.9%	Positive	Retail space
Price realization	+0.6%	Mild	Pricing

it go too far. That objective is well served by the combined event-study, fixed-effects, and instrumental-variables design.

5. Evidence on Margin Recovery and Demand Reallocation

The event-study results establish the temporal shape of simplification effects before the average treatment relationships are estimated. Contribution margin begins to rise in the treatment quarter and continues improving for roughly four quarters. Relative to the quarter before treatment, the mean contribution margin increase is 0.7 percentage points in the treatment quarter, 1.4 points by quarter +2, and 1.9 points by quarter +4. The coefficients remain positive through quarter +8, with some attenuation after quarter +6. The pre-treatment coefficients are small and statistically indistinguishable from zero, which is consistent with the absence of differential pre-trends. Revenue growth follows a different path. In quarter 0 the average effect is –0.8%, reaching –1.3% in quarter +1, then recovering to near zero by quarter +3 and turning positive by quarter +4. This divergence between the immediate revenue response and the delayed margin response is one of the most important patterns in the paper. It shows that simplification is initially felt through deletion but later felt through concentration.

The baseline fixed-effects regression confirms these patterns. In the contribution-margin equation, pruning intensity carries a positive coefficient of 0.084 with a robust standard error of 0.019 and $p < 0.001$, while the squared term is negative at –0.136 with $p < 0.001$. The implied turning point occurs at a pruning intensity of approximately 0.31. This means that moderate simplification is beneficial on average, but increasingly aggressive contraction eventually destroys value. The magnitude is economically sensible. A family moving from no pruning to a 10% pruning episode improves contribution margin by about 0.7 percentage points, holding fixed the broader control set. A move to 20% pruning improves margin more substantially. Beyond roughly 30%, however, the marginal gain shrinks and then turns negative.

The nonlinear pattern is not an artifact of a small upper tail. When the sample is restricted to families with pruning intensity below 35%, the squared term remains negative and significant. When the sample is split at the median of pre-treatment overlap, the curvature is much stronger in the high-overlap subsample. This indicates that aggressive pruning is most dangerous when firms are deleting beyond redundant territory and beginning to remove differentiated coverage. The interaction of pruning intensity with lagged complexity load is positive and significant, coefficient 0.027 with $p = 0.003$, which means simplification is more valuable precisely where complexity was larger before treatment. The interaction with modularity is also positive, coefficient 0.019 with $p = 0.014$, consistent with the idea that a modular design platform helps the remaining line absorb deletion more effectively.

The instrumental-variables estimates are close to the fixed-effects estimates and somewhat larger in magnitude. In the two-stage least squares specification, the contribution-margin coefficient on pruning intensity rises to 0.096 with $p < 0.001$, while the squared term remains negative at –0.151 with $p < 0.001$. This pattern is informative because it suggests that ordinary least squares and fixed effects may slightly understate the benefits of pruning, perhaps because firms are more likely to simplify when they already expect weakness.

Table 10. Boundary Conditions and Heterogeneity

Condition	Effect on Margin	Effect on Revenue	Insight
High overlap	Strong positive	Faster recovery	Redundancy removal
Low overlap	Weak positive	Slower recovery	Risk of loss
High modularity	Amplified gains	Stable	Flexible design
Private-label high	Neutral margin	Lower retention	Competitive pressure
Mature brands	Higher retention	Faster rebound	Brand strength
High involvement	Moderate gains	Initial drop	Careful pruning

