The Impact of Private Label Introductions on Assortment, Prices, and Profits of Retailers

Meilin Ma

Department of Agricultural Economics, Purdue University

Ralph Siebert

Department of Economics, Purdue University and CESifo

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Abstract

We study how the introduction of private label (PL) products affects retailers' prices, demand, and profits, while explicitly accounting for retail assortment adjustments of national brands (NBs). Using a comprehensive dataset on the US beef market, we find that retail stores reposition NBs after introducing a PL to further differentiate them from the PL. Moreover, when PLs are added to the low-priced market segment, stores remove NBs from the same market segment. However, if PLs are introduced into the high-priced segment, NBs are not removed from the retailers' assortment due to intense competition in product variety across stores. We provide evidence that PL introductions and PL-driven assortment changes have ambiguous but small effects on prices. In contrast, assortment changes serve as an instrument to steer consumers toward PLs, having unambiguous and large effects on demand and profits.

Keywords: Prices and demand of national brands, Private label, Retailer assortment decisions.
JEL codes: D22, L66, L81

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1. Introduction

Over the past decades, firms introduced many new products into the retail market (Draganska and Jain, 2005; Saitone and Sexton, 2010). For example, the number of unique products offered by an average supermarket in the US grew from 9,000 in 1975 to 47,000 in 2008 (Consumer Reports, 2014). The substantial product expansion is partly explained by the introduction of private-label brands (hereafter, PLs), also known as store brands (Pauwels and Srinivasan, 2004). The decision on introducing and pricing the PL is made by individual retail stores. Theoretical studies show that PL introductions can have ambiguous effects on product prices of national brands (NBs) in the market (Anderson et al., 1992).[1] The effects on prices and consumer surplus can be large, which explains why PL introductions attract a lot of attention among scholars and policy makers. Empirical studies find mixed results of PL introductions on prices of NBs (e.g., Bontemps et al., 2008). Those studies evaluate price effects, under the assumption that the store's assortment of NBs remains fixed. Our study considers retailers' product assortment changes, while evaluating the effects of PLs on prices, demand, and profits.

The introduction of PLs can intensify intra-store brand competition and enhance the store's competence in inter-store variety competition. To address those competitive forces, retailers can make assortment adjustments (e.g., Draganska et al., 2009; Draganska and Jain, 2010). Our study accounts for assortment adjustments and changed product portfolio of retailers in response to the introduction of PLs. We concentrate on two research questions: how do retail stores change the positioning and the number of NBs after PLs are introduced, and how do those assortment changes affect prices, demand, and profits?

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[1] While some theories suggest that prices tend to decrease (Connor and Peterson, 1992), others show that prices can increase (Hotelling, 1929; Salop, 1979).

Our study provides novel insights when evaluating the effects of PL introductions. We find that retailers conduct assortment changes that affect prices and demands of NBs. Though the price effect of selling PLs is rather limited, the introduction of PL increases a store's profits via assortment changes that strongly divert consumers from purchasing less profitable NBs toward more profitable PL products.

In the late 1970s, retail stores introduced PLs that were considered discount brands to their NB counterparts (Janofsky, 1993). In the early 1990s, the retail market experienced an expansion of PLs that were introduced into economy, standard as well as premium market segments. PL is under full control of the retailer, and PL products are acquired by retailers close to marginal costs of manufacturing from vertically integrated manufacturers (Connor and Peterson, 1992). Selling PLs is likely more profitable for retailers compared with NBs, because PLs eliminate double margins (Mills, 1995; Raju et al., 1995; Narasimhan and Wilcox, 1998). The elimination of double margins allows retailers to sell PLs for low prices, which in turn imposes downward pressure on prices of NBs, especially NBs that are relatively less differentiated from the PL.[2] Even if the price of PL is not lower than NBs, selling PL cannibalizes the demand of existing NBs and causes the "business stealing effect" (Connor and Peterson, 1992; Hamilton and Richards, 2009; Ellickson et al., 2018). Adding the PL as a new brand intensifies within-store competition among brands as argued by Anderson et al. (1992), Connor and Peterson (1992), Shaked and Sutton (1982), and Siebert (2015).

To reduce price competition and the stealing effect, NBs may be further differentiated from PLs in the variety space (Hauser and Shugan, 1983; MacDonald, 1998; Nijssen and Van Trijp,

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[2] For further reasons to sell store brands, such as gaining more bargaining power, improving store image, etc., see Scott-Morton and Zettelmeyer (2004), Steiner (2004), and Draganska et al. (2010).

1998). Some less differentiated NBs may even be withdrawn by the store. Such assortment adjustments soften internal competition among brands (Hotelling, 1929; Shaked and Sutton, 1982), likely leading to relatively high equilibrium prices of all brands and hence store profits (Scott-Morton and Zettelmeyer, 2004; Draganska et al., 2009; Draganska et al., 2010).

Our empirical study investigates the effect of PL introductions on assortment, prices, demand and profits in the context of the US fresh beef retail market from 2006 to 2016. The beef market, which is the highest valued meat market in the United States and generates retail values of over $100 billion in recent years, is well suited for our study for the following reasons. (1) The number of PLs has grown considerably over the period of interest. (2) Retail stores carry a wide range of PLs and NBs. (3) Beef varieties and prices vary across brands, retail stores, and market segments. (4) Retail stores frequently adjust beef prices and assortments, but beef brands rarely change their variety offerings.

We use a big database – the Nielsen Retail Scanner Data. The database contains sales information collected from more than 28,000 retail stores in 49 US states. The database includes more than 1,100 unique beef products and over 200 beef brands, suggesting considerable room for assortment adjustments by retail stores. Each brand offers several beef varieties that differ by their cuts (such as fillet steak, ground/patties ribeye steak, striploin steak, etc.) and packaging sizes (measured in pounds). We classify beef products into 21 varieties as explained in Section 2.

Descriptive analyses show that an increasing number and proportion of stores sell PLs from 2006 to 2016. By 2016, over 75% of the market by volume was occupied by PL products. We consider two assortment adjustments that can be made by stores. First, stores have the opportunity to reposition NBs, that is, they withdraw or replace some of the beef varieties offered by an NB. Second, the store has the opportunity to remove an entire NB. Econometric outcomes show that stores react to introducing PLs by changing the assortment of NBs, differentiating NBs from PLs in the variety space. Stores adding the PL to the low-priced market segment tend to remove NBs that are less differentiated from the PL.

Next, we conduct regressions closely related to previous studies and evaluate direct effects of PL introductions on prices, while not accounting for assortment changes in NBs. Our results show that PL introduction has an insignificant effect on prices of NBs. We then turn to the novelty of our study and argue that assortment changes should be incorporated as they change the degree of brand differentiation and may affect equilibrium prices and sales of brands, and, consequently, store profits.

Estimation results show that PL introduction exerts two countervailing effects on prices. On the one hand, the PL induces stores to reposition NBs to further differentiate NBs from the PL, which increases the degree of product differentiation and increases NB prices. On the other hand, PL introduction imposes downward pressure on prices of NBs by adding products of lower marginal costs (due to eliminated double margins). Though the net price effect is small and ambiguous, the PL-driven assortment changes unambiguously enable stores to steer consumers toward PL products, meaning that the assortment functions as a strategic tool by retailers (Heidhues et al., 2021). Steering consumers to the PL is likely a profitable strategy for the store as PLs are more profitable due to eliminated double margins (see also Luco and Marshall, 2020).

We make two major contributions to the literature. First, we show the relevance of considering NB assortment changes caused by selling PLs and emphasize the heterogeneity in the assortment effect of PLs across market segments. Second, we show the relevance of assortment changes in evaluating PL impacts on prices and sales of NBs. Assortment changes serve as a strategic instrument for stores in altering the degree of product differentiation within-store and help steer consumers toward purchasing PL products. Prior studies do not explicitly consider assortment changes of NBs and, thus, overlook an important channel through which the PL affects NBs and store profits.

1.1 Related Literature

Our study is related to three main areas of research that we introduce below.

(1) There is a rich empirical literature on the price effect of selling PL products on NBs as mentioned earlier. These studies cover a wide range of product categories and make no explicit consideration of the assortment of NBs when estimating the price effect. Some studies show that prices decline (Putsis, 1997; Cotterill and Putsis, 2000; Sayman et al., 2002; Choi and Conghlan, 2006; Chung and Lee, 2017), while other studies provide evidence that prices increase (Ward et al., 2002; Pauwels and Srinivasan, 2004; Bontemps et al., 2008).

(2) A group of studies investigate the effects and aspects of selling PLs beyond price. For instance, a few empirical studies find mixed evidence on the effect of selling a PL on market shares of existing brands (Sethuraman, 2009; Geyskens et al., 2010). Empirical studies on the effect of PLs on the assortment of NBs are rather rare. Pauwels and Srinivasan (2004) offer one of the few examples and find that NBs may add unique products in response to PL introduction.

A few theoretical models discuss the optimal positioning of PLs in the variety space (Choi and Coughlan, 2006; Chung and Lee, 2017). Caprice (2017) establishes the only model without assuming a fixed set of incumbent brands and allows the monopoly retailer to choose to sell a PL instead of a NB to maximize profits. Ter Braak et al. (2014) conduct a survey on factors that determine stores' decision to sell a PL in the low- (standard) or the high-priced (premium) market segment. They find that stores are more likely to introduce PLs in the high segment if the category has a higher need for variety and if NBs in the category spend relatively little on advertisement.

(3) There is an extensive literature on product assortment under competition. Borenstein and Netz (1999), Corts (2001), and Davis (2006) study product assortment in the context of departure times for airlines and showtimes for movies in theaters. They consider the fact that closer departure times and showtimes reduce product differentiation, toughen price competition, and increase demand cannibalization effects. Gandhi et al. (2008) use a theoretical model to show that firms reposition products post-merger to reduce the cannibalization effect, an effect that we study as well. Mazzeo et al. (2018) study retail stores' joint product and price decisions after a merger. They examine firms' product assortment decisions, including the number of products offered which we are also interested in.

Several studies show that firms' decisions on product assortment are dependent on economic attributes, including the degree of product differentiation as it affects price competition, demand of heterogeneous products, and cannibalization effects. For example, Sweeting (2010) studies mergers in the music radio industry and finds that music stations under common ownership are repositioned to reduce overlap in their playlists. In a recent study, Atalay et al. (2020) examine a large number of mergers and acquisitions in retail markets. They find that merging firms reduce the number of products to strengthen core competencies in particular segments of the market. Other important studies that address repositioning and cannibalization effects include Berry and Waldfogel (2001), Einav (2010), Berry et al. (2004), and Draganska et al. (2009).

The remainder of the study is structured as follows. Section 2 introduces our data and a few stylized facts on the introduction of PLs and the correlations with prices and assortment of NBs. In Section 3, we introduce the empirical models and discuss the estimation results on the impact of selling PLs on assortment choices, prices, and sales of NBs. We also conduct several robustness tests. Finally, we draw a few concluding remarks.

2. Data

Our study concentrates on the US fresh beef market – the highest valued meat market in the nation. In 2016, the retail equivalent value of beef produced in the US was worth over $100 billion. Our data come from the Nielsen Retail Scanner Data and contain monthly product-level sales information on more than 28,000 beef-selling stores in 49 US states from 2006 to 2016.[3] A variety of stores, including grocery stores, mass merchandisers, and drug stores (as defined by the NielsenIQ Company) enter the database. These stores provide a nationally-representative sample of beef retailers.

Table 1 displays a few key statistics of our data. The number of retail chains that sell beef varies between 82 and 101 between 2006 and 2016 (see column 2). At the same time, the number of stores selling beef increased from 9,134 to 26,452 during this period (column 3), part of which is driven by Nielsen's adjustments of store selection. During that time, the number of NBs increased from 51 in 2006 to 114 in 2016 (see column 4).

[Table 1 approximately here]

The decision to develop a PL is made at the chain level and the number of PLs increased from 38 to 60 throughout the time frame (see Table 1, column 5). The timing of introducing PLs in specific stores under the chain varies. The number of stores that sold PLs increased from 5,436 to 16,978 stores (see column 6), which relates to an increase in the proportion of PL-selling stores from 59% to 64%. The collective market share of PLs increased from 59% in 2006 to 77% in 2016

[3] The original Nielsen dataset contains weekly observations of a beef product in a store if it is sold for at least once in the week. For the remainder of the study, we aggregate weekly observations to the month level, which helps avoid missing brands due to zero weekly sales of products. If we used weekly observations instead, we risked under-counting the number of brands due to zero sales in some weeks. Because fresh beef is perishable, brands not having at least one transaction in a month would most likely be not available in the store.

(see column 7). No surprisingly, some large NBs experienced steady declines in market shares over the same period (see Table A1).

Figure 1 shows that PLs are introduced by some stores almost every month; at least one store introduced the PL in all but four months from 2006 to 2016. The fact that stores introduce PLs in different months causes challenges in establishing counterfactuals, which rules out the application of specific econometric methods such as difference-in-differences. We, therefore, apply an estimation technique that builds on augmented generalized synthetic control method. Further details on our identification strategy are explained in Section 3.

[Figure 1 approximately here]

The Nielsen database contains more than 1,100 unique beef products belonging to various PLs and NBs. Every beef product is denoted by a universal product code (UPCs). Fresh beef products involve little processing other than cutting and packaging and the only ingredient is the flesh itself. Thus, beef varieties are straightforward to define based upon the sizes and cuts. Specifically, beef cuts include ribeye steak, fillet steak, striploin steak, round, ground, patties, and so on. In terms of package sizes, the majority of beef UPCs weigh less than three pounds. Given the cuts and package sizes, we can group the beef UPCs into 21 varieties. A complete list of the varieties is shown in Table A2.

Noticeably, data show that beef NBs rarely adjust their variety offerings; over 95% of NBs offer the same set of varieties from month to month. This stylized fact ensures that the significant changes in variety offerings of NBs that we identify in Section 3 are primarily driven by retail stores instead of the manufacturers or NB brand managers.

2.1 National Brand and Private Label Prices

For our empirical analysis, we use information on brand prices and brand assortment at the store-market-month level. Local markets are defined at the level of three-digit ZIP codes which indicate the smallest geographic boundary in the Nielsen database. We begin with computing the price of each brand carried by a store for every month measured in dollars per pound.[4] The average price of NBs is \$5.74 and the median price is \$4.94 with a standard deviation of \$2.88 (see Table 2).

[Table 2 approximately here]

Panel A of Figure 2 shows the average prices of beef products for NBs and PLs across the 132 months in our dataset. The average beef price of NBs began to strongly increase after 2009 and reached a peak in 2015; it began to decline thereafter. A similar trend is observed for the average beef price of PLs. The PL price lies below the NB price, which might be indicative of PLs being characterized by lower quality or that the PLs can be produced at lower marginal costs by eliminating double marginalization and, if passed on to consumers, sold at lower prices. The price gap between NBs and PLs narrows over time which likely reflects an upgrading strategy of retailers in the beef market, that is, PL introductions are not limited to the low market segments, but are also realized in high market segments.

[Figure 2 approximately here]

Beef varieties are priced differently. Ground beef varieties cover over 80% of all beef UPCs and hold large market shares (in volume or revenue), contributing 85% of the total beef sales.

[4] The price is calculated by dividing the monthly store-level revenue by the volume sales of brand. All monetary values are measured in 2015 dollars.