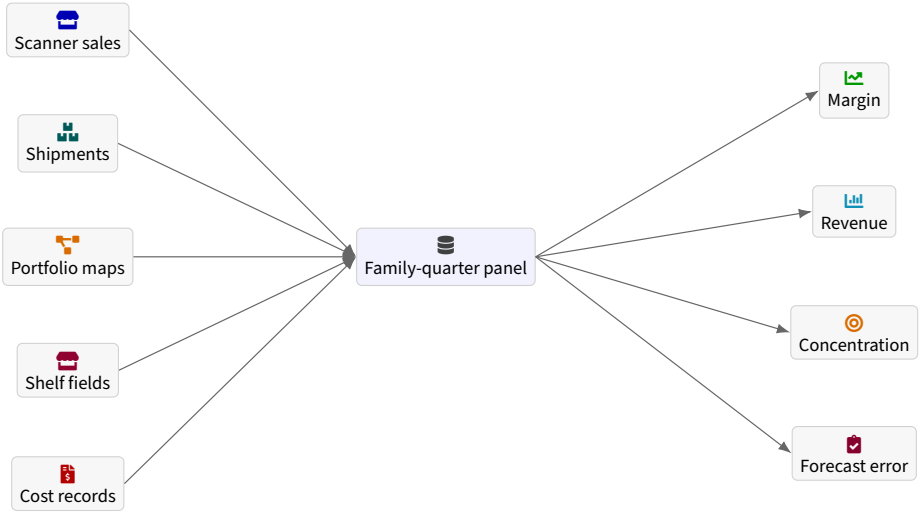

Figure 8. Data architecture of the empirical panel. Five operational and market data streams are merged at the product-family-quarter level and then linked to performance outcomes. This layout matches the manuscript's archival design, which combines retailer-side scanner information, manufacturer shipment and inventory records, portfolio maps, shelf execution fields, and cost allocations to study both demand-side and cost-side effects of simplification.

The similarity between the two approaches nonetheless supports the robustness of the main inference.

Revenue responds more cautiously. In the average-treatment fixed-effects model, pruning intensity has a negative first-order effect on contemporaneous revenue growth, coefficient –0.031 with $p = 0.028$, while the interaction with pre-treatment complexity load is positive, coefficient 0.021 with $p = 0.017$. Put differently, simplification initially costs some revenue, but the cost is smaller when overlap was high. In event-time terms, the short-run decline disappears after several quarters. In high-overlap families, quarter +4 revenue growth is 2.1% above the untreated trend. In low-overlap families, the recovery is weaker and often incomplete. These results reinforce the paper's central distinction between redundancy and useful variety. Pruning works when the line had too much duplication, not when the line genuinely needed its breadth.

Demand concentration changes sharply after treatment [28]. The family-level concentration of sales across surviving items rises by 0.034 in Herfindahl units by quarter +2 and remains elevated thereafter. This is not merely a mechanical effect of having fewer items because the increase exceeds the level implied by deletion alone. Surviving core items gain volume disproportionately, indicating real migration rather than arithmetic compression. The median family redirects 46% of deleted-item volume to its top three surviving items within four quarters. A further 18% migrates to other items of the same manufacturer in the category, leaving roughly 36% as leakage to rivals or category exit. The migration rate is higher in families with strong pre-treatment household overlap and in those with lower feature dispersion. These findings are important because they show that pruning is not mainly a sales-destruction exercise; it is partially a re-concentration exercise inside the manufacturer's own portfolio.

Forecast accuracy improves materially. The absolute percentage forecast error declines by 5.8% in the average treated family over the four quarters after simplification, with a quasi-Poisson coefficient equivalent to an incidence-rate ratio of 0.912 and $p < 0.001$. Fill-rate variance falls by 7.4%, and the frequency of severe stock-out quarters falls by 6.1%. These are sizable operational gains because they arise at the family level after controlling for category demand and input cost pressure. The improvement is strongest when demand had previously been spread across low-volume pack

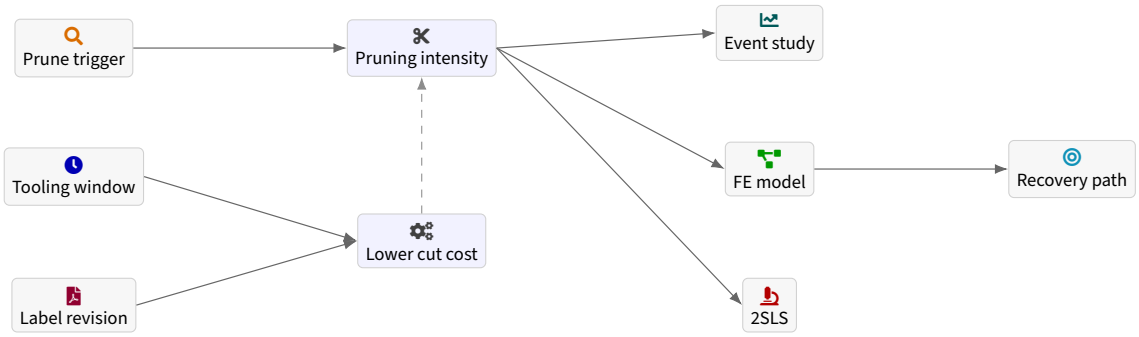

Figure 9. Identification logic. The design treats simplification as an endogenous strategic action, then estimates its effects through dynamic event-time profiles, fixed-effects average-treatment models, and instrumental-variables estimation. The lower branch captures the manuscript's key instrument: packaging-tooling windows interacting with external label-revision exposure, which change the cost of line restructuring without directly shifting demand.