Ground beef is relatively inexpensive ($3-$5 per pound, see Table A2); this especially applies to ground beef with fat content above 15%. Various high-priced steak products ($6-$11 per pound) cover only small shares of volume and revenue.

Figure 2, Panel B, illustrates average store-level NB prices for several months before and after the introduction of PLs in stores. Note, month "0" refers to the month when the PL is introduced by the store. Negative numbers denote months before PL introduction, and positive numbers refer to months after PLs are introduced. The figure shows a 10-15% increase in the average price of NBs during the first 12 months of selling the PL (without controlling for other factors determining prices).

2.2 Assortment: Brand Proximity and Brand Numbers

After a PL is introduced into a store has opportunities to adjust the assortment of its NB products. The assortment adjustment of NBs can serve the purpose to soften price competition against the store's own PL products. The adjustment can also be useful to limit the extent to which NBs cannibalize the demand of PLs.

More specifically, we consider two alternatives to adjust NB assortment. First, a store can change positions of NBs in the variety space and hence alter the proximity between NBs and the PL. For example, consider a store that carries one NB offering each of the 21 beef varieties. If the store introduces a PL variety of the low-fat ground beef, it may withdraw the low-fat ground beef variety offered by the NB. Hence, while this NB is still being sold in the store, it only offers 20 varieties. Second, the store would have the opportunity to withdraw all varieties offered by the NB. The two strategies, the repositioning of the NB and the removal of all varieties offered by the NB, have differential implications on the proximity between NBs and the PL, the degree of product differentiation, and price competition. Moreover, the strategies change the extent to which the demand of the PL is cannibalized by NBs. We measure the change in assortment – repositioning of NBs and withdrawal of NBs – using two alternative variables specified below.

Brand Proximity

We measure the change of positions of NBs in the variety space using the uncentered correlation coefficient, also frequently referred to as the Jaffe (1986) index. This index is widely used (Bloom et al., 2013; Harris and Siebert, 2017) and especially appropriate in our context since it allows us to measure the closeness or proximity between national and private brands offering different beef varieties. We consider the 21 beef varieties as introduced earlier and construct for each NB a 21-dimensional vector. Each element of the vector indicates the proportion of UPCs that the NB offers in a specific variety. The vector is established at the store level and adjusted over time as stores can change the assortment offered by NBs.

For example, let brand i in store s sell m_{ist} different UPCs in month t. Among the m_{ist} UPCs, $m_{ist}^{1} \geq 0$ UPCs belong to variety 1, $m_{ist}^{2} \geq 0$ variety 2, so on and so forth until $m_{ist}^{21} \geq 0$. The variety vector for brand i in store s and month t is specified as $v_{ist} = \left(\frac{m_{ist}^{1}}{m_{ist}}, \frac{m_{ist}^{2}}{m_{ist}}, \ldots, \frac{m_{ist}^{21}}{m_{ist}}\right)$ and describes the brand's location in the 21-dimensional variety space.

Similarly, we construct the variety vector for another brand j carried by the store s in t, v_{jst}. The Jaffe index that describes the proximity between two brands i and j in store s at time t and is calculated as the uncentered correlation between brand i and brand j:

$$V_{ijst} = \frac{v_{ist}v_{jst}'}{(v_{ist}v_{ist}')^{\frac{1}{2}}(v_{jst}v_{jst}')^{\frac{1}{2}}}.$$

This index ranges between zero and one. When $V_{ijst} = 0$, the vectors v_{ist} and v_{jst} are orthogonal, hence, the two brands offer completely different varieties in the store. When $V_{ijst} = 1$, the variety distributions of the two brands perfectly overlap, and they offer identical varieties. A larger V_{ijst} indicates that brands i and j offer more similar varieties, indicating lower degree of brand differentiation and more intense price competition as well as cannibalization effects.

Since we are interested in evaluating the assortment changes of NBs after PL introduction, we compare the Jaffe index of NB-PL pairs in a store before and after PLs are introduced. When computing the Jaffe index for NB-PL pairs before the PL is introduced, we face the caveat that the variety vector of the PL is unobserved. We have to declare a hypothetical or "forthcoming" PL as a benchmark so we are able to compute the Jaffe index between NBs and a PL before the PL is actually sold. More specifically, the "forthcoming" PL variety vector, v_{jst}, is set to be the same as the PL variety vector in the first month of selling the PL.

Next, we average the brand proximities between NBs (brands i) and the PL (brands j), for a store s in a month t as follows:

$$V_{st} = \frac{\sum_i V_{ijst}}{n_s},$$

where n_s is the number of NBs in the store. Again, this store-level Jaffe index varies from 0 to 1. If the store carries only the PL, the index is set to zero, meaning that the PL is unique in the variety space. Table 2 shows that this store-level Jaffe index (referred to as *Jaffe Index NB-PL* from now onward) has a mean of 0.34 and a standard deviation of 0.42.

Figure 3 shows the *Jaffe Index NB-PL* for the months before and after PL introduction. After a PL is introduced, the *Jaffe Index NB-PL* drastically declines, implying that NBs are further differentiated from the PL in the variety space. The index falls by over 80% in the first year of selling a PL. Repositioning and further differentiating NBs from the PL could be explained by softening price competition against the PL and reducing the extent to which NBs cannibalize PL demand in the store. We empirically test those conjectures later.

[Figure 3 approximately here]

Brand Numbers

Beyond changing varieties of NBs, the store has the opportunity to withdraw all varieties belonging to an NB. The withdrawal of an entire NB from a store affects the degree of product differentiation, the average proximity between NBs and the PL in the store, the degree of price competition, and cannibalization of PL demand. Since the NB is removed entirely, we are not able to adopt the *Jaffe Index NB-PL* due to missing observations. We hence establish an alternative measure that accounts for the *Number of NBs* in a store across market segments which enables us to incorporate the proximity between NBs and the PL.

Market segments are supposed to capture quality differences across brands in varieties (e.g., brand selling low-fat ground beef *versus* brand selling high-fat ground beef) and other horizontal differences (e.g., different steak cuts or package sizes). Brands in the same market segment are considered less differentiated from each other. The market segments are constructed as follows. Every brand is categorized into a low-priced (L) or high-priced (H) segment by comparing its annual average store-specific price with the median nationwide brand-store prices in a year.[5] Brands with average store-specific prices below (above) the median nationwide brand-store price are then classified as L- (H-) segment brands.

Figure 4 shows the brand-store price distribution where the vertical solid line indicates the median price. The skewed distribution implies that the price range below the median price is much

[5] We consider the market segment as a comprehensive, though rough indicator of the proximity of brands in the variety space. Annual average prices are computed by dividing brand-level annual revenue by annual volume sold in store. The use of yearly average prices limits mismeasurement caused by confounded effects such as temporary price discounts or other price shocks.

smaller compared to the price range above the median. Since brands characterized by prices below the median belong to the L-segment, we expect the low market segment to be characterized by a smaller degree of product differentiation, more intense price competition, and potentially higher cannibalization effects. Table 2 shows that the majority of PLs (68.5%) are introduced into the L-segment. This finding confirms that PLs are frequently considered inexpensive alternatives for NBs rather than premium brands (see Scott-Morton and Zettelmeyer, 2004).

[Figure 4 approximately here]

Figure 5 illustrates the change in the number of NBs in a market segment before and after PL introduction. The right panel shows that the number of NBs strongly declines (by almost 40%) after a PL has been added into the same segment of the NBs. The lower number of NBs persists throughout the first year of selling the PL. The strong reduction could be driven by the store's effort to increase product differentiation that would result in lower price competition and cannibalization effects. The left panel of the figure, in contrast, shows that a PL introduction only modestly reduces the number of NBs in the other market segment. One reason that few NBs are withdrawn in the other segment could be that the competition across segments is rather soft.

[Figure 5 approximately here]

2.3 Other Variables

Assortment decisions by stores depend on competition across stores within a market. We construct control variables that describe the intensity of variety competition in a local market. A competitor store is defined as a store of a different retail chain within the same local market. Nielsen does not survey all stores in a local market, making the number of competitor stores in the local market *per* *se* a suboptimal measurement of competition. We compute the average number of brands carried by a competitor store in a particular market segment as a more precise measurement of the intensity of local competition in variety. Table 2 shows that a competitor store carries on average 1.3 brands. Competition in product variety is an essential factor in assortment decisions that has been highlighted in earlier studies, see also Sweeting (2010). We return to this aspect later.

3. Empirical Models and Results

Our ultimate goal of the study is to examine how the introduction of PLs affects NB assortment and how that impacts prices and demand of NBs. To achieve this goal, we first identify how PL introductions affect assortments of NBs, accounting for proximities between NBs and PLs and as well as the number of NBs. We empirically evaluate the effects of PL by comparing one year before a PL is launched with one year after PL introduction throughout this section. Choosing a relatively short, one-year window around PL introduction helps mitigate any unobserved confounding effects that may affect NB assortment. The causal relationship between selling PLs and assortment changes is identified by considering differential timings of PL introductions across stores, the adoption of a generalized synthetic control estimator using interactive fixed effects, and a series of robustness tests. Once we have evaluated the assortment effects, evaluate the effects on prices and demand of NBs are estimated.

3.1 Empirical Model: Assortment Effects

First, we empirically evaluate the impact of PL introductions on brand proximity between NBs and PLs using the *Jaffe Index NB-PL*. The basic empirical model is specified as follows:

$$V_{st} = \alpha_0 + \alpha PL_{st} + \gamma X_{st} + Z_s + T_t + \epsilon_{st}, \quad (1)$$

where V_{st} refers to the *Jaffe Index NB-PL* in store s and month t.[6] Indicator variable PL_{st} equals 1 if a PL has been introduced, and zero otherwise. Control variable X_{st} is the average number of brands carried by a competitor store in the local market, Z_s represents store format (e.g., grocery store and mass merchandiser), retail-chain, and local market fixed effects, T_t contains month and year fixed effects, and ϵ_{st} is the error term. We consider the fact that stores of the same retail chain tend to experience similar demand (e.g., due to chain-level marketing activities) and supply shocks (e.g., due to chain-level cost changes) and make similar pricing and other non-price decisions, including developing the PL (see DellaVigna and Gentzkow, 2019; Hitsch et al., 2019). Standard errors are, therefore, clustered at the chain level to account for potential correlations of errors across stores within the same chain and autocorrelated errors within a store over months.[7]

We estimate equation (1) using ordinary least squares (OLS). The effect of PL introductions is identified, as long as the timing of introducing a PL is independent of the NB-PL proximity conditional on control variables and fixed effects. The estimation results are shown in column 1 of Table 3. R-square is fairly high, suggesting a good fit of our specification. Selling PLs has a significantly negative effect on the *Jaffe Index NB-PL*. The *Jaffe Index NB-PL* decreases by 0.34 on average or by 0.8 of its standard deviation, which is economically significant. The result echoes Figure 3 and supports that stores reposition NBs to further differentiate NBs from PLs, which softens price competition and diminishes cannibalizing the demand of the PL.

[Table 3 approximately here]

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[6] Since the NB-PL Jaffe index can be calculated only if a store sells a PL for at least one month during the period of interest, the estimation excludes stores that never sell PLs, which shrinks the data sample.

[7] Clustering at the state or local market levels leads to slightly smaller standard errors, which would strengthen our baseline findings.

Next, we run a similar regression, but distinguish between stores selling a PL in the L- and the H-segment. The results are shown in Table 3, columns 2 and 3, respectively. The estimation returns significantly negative coefficient estimates for the *Jaffe Index NB-PL* that lie in the neighborhood of -0.3. Hence, the PL effect on brand proximity is quite similar regardless of whether the PL is in the L- or the H-segment.

We next evaluate the evolution of the proximity effect before and after the PL introduction. Specifically, we write the variable PL_{st} as a series of two-month indicator variables. Taking the 11th and 12th month prior to the PL introduction as the benchmark, the two-month indicators include PL_s^{-10} (i.e., the 9th and 10th months prior to PL introduction), …, PL_s^0 (i.e., the month of PL introduction),…, PL_s^{12} (i.e.,, the 11th and 12th months after PL introduction). The model specification is written as:

$$V_{st} = \alpha_0 + \sum_\tau \alpha_\tau PL_s^\tau + \gamma X_{st} + Z_s + D_\tau + T_t + \epsilon_{st}, \tag{2}$$

where $\tau \in \{-10, -8, \ldots, 0, \ldots, 10, 12\}$ indicates the two-month windows relative to PL introduction and other variables are defined in equation (1). The index τ is positive (negative) for months after (prior to) the introduction. D_τ includes dummy variables that take on a value of one if the observation falls within a specific two-month window indicated by τ.

The evolution of the proximity effect over time is shown in Panel A of Figure 6. The solid line depicts the point estimates of PL_s^τ, while the dashed lines represent the corresponding 95% confidence intervals. The reduction in the *Jaffe Index NB-PL* is significant and fairly stable throughout the first year of selling the PL. Importantly, there is no significant trend in the index prior to PL introduction, suggesting that potential confounding factors related to the endogeneity of PL introduction are largely absorbed by control variables and fixed effects. We return to this point in more detail later.

[Figure 6 approximately here]

We now consider the PL effect on the number of NBs in the L- and H-segments. The number of NBs in segment g store *s* and period *t* is denoted as n_{gst}. Unlike the *Jaffe Index NB-PL*, which can only be computed for stores that sell PLs, n_{gst} can also be computed for stores that do not sell PLs, which results in more observations for estimation. We estimate the PL effect on the *Number of NBs in a Segment* (n_{gst}) with a similar set of right-hand-side variables as follows:

$$n_{gst} = \beta_0 + \beta PL_{st} + \gamma_1 H_{gst} + \gamma_2 X_{gst} + E_s + Z_s + T_t + \epsilon_{sgt}, \qquad (3)$$

using store-segment-month observations. The dummy variable H_{gst} represents the H-segment. X_{gst} includes two measures of local competition: the *Average Number of brands in the Same Segment of a Competitor Store*, and the *Average Number of brands in the Other Segment of a Competitor Store*. E_s is the *Store Ever Selling a PL* variable, which equals 1 if a store ever sells a PL from 2006 to 2016. This variable captures any systematic differences between PL-selling and NB-only stores in choosing the number of NBs.

The estimation results of equation (3) are displayed in column 4 of Table 3. Selling a PL leads to a significant reduction in the number of NBs. On average, every four stores remove one NB. R-square is fairly high, suggesting a good fit of the model specification. The coefficient of *Store Ever Selling a PL* is insignificant, meaning that a store that sells the PL does not carry a significantly different number of NBs if the PL is not launched.

We also estimate an extended specification of equation (3) and include a series of two-month indicator variables PL_{st}^{τ} as in equation (2). Panel B of Figure 6 shows the evolution of the PL effect on the *Number of NBs in a Segment*. Prior to PL introduction, the *Number of NBs in a*

Segment remains fairly stable, suggesting, again, limited endogeneity concerns using OLS. Once a PL is introduced, the point estimates become significantly negative and level off around -0.25.