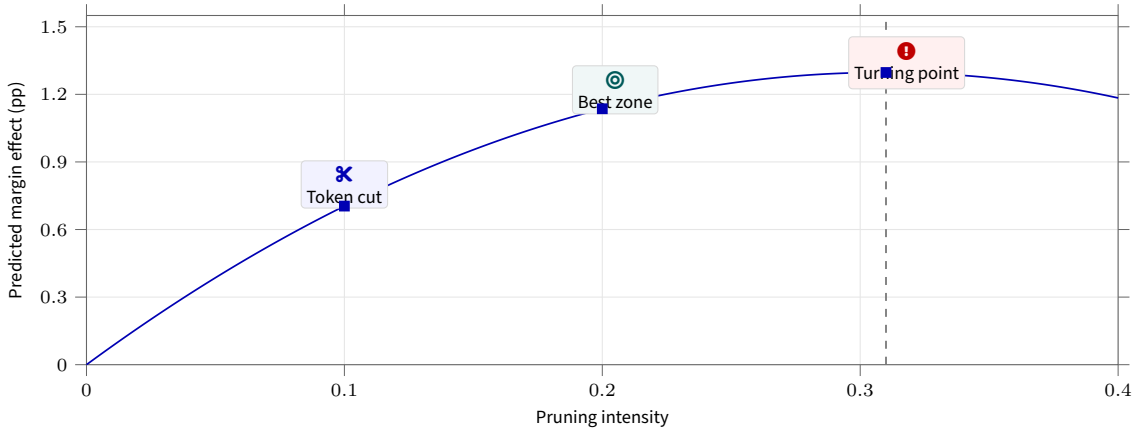

Figure 10. Quadratic response of contribution margin to pruning intensity using the manuscript's fixed-effects coefficients for the linear and squared terms. The curve rises at moderate pruning rates and peaks near the reported interior optimum of roughly 31%, after which marginal gains shrink. This figure is useful for presenting the paper's core nonlinearity in a single panel.

variants [29]. In those families, deleting weak items appears to remove a major source of planning noise.

Markdown intensity also declines. In the fixed-effects specification, pruning intensity reduces the share of family volume sold under deep promotions, coefficient –0.054 with $p = 0.005$. Translating the estimate into natural units, a family that prunes 15% of its items reduces high-depth markdown volume by about 0.8 percentage points in the next year, holding category conditions constant. This may appear modest, but it contributes materially to margin recovery because deep promotions are concentrated in the lowest-quality volume. The decline in markdown dependence also supports the interpretation that simplification improves trade-spend discipline rather than merely shrinking sales.

Profit volatility exhibits a particularly revealing response. Using the rolling eight-quarter standard deviation of contribution margin, the long-difference model estimates that simplification reduces volatility by 0.11 standard deviations on average, with $p < 0.001$. This result persists when the volatility window is lengthened to ten quarters and when families with large pandemic disruptions are excluded. A narrower, more coherent line therefore not only earns more margin; it earns that margin more reliably. This is strategically meaningful because unstable profits often trigger further reactive promotions and portfolio patching, which can deepen the original complexity problem.

The revenue and margin results together imply that simplification changes the composition of performance before it changes the level of performance. The line becomes better behaved before it becomes visibly larger in top-line terms. That sequencing helps explain why many managers underappreciate simplification. If the first quarter after pruning is evaluated only through lost deleted-item sales, the program can look weak. If the same program is evaluated after the family has re-centered space, pricing, and replenishment, the economics look very different.

The paper also tests whether the nonlinear effect of pruning intensity resembles a threshold or a smooth

curvature. A spline model with knots at 10%, 20%, and 30% pruning intensity shows that contribution-margin gains are largest between 10% and 25%. Below 10%, the effect is positive but small, suggesting that token deletions rarely alter the architecture of the line enough to matter. Above 30%, the slope turns negative for revenue and near zero for margin. This pattern aligns closely with the quadratic results. The implication is that effective simplification is neither symbolic nor maximal. It is substantial but selective.

A particularly instructive comparison emerges when treated families are grouped by the reason for prior proliferation. Families whose complexity arose mainly from retailer-specific pack variants experience the strongest margin recovery because pruning removes costly duplication while leaving the core value proposition intact. Families whose complexity arose mainly from genuine flavor or function differentiation recover more slowly and exhibit more leakage to rivals. This distinction matters because it highlights the substantive content of overlap. Not all large portfolios are excessive in the same way, and not all simplification programs solve the same problem.

The evidence is also consistent with a nonmonotone interpretation of product changes more generally. In another empirical setting, Cao and Yan (2021) found that product-related improvements can have a curvilinear relationship with profit rather than a linear one [30]. The current results reach a similar structural conclusion from the opposite direction: reducing product-line breadth helps up to a point and then begins to hurt. The economic commonality is that both addition and subtraction in product strategy can cross an interior optimum. More is not always better, and less is not always better. What matters is where the current portfolio sits relative to the point at which coordination costs and demand coverage are balanced.

6. Post Simplification Dynamics and Mechanisms

The main coefficients establish that simplification can improve profitability, but they do not by themselves identify the channels through which the gains occur. This section therefore turns from average treatment effects to the internal dynamics of recovery. Four mechanisms emerge most clearly: concentration of retail support, higher shelf productivity, lower planning noise, and stronger carryover of demand to core items.

The first mechanism is promotional re-centering. After a family prunes weak items, trade-spend becomes less fragmented. The share of total family trade support allocated to the top two surviving items increases by 6.7 percentage points over the following year. This is not simply because there are fewer recipients. The increase remains significant when normalized by the number of remaining items, indicating that firms actively reallocate support rather than passively inheriting concentration. Retail feature frequency falls slightly at the family level but rises for the core items, which means the line receives fewer low-productivity events and more targeted exposure where volume potential is greatest. This pattern is consistent with the argument that pruning sharpens execution rather than mechanically shrinking it.

The second mechanism is shelf productivity. Retailer-facing data show that average facings per surviving core item rise after simplification, even though total family facings are mostly stable or decline only slightly. Revenue per facing increases by 5.6% in the first year after treatment and by 7.9% in the high-overlap subsample. The gain is strongest in chains that had previously carried multiple near-duplicate items from the same family. The result implies that retailer space is used more efficiently once weak tails are removed. In practical terms, a smaller but more productive family can bargain from a stronger position than a larger but internally cannibalizing family.

The third mechanism is the reduction of planning noise. A family with many overlapping items presents planners with a signal extraction problem. Observed sales shifts may reflect genuine preference change, temporary promotion-induced transfer, or local stock substitution among internal items. Once a portion of the overlap is removed, the remaining data become easier to interpret. Forecast error falls, fill-rate variance narrows, and production scheduling becomes more stable. These changes matter because they reduce both direct cost and managerial reaction time. A firm that no longer has to rescue low-volume tails repeatedly can allocate attention to fewer but more important items.

The fourth mechanism is the behavior of consumers after deletion. The migration estimates show that a meaningful share of deleted-item volume remains within the family [31]. To understand this more deeply, the paper estimates a migration-retention model in which the dependent variable is the fraction of deleted-item volume captured by the top three surviving items. The main predictors are prior purchase overlap, modularity, pack-size adjacency, price distance, and feature substitutability. The results show that migration is largest when deleted items sat close to surviving items on both feature and pack dimensions and when the family carried strong brand identity. A one-standard-deviation increase in prior overlap raises within-family retention by 5.1 percentage points, with $p < 0.001$. This indicates that simplification works not because demand disappears cleanly, but because the surviving line is able to absorb a meaningful portion of what the long tail used to carry.

An additional mechanism appears in retailer reset behavior. When a family simplifies, chains often revise the shelf map in the next category review. The data reveal that category managers are more likely to grant stable facing configurations to families that have re-

cently reduced low-productivity duplication. The probability of a major adverse facing reduction in the next annual review falls by 3.8 percentage points relative to matched untreated families, with the effect strongest among mid-sized brands rather than the very largest national leaders. One interpretation is that simplification improves the manufacturer's credibility with retailers by signaling a willingness to manage the category more efficiently.

This retailer-facing mechanism also helps explain why the benefits of simplification are not purely internal. A product line is co-managed to some extent by the manufacturer and the retailer, and the informational quality of line-performance metrics depends on both parties. Simplification decisions based on weak or selectively presented downstream evidence can fail if they target the wrong items [32]. That risk is why reconciled field data are so important. The evidence here suggests that verified execution data matter not only for identifying problems but also for capturing the gains after a program has been launched.