Remember, Figure 5 shows that PLs have a stronger impact on the number of NBs in the same market segment. We hence extend equation (3) and add an indicator variable $Same_{gst}$ which equals 1 if the PL and NBs share the same g. Note, since $Same_{gst}$ is specified only if the store sells PL for at least one month, stores that never sell PLs do not enter the estimation. We include an interaction term between PL_{st} and $Same_{gst}$ denoted by PS_{gst}. The interaction term shows differential PL effects on the *Number of NBs* in the same and in different segments. The extended specification is written as:

$$n_{gst} = \beta_0 + \beta_1 PL_{st} + \beta_2 PS_{gst} + \gamma_1 Same_{gst} + \gamma_2 X_{gst} + \gamma_3 H_{gst} + Z_s + T_t + \epsilon_{gst}. \quad (4)$$

The effect of PL on the number of NBs in the different-segment is β_1 and the corresponding effect on NBs in the same-segment equals $\beta_1 + \beta_2$.

Column 5 of Table 3 displays the estimation results for stores introducing a PL into the L-segment. PLs sold in the L-segment reduce the *Number of NBs* in the same segment by 0.62, while the impact on the *Number of NBs* in the H-segment is positive and much smaller. This result is consistent with what is shown in Figure 4 that the L-segment is characterized by a denser price distribution which is indicative for less differentiated products and tougher price competition. The addition of a PL to the L-segment likely largely intensifies internal brand competition and incentivizes assortment adjustments of NB aimed at reducing price competition and cannibalization of the PL demand. This argument is further supported by Figure 7 that shows that the number of NBs in the L-segment is slightly declining over time.

[Figure 7 approximately here]

Column 6 of Table 3 shows that a PL introduced into the H-segment exerts no impact on the number of NBs in either segment. This result coincides with Figure 4 that shows a wider price range which is indicative for the product space in the H-segment being less crowded and price competition is not as intense as in the L-segment. For a store selling the PL in the H-segment, the value of PL in enriching the brand portfolio seems to outweigh its cost of intensifying competition with the store's NBs.

Evidence suggests that variety competition is more intense in the H-segment. First, the significantly positive coefficient on the *Number of Brands in the Same-Segment in a Competitor Store* implies that stores adding PLs to the H-segment are likely to carry more NBs as competitors enlarge brand offerings. Second, there is a strong trend of adding brands in the H-segment. Figure 7 shows that the number of NBs in the H-segment consistently increases over time. In 2006, stores sold on average 1.5 NBs in the H-segment and this number increased to 2.5 by the end of 2016, representing an increase of 66%. More broadly, Jaravel (2019) shows that stores significantly enlarge high-priced product portfolios in response to the increasing size of market segments for high-income consumers.

Overall, the estimation results show that stores adopt differential assortment strategies depending on whether PLs are introduced into the L- or the H-segment. PL introductions in the L-segments trigger removal of NBs from the same segment to soften price competition, while PL introductions in the H-segment would not eliminate NBs in the same market segment due to competition in variety.

3.2 Alternative Identification Strategy

One may be concerned that the variable PL_{st} remains endogenous despite the control variables and fixed effects. Some unobserved factors could have an effect on the store's decision to introduce a PL as well as the store's assortment decision on NBs. Though our baseline outcomes provide support for no systematic changes in *Jaffe Index NB-PL* and *the Number of NBs* prior to PL introduction (see Figure 6), we also adopt an alternative estimation method and provide further robustness checks that confirm the causal effects of PL introductions.

One common estimation method for identifying causal effects is a difference-in-differences (DID) approach. This method is rather difficult to apply in our context, since the "treatments", or PL introductions, take place at different months across stores (see Figure 1). Hence, a control group would likely be confounded by the choice of different timing decisions. Alternatively, one could adopt an instrumental variable (IV) estimation method. This technique requires the use of a variable that is strongly correlated with the PL introduction decisions of stores but uncorrelated with the endogenous variables, that is, the *Jaffe Index NB-PL* and the *Number of NBs*. The existence of such an IV is rather unlikely for a variable affecting PL introduction, which is an assortment decision, tends to have a direct effect on assortment of NBs as well. The difficulty in finding an appropriate instrument is supported by the fact that we are not aware of a prior empirical study on PL effects that employs the IV method.

To strengthen the identification of PL effects, we employ a third alternative and adopt a generalized synthetic control method recently developed by Liu et al. (2020). The method builds an interactive fixed effects estimator (IFE) to evaluate the treatment effect for each "treated" store (here, store that introduces a PL) in each period. The method has three major advantages over alternative estimators such as DID and IV. First, the IFE estimator returns individual treatment effects for treated subjects in different periods. It corrects biases induced by heterogeneity in the treatment effects across treated subjects and allows us to study the determinants of store-period specific treatment effects. Second, the IFE approach uses a latent factor approach to adjust for potential time-varying confounders that researchers do not observe. Such confounders are decomposed into time-specific factors interacted with factor loadings. Third, the IFE estimator takes care of treatments taking place at different timings for different individuals during the period of interest. Since the estimator has been derived in Liu et al. (2020), a summary for our case is deferred to Appendix 3.

The IFE method requires that PL introducing stores are observed continuously over a 2-year window. Hence, the sample is considerably smaller than the one used in our earlier regressions. The IFE method also requires the inclusion of a control group, that is, stores that never sell PLs. Since stores that never sell PLs cannot be characterized by a *Jaffe Index NB-PL*, this rules out the inclusion of this measure as the dependent variable. We hence focus on the *Number of NBs* as the dependent variable.

IFE estimates individual treatment effects, $\widehat{\beta_{gst}}$, which we use as the dependent variable in the following regression:

$$\widehat{\beta_{gst}} = \theta_0 + \theta_1 Same_{gst} + \theta_2 X_{gst} + \gamma_1 H_{gst} + Z_s + T_s + \epsilon_{gst}, \quad (5)$$

where the same-segment indicator $Same_{gst}$ as defined in equation (4) is the main explanatory variable for the variation in $\widehat{\beta_{gst}}$. We focus on the first year after a PL has been introduced and conduct the estimation for stores introducing a PL into L- and H-segments, respectively.

The estimation results are shown in Table 4. Column 1 reports the basic results from regressing $\widehat{\beta_{gst}}$ on the variable $Same_{gst}$ and a constant. The positive and small coefficient estimate on the constant represents the effect of introducing a PL into the L-segment on the number of NBs in the H-segment (the constant term is comparable to the coefficient of the PL indicator in column 5 of Table 3). The significantly negative coefficient estimate on $Same_{gst}$ shows that introducing a PL into the L-segment reduces the number of NBs in the L-segment (the coefficient of $Same_{gst}$ corresponds with the interaction term, PS_{gst}, in column 5 of Table 3).

The estimation results in column 2 of Table 4 are comparable to the ones in column 6 of Table 3. When introducing a PL into the H-segment, there is a significantly negative effect on the number of NBs in the L-segment, while the effect on NBs in the H-segment is nearly zero. Consistent with our previous results, we find that a PL introduced into the H-segment does not crowd out NBs in the high segment, possibly explained by intense competition in variety in the high market segment. The results in columns 3 and 4 of Table 4 account for a large number of fixed effects and control variables. The results show that the coefficients on $Same_{gst}$ stay at the values in columns 1 and 2.

[Table 4 approximately here]

3.3 Sensitivity Tests

We conduct a series of robustness tests. First, we consider an alternative measurement of brand proximity and use the Uniqueness Index applied by Sweeting (2010). Similar to the *Jaffe Index NB-PL*, the *Uniqueness Index* measures the degree of variety differentiation between the PL and the NBs in a store based on the 21-dimensional variety space. The *Uniqueness Index NB-PL* equals the proportion of varieties carried by the PL, but not by any NB. The index varies from 0 (all varieties carried by the PL are common with the NBs) to 1 (no variety in common). The larger the index, the further the PL is differentiated from NBs in the variety space. By construction, this index negatively correlates with the *Jaffe Index NB-PL*. For example, consider a store that sells NBs offering varieties 1 and 2. The store also sells a PL that offers varieties 2 and 3. Variety 2 is offered by both NBs and the PL, while variety 3 is carried only by the PL. In this example, the proportion of varieties offered only by the PL is one out of two, so the *Uniqueness Index NB-PL* equals $\frac{1}{2}$. In contrast, if the PL only offers variety 4, the proportion of unique varieties for the PL is one (i.e., one out of one).