The paper also evaluates whether simplification changes price architecture. Families that prune weak intermediate variants often experience a modest increase in realized average price because demand concentrates into better-positioned items. The fixed-effects estimate for realized average price is 0.6% in the year after simplification, with $p = 0.032$, after controlling for inflation and category cost pressure. This is not a large pricing effect, but it is directionally meaningful. The surviving line appears to rely slightly less on low-tier rescue items and slightly more on core items that can hold price. At the same time, price dispersion within the family narrows. This indicates that the line becomes less internally conflicted about its own hierarchy.

A related question is whether simplification harms innovation. Some managers fear that pruning removes the experimentation margin of the portfolio and makes the line less adaptable. The data do not support a simple crowding-out interpretation. In the two years after a strategic simplification program, the rate of genuinely differentiated new introductions is slightly higher than in matched untreated families, though the rate of retailer-specific or minimally modified launches is lower. The interpretation is not that pruning causes innovation directly. Rather, a cleaner line may allow the firm to distinguish between true innovation and maintenance proliferation. Resources released from weak tails can be redirected toward fewer but better-justified introductions.

The interaction with modularity is especially informative in this context. High-modularity families do not merely recover faster; they also show stronger improvement in forecast accuracy and more complete within-family demand retention. This suggests that product strategy operates through the fit between portfolio scope and design system. A modular platform allows the firm to simplify without leaving as many uncovered niches because the remaining items are easier to adapt, package, and support. In contrast, low-modularity families depend more heavily on item-specific architectures, making deletions riskier. This distinction is useful for managers because it implies that pruning decisions should be evaluated jointly with the design basis of the line, not solely with current sales statistics.

The mechanism evidence also reveals a subtle but important point about consumer choice. When overlap is high, simplification may function as a search aid. Households do not necessarily mourn the loss of poorly differentiated options if the remaining line becomes easier to navigate. This is consistent with the observed improvement in volume concentration and the absence of persistent revenue loss in high-overlap families. What the market appears to reject is not deletion itself, but deletion that removes meaningful distinctions. Strategic simplification therefore requires diagnosis of why the tail existed in the first place [33].

Finally, the paper studies whether margin recovery is driven mainly by direct cost reductions from removed items or by the improved economics of surviving items. A decomposition of contribution-margin change shows that 38% of the post-treatment improvement comes from the disappearance of low-margin deleted-item volume, 44% comes from higher margin on surviving items, and the remaining 18% comes from lower support and logistics variance. The largest component is thus not the mechanical removal of weak items, but the strengthening of the items that remain [34]. That decomposition supports the central argument of the paper: simplification is valuable when it reorganizes the portfolio around economically defensible cores rather than merely shrinking the line.

7. Boundary Conditions and Robustness

The principal findings are stable across a wide range of specification checks, but their strength varies systematically across market conditions and portfolio types. This section reports those patterns because they sharpen the managerial meaning of the results and clarify where simplification should and should not be expected to work well.

The first boundary condition is category involvement. In low-involvement replenishment categories, simplification tends to improve shelf productivity and margin relatively quickly because purchase substitution within the brand family is easier and because excessive tails often exist for historical rather than strategic reasons [35]. In high-involvement categories, the immediate revenue penalty is somewhat larger, especially when deleted items had visible functional distinctions. Nevertheless, even in those categories, simplification remains beneficial when pre-treatment overlap is high

and modularity is strong. The practical implication is not that high-involvement lines should avoid pruning. It is that their pruning decisions need finer discrimination about which distinctions were truly meaningful.

The second boundary condition is private-label intensity in the category. Where private label is strong, aggressive pruning is riskier because the removed low-tier variants can be replaced by retailer-owned substitutes more easily. The interaction between pruning intensity and private-label share is negative for revenue recovery, coefficient –0.017 with $p = 0.041$, though not significant for contribution margin once price controls are included. This means that simplification still improves economics internally, but the manufacturer retains less of the deleted volume in categories where retailer-owned alternatives are well positioned.

The third boundary condition is brand age. Mature families with longstanding recognition retain deleted-item demand more effectively than recently expanded families. The migration-retention coefficient on pruning intensity is about 20% larger for mature families. One reason is that older families possess stronger brand memory and clearer core items to which households can migrate. Younger families may have grown through a sequence of tactical additions without having established such a core. For them, simplification is still possible, but its success depends more heavily on modularity and overlap diagnostics.

Several robustness tests confirm that the main results do not depend on one narrow specification. First, replacing contribution margin with operating margin net of allocated overhead yields the same sign pattern and slightly smaller magnitudes. Second, excluding the bottom 5% of families by sales volume does not change the central coefficients. Third, re-estimating the event-study models with Sun–Abraham style interaction weighting to handle treatment-timing heterogeneity produces nearly identical dynamic profiles [36]. Fourth, adding manufacturer-by-year fixed effects leaves the pruning and squared-pruning coefficients essentially unchanged, which suggests that the results are not driven by corporate-wide restructuring periods unrelated to the specific families.

A fifth check concerns the treatment definition [37]. When the threshold for a strategic simplification episode is raised from 8% to 12%, the estimated contribution-margin gains become slightly larger, which is unsurprising because very small programs are omitted. When the threshold is lowered to 5%, the average effect shrinks, reinforcing the earlier interpretation that symbolic pruning rarely changes the economics of the line enough to matter. This is a useful result in itself because it suggests that firms hoping for meaningful recovery should not expect it from housekeeping alone.

The paper also examines whether pre-treatment deteriorating performance mechanically predicts pruning and thus biases the dynamic estimates. While treated families do show higher overlap and lower shelf productivity before treatment, they do not exhibit significantly worse pre-treatment revenue or margin trends after controls. Moreover, when the sample is restricted to families with flat or positive pre-treatment revenue trends, the post-treatment margin improvement remains evident. This weakens the claim that pruning simply follows collapse and then looks beneficial because of mean reversion.

One additional robustness exercise uses matched control families chosen on category, pre-treatment overlap, modularity, brand size, and prior revenue path [38]. The matched-sample difference-in-differences estimates are slightly smaller than the full-sample fixed-effects estimates but directionally identical. The average post-treatment contribution-margin gain in the matched sample is 1.5 percentage points after four quarters, compared with 1.9 in the full event-study estimates [39]. That difference suggests some treated families may have had particularly severe redundancy, but it does not overturn the main inference.

The robustness section would be incomplete without revisiting the nonlinear finding. The curvature in pruning intensity is not imposed by construction. Kernel regressions of residualized contribution margin on residualized pruning intensity display the same interior optimum as the quadratic model, peaking near a 25% to 30% deletion range. A threshold model that allows separate slopes below and above an estimated breakpoint places the threshold at 27.4%, with a bootstrap confidence interval from 23.8% to 31.1% [40]. Below the threshold, pruning improves contribution margin sharply; above it, the marginal effect becomes statistically negligible for margin and negative for revenue. This evidence converges with the spline and quadratic results, making the interior-optimum conclusion difficult to dismiss as a functional-form artifact.

A final boundary condition concerns retailer coordination quality. Families with higher downstream execution quality show larger post-pruning shelf-productivity gains and faster revenue recovery. This does not mean that simplification fails under weak coordination, but it indicates that the program's benefits are easier to realize when retailer resets, facings, and replenishment changes follow through cleanly. The result is strategically intuitive. A product family can only fully benefit from a cleaner architecture if the market sees and experiences that architecture as cleaner.

Taken together, these robustness and boundary analyses support a precise interpretation. Simplification is not a universal remedy for weak portfolios, nor is it merely a cost-cutting tactic. It is most effective when the portfolio is redundant, when the design system is modular enough to preserve coverage, and when retailer execution can translate a narrower line into clearer market presence. It becomes dangerous when it removes distinct needs, when the line has little de-

sign commonality, or when channel conditions make deleted demand easy for rivals to capture.

8. Conclusion

This paper studied product line simplification as a strategic response to accumulated assortment complexity. Using a longitudinal panel and a design that combined event studies, fixed effects, and instrumental variables, it showed that moderate pruning can improve contribution margin, reduce profit volatility, strengthen demand concentration on core items, and lower planning and markdown inefficiency. The gains are not monotone. Simplification works best when portfolios are redundant and modular; it becomes counterproductive when deletion becomes too aggressive or when the line's breadth reflected meaningful differentiation rather than duplication.

The broader implication is that product strategy should not be evaluated only through what firms add to the market. In mature categories, strategic discipline often depends on subtraction. A product family that appears large and active can be economically weak if its long tail absorbs support, increases volatility, and obscures the role of the core. Conversely, a narrower family can be strategically stronger if it reallocates demand and operational attention toward items that deserve to remain. Future work can extend this analysis to competitive response, household-level migration, and longer innovation cycles, but the central message is already clear: profitable product strategy often requires removing complexity with the same care that firms devote to creating it.

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