We calculate the index for every PL-selling store in every month. For stores that have not yet introduced a PL, we calculate the index for the months prior to the introduction of a PL, using a hypothetical PL as that defined in Section 2.1. When the store carries no NB after introducing the PL, this index is set to one, meaning that the PL is entirely unique in the variety space. The mean of the *Uniqueness Index NB-PL* is 0.60 with a standard deviation of 0.47. Its correlation coefficient with the *Jaffe Index NB-PL* equals -0.94.

We estimate the effect of PL introduction on the *Uniqueness Index NB-PL* using the baseline specification as shown in equation (2). The estimation results are displayed in Figure 8. The figure shows that the *Uniqueness Index NB-PL* significantly increases, by nearly one standard deviation, after PL introduction. The increased index indicates that the store further differentiates NBs from PLs in the variety space. This result is consistent with our earlier results where the *Jaffe Index NB-PL* decreases after PL introduction (see column 1 of Table 3); the key insights from the baseline model remain unchanged. Note also that the *Uniqueness Index NB-PL* hardly changes prior to the introduction of a PL, again supporting the causal effect of PL introductions.

[Figure 8 approximately here]

We perform a series of further robustness tests regarding the causal effects of PL introductions. For example, we use alternative samples to estimate the baseline models, including shortening the window from one year to a half year around the PL introduction and dropping stores that do not sell any NBs prior to introducing a PL. The estimation results closely resemble our earlier results. We also conduct a placebo test and randomly assign a month of PL introduction and a segment of PL to stores that never sell any PL. Estimation results of the placebo test show no significant effects of the fake PL on the *Number of NBs in a Segment* (see robustness outcomes in Appendix 4).

3.4 Price and Sales Effects

We use the impact of PL introductions on assortment changes to deepen our understanding of PL effects on prices and demand of NBs. Prior studies on PL introductions usually ignore assortment changes and estimate the direct effect of PL on prices of NBs. They regress the logarithm of store-specific NB prices on a PL dummy variable. We specify this benchmark price regression as:

$$\log(p_{bst}) = \xi_0 + \xi_1 PL_{st} + \gamma X_{gst} + B_b + Z_s + T_t + \epsilon_{bgst}, \qquad (6)$$

where the subscript b indicates NBs and B_b is a vector of NB fixed effects. The corresponding estimation results in column 1 of Table 5 show no significant price effect.

[Table 5 approximately here]

The benchmark specification ignores the PL effect on prices via assortment changes. As shown earlier, PL changes the proximity and the number of brands in the store. To explicitly consider the price effect through brand proximity and brand number, we consider the specification in equation (7):

$$\log(p_{bst}) = \xi_0 + \xi_1 PL_{st} + \xi_2 V_{st} + \xi_3 n_{st} + \gamma X_{gst} + B_b + Z_s + T_t + \epsilon_{bgst}, \qquad (7)$$

where n_{st} denotes the number of NBs in a store and other variables are defined in equations 1 and 3. Mean of n_{st} is 2.78 with a standard deviation of 2.04 weighted by the observations used to estimate equation 7.

Column 2 of Table 5 shows that a reduction in the *Jaffe Index PL-NB* (i.e., larger differentiation between NBs and PLs) increases NB prices which is explained by softened price competition within the store. Given our earlier finding that PL introduction reduces the *Jaffe Index PL-NB* by 0.34 (i.e., the average effect in column 1 of Table 3), the price is expected to increase on average by 2.0% due to changes in brand proximity. The estimated coefficient on *PL Introduced* is significantly negative in column 2 of Table 5, suggesting that adding the PL reduces NB prices by 1.3%. Note that this price reduction is conditional on any assortment changes. Therefore, this price reduction is most likely explained by PL's increasing competition due to eliminating double margins and lower marginal costs passed on to retail prices. The *Number of NBs* has no significant impact on NB prices.

The countervailing effects on prices stemming from the assortment changes (*Jaffe Index NB-PL*) and the *PL Introduced* help reconcile the insignificant effect found in column 1 and the mixed evidence of the price effect of selling PL as discovered in prior studies (e.g., Cotterill and Putsis, 2000; Ward et al., 2002; Pauwel and Srinivasan, 2004; Bontemps et al., 2008). The net price effect of selling PL depends on the magnitude of NB assortment adjustments made by the store and is case-specific.

Next, we evaluate to what extent PL introductions impact demand (volume share) of NBs via assortment changes. The regression is specified as:

$$S_{st} = \xi_0 + \xi_1 PL_{st} + \xi_2 V_{st} + \xi_3 n_{st} + Z_s + T_t + \epsilon_{st}, \quad (8)$$

where S_{st} is the store-level volume share of all NBs. The volume share equals NBs' volume divided by the store's total volume sold and ranges from 0 to 1.

The estimation results are shown in column 3 of Table 5. After the store introduces a PL, the volume share of NBs is reduced by 34 percentage points due to cannibalization effects of the

PL and controlling for assortment of NB. Given the previous finding that the PL introduction results in a reduction of the *Jaffe Index NB-PL* of 0.34 (see column 1 of Table 3), the change in brand proximity reduces the volume share of NBs by another 6.8 percentage points. We have also shown that PL induces removals of NBs in the store by 0.50 (i.e., the average effect in column 2 of Table 3 multiplied by two segments per store), which further reduces the volume share of NBs by 2.5 percentage points. Summing the sales effects due to two assortment adjustments suggests that 9.3% of the NBs volume sales are transferred to PL products. We hence argue that stores change assortment of NBs after introducing PLs in order to steer more consumers toward purchasing the PL products.

One explanation why stores have incentives to steer consumers toward the PL could be that PLs benefit from eliminating double margins between retailers and the manufacturers (see Luco and Marshall, 2020). Consequently, marginal retail costs of selling PL products are relatively low. Thus, stores can increase profit margins and total profits by steering more consumers toward PLs.

To further evaluate the impact of PLs on store profits, it would be natural to examine the revenues and costs of the store. However, retailing costs of beef products are rarely observed. Wholesale prices are usually private information. In case they are published, they would be available only as nationwide averages, which does not serve our purpose of comparing store-brand specific profits which would require store-brand level wholesale costs.

Given the data limitations, we consider a different strategy to infer the impact of PL introductions on store-level profits. Based on findings by prior studies, we operate under the assumption that PL products are characterized by lower marginal costs than comparable NBs. We then evaluate changes in store-level revenues due to PL introductions, and those results will provide necessary conditions that apply to store-level profits. More specifically, if store-level revenues increased or remained constant after PL introduction, the store-level profits must have increased given the marginal costs of PLs do not exceed those of NBs and the average costs of the store would be lower with PLs.

We estimate the effect of PL introductions on store-level revenues using the model specification as shown in equation (3). Table 5, column 4, reports the results. The store-level revenue is not significantly affected by selling the PL. Based on our assumption on the marginal costs of PLs, we can infer that store-level profits have increased.

4. Concluding Remarks

Our study evaluates the impact of PL introductions on assortment, prices, and demands of NBs in retail stores. Prior studies typically evaluate the direct effect of PL introductions on prices, ignoring or fixing the assortment of NBs, and found mixed results. The novelty of our study is to consider PL effects on NB assortment that have impacts on prices and demand.

Using data on the US beef market, we find that PL introductions have differential effects on NB assortment. When a PL is introduced, stores reposition NBs by changing some of their varieties to further differentiate NBs from the PL, which softens price competition and diminishes cannibalizing the PL demand. When a PL is added to the low-price segment, stores also tend to remove all varieties of some NBs, that is, withdrawing entire NBs. PL introduction causes offsetting price effects: on the one hand, assortment changes increase product differentiation, relax price competition, and increase prices of NBs. On the other hand, the PL enjoys low costs due to elimination of double margins, intensifies price competition, and imposes downward pressure on NB prices. Despite an ambiguous net price effect, PL introduction and the assortment changes unambiguously serve as an instrument to steer consumers to purchasing PL products, which are characterized by lower marginal costs, and hence increase store profits.

Our study provides new insights into the impact of PL introductions. We find evidence that PL introductions may impose little direct effects on prices, but exert strong effects on the assortment of NBs that increase PL demand and store profits. It implies that stores do not use price as the main device to increase profits after introducing PLs; rather, stores use assortment changes as the key strategic instrument to steer consumers to more profitable PL products.

The impact on assortment of NBs adds complexity to the evaluation of welfare changes of PL introductions. While the PL expands the choice set of consumers, the repositioning and removals of NBs introduce ambiguous effects on consumer welfare. In order to evaluate the net welfare effect accurately, consumers' preferences for quality and love of variety have to be considered. We leave this evaluation for future research.

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TABLES

TABLE 1: Numbers and Volume Shares of Beef Brands and Stores

	Value (Bil $) (1)	*#Retail Chains* (2)	*#Store* (3)	*#NB* (4)	*#PL* (5)	*#Stores Selling PL* (6)	*PL Vol. (%)* (7)
2006	71.2	82	9,134	51	38	5,436	59.0
2007	74.4	83	9,600	59	36	5,487	60.2
2008	75.9	84	9,520	60	32	4,890	62.8
2009	73.0	90	10,001	61	31	5,189	62.2
2010	75.8	92	10,433	65	51	5,836	65.5
2011	79.3	101	13,746	67	55	6,100	67.8
2012	84.7	101	21,773	80	56	7,860	64.1
2013	88.2	95	21,242	88	52	8,416	69.2
2014	96.9	99	26,235	97	55	13,264	74.8
2015	104.9	95	26,647	110	59	17,015	76.9
2016	103.3	97	26,452	114	60	16,978	77.0

Note: The table reports key summary statistics of our baseline dataset. Column 1 reports the annual retail equivalent value of beef produced in the United States in nominal $billion. PL vol. (%) is the collective volume market share of all PLs in the US in each year.

Sources: Nielsen Retail Scanner Data and https://www.ers.usda.gov/topics/animal-products/cattle-beef/statistics-information.aspx

TABLE 2: Summary Statistics of Key Variables

	Mean	SD	Min	Max
NB Price ($/lb.)	5.74	2.88	1.76	14.41
Jaffe Index NB-PL	0.34	0.42	0	1
No. NBs/H-Segment/Store	0.85	0.94	0	9
No. NBs/L-Segment/Store	0.99	1.13	0	12
PL Introduced (1, if yes)	0.38	0.49	0	1
No. Brands/L-Segment/Competitor Store	1.26	0.66	0	8
No. Brands/H-Segment/Competitor Store	1.27	0.82	0	6

Note: The table reports summary statistics of key variables. Statistics are weighted by observations in column 1 or 3 of Table 3. Prices in the lower and upper one-percentiles are excluded.

Source: Nielsen Retail Scanner Data.

TABLE 3: Determinants of PL Effects on Assortment of NBs

Dependent Variable	*Jaffe Index NB-PL*			*No. NB/Segm.*		
	All PL	*PL in L*	*PL in H*	*All PL*	*L-Segm. PL*	*H-Segm. PL*
	(1)	(2)	(3)	(4)	(5)	(6)
PL Introduced (PL)	-0.34***	-0.41***	-0.29***	-0.25***	0.20***	-0.16
(1, if yes)	(0.10)	(0.10)	(0.08)	(0.08)	(0.05)	(0.19)
PL Introduced Interacted					-0.82***	0.19
with Same Segm. (PS)					(0.12)	(0.12)
No. Brands/Cmp Store	0.003	0.01	0.02***			
	(0.004)	(0.01)	(0.004)			
No. Brands/Cmp Store				0.07	0.02	0.10*
Same Segm				(0.05)	(0.02)	(0.06)
No. Brands/Cmp Store				-0.01	0.001	-0.04
Diff Segm				(0.04)	(0.01)	(0.04)
Store Ever Selling PL				0.03		
(1, if yes)				(0.05)		
Control Variables	Y	Y	Y	Y	Y	Y
Retailer/Market/Time FE	Y	Y	Y	Y	Y	Y
R^2	0.80	0.85	0.80	0.47	0.58	0.61
No. Observations	284,305	156,447	127,858	1,465,282	319,172	254,152

Note: This table reports the estimation results of equations (1), (3), and (4). "Segm." refers to segment, and "cmp" stands for competitor. Stores that introduce PLs before November 2006 or after February 2016 are excluded to ensure at least 10 months of observations before and after PL introduction. *** p-value<0.01, ** p-value <0.05, * p-value <0.10.

TABLE 4: Determinants of Individual PL Effects

	L-Segm. PL (1)	*H-Segm. PL* (2)	*L-Segm. PL* (3)	*H-Segm. PL* (4)
PL in the Same Segm.	-0.17***	0.20***	-0.17***	0.20***
(1, if yes)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.03***	-0.28***	0.67*	0.57
	(0.01)	(0.01)	(0.34)	(0.49)
Control Variables	N	N	Y	Y
Retailer/Market/Time FE	N	N	Y	Y
R^2	0.01	0.01	0.17	0.25
No. Observations	24,690	34,062	24,690	34,062

Note: The table reports the estimation outcomes of equation (5). "Segm." means segment.

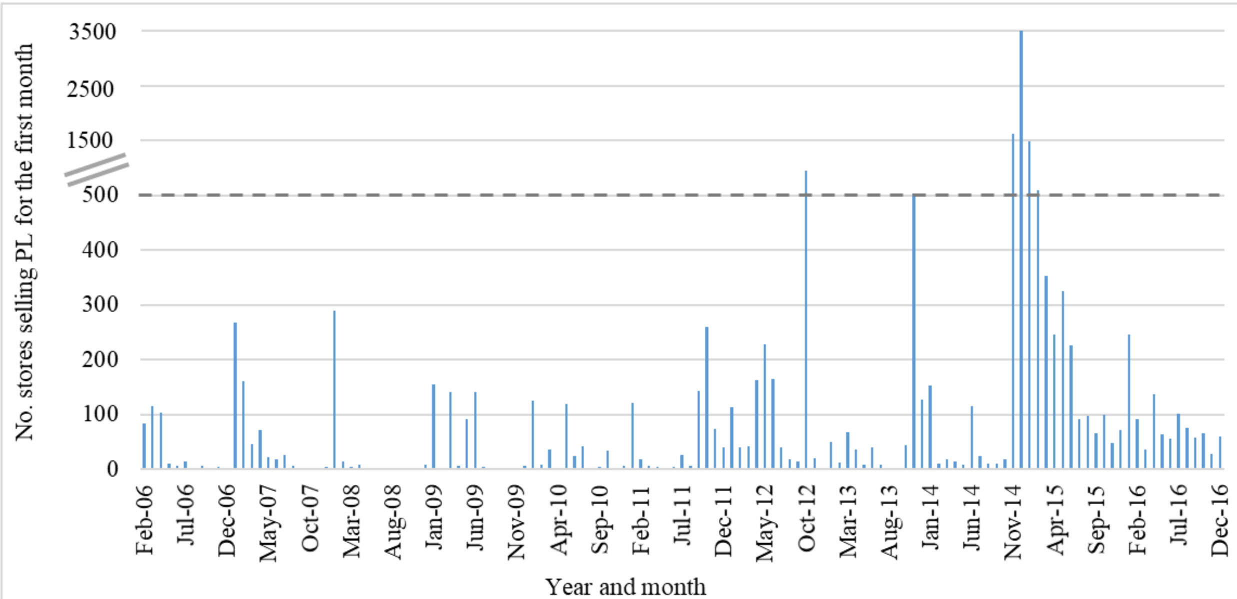
TABLE 5: Effects of Assortment on Prices and Sales of National Brands

Dependent Variable	*Log(Price by NB)* (1)	*Log(Price by NB)* (2)	*NB Vol Share* (3)	*Log(Store Revenue)* (4)
PL Introduced (PL)	-0.01	-0.01*	-0.34***	0.02
(1, if yes)	(0.01)	(0.01)	(0.06)	(0.07)
Jaffe Index NB-PL		-0.06**	0.20***	
		(0.03)	(0.06)	
No. NB in the Store		-0.005	0.05***	
		(0.003)	(0.01)	
Constant	0.74***	1.24***	1.24***	4.08**
	(0.15)	(0.05)	(0.18)	(1.68)
Control Variables	Y	Y	Y	Y
FE	Y	Y	Y	Y
R^2	0.87	0.89	0.78	0.87
No. Observations	1,206,598	416,003	191,519	732,641

Note: The table reports the estimation results of equations (6), (7), and (8). Prices in the lower and upper one-percentiles are excluded. FE includes brand, market, retailer, and time fixed effects for the left three columns, and market, retailer, and time fixed effects. *** *p*-value<0.01, ** *p*-value <0.05, * *p*-value <0.10.

FIGURES

FIGURE 1: Number of Stores Introducing Private Labels over Time

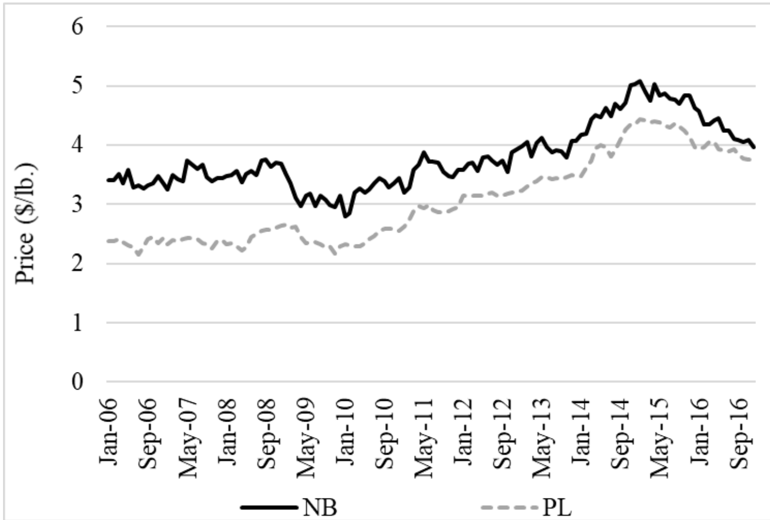


Note: The figure displays the number of stores that introduced PLs over time. The vertical axis is broken at 500 to provide a more condensed view. We exclude a large number of stores that started selling PLs in January 2006, because January 2006 is the first month of the Nielsen database and we are unable to tell if those store introduced PL before or upon January 2006.

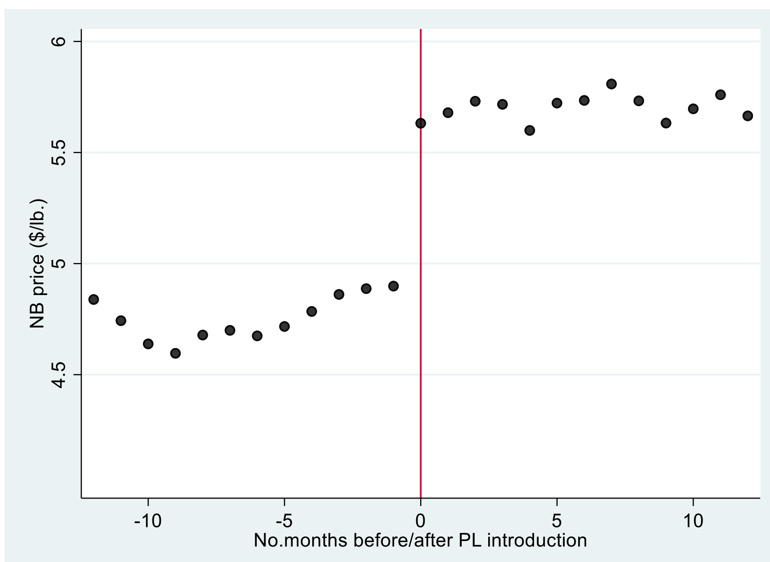
Source: Nielsen Retail Scanner Data.

FIGURE 2:

Panel A: Average Prices for National-Brands and Private-Labels over Time



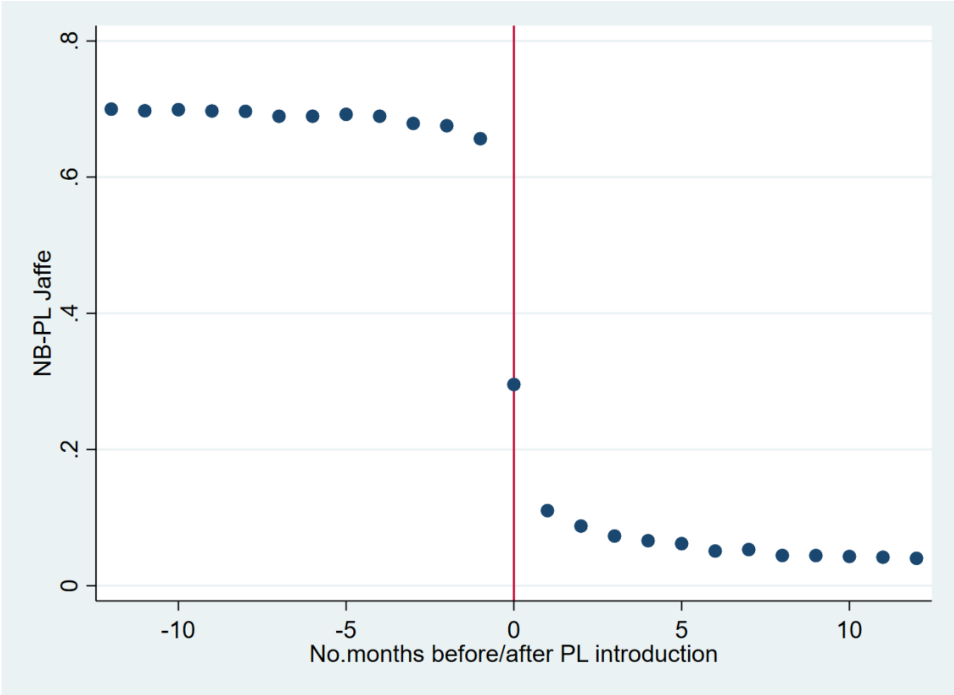
Panel B: Average National-Brand Prices in a Store over Time



Note: The figure summarizes price patterns over time. In Panel A, the solid black curve refers to market-level average prices of NB products, while the gray curve stands for market-level average prices of the PL products. In Panel B, the horizontal axis shows the month relative to the introduction of the PL and covers 12 months before and 12 months after PL entry. For example, -10 means 10 months before PL introduction, and 10 means 10 months after the introduction.

Source: Nielsen Retail Scanner Data.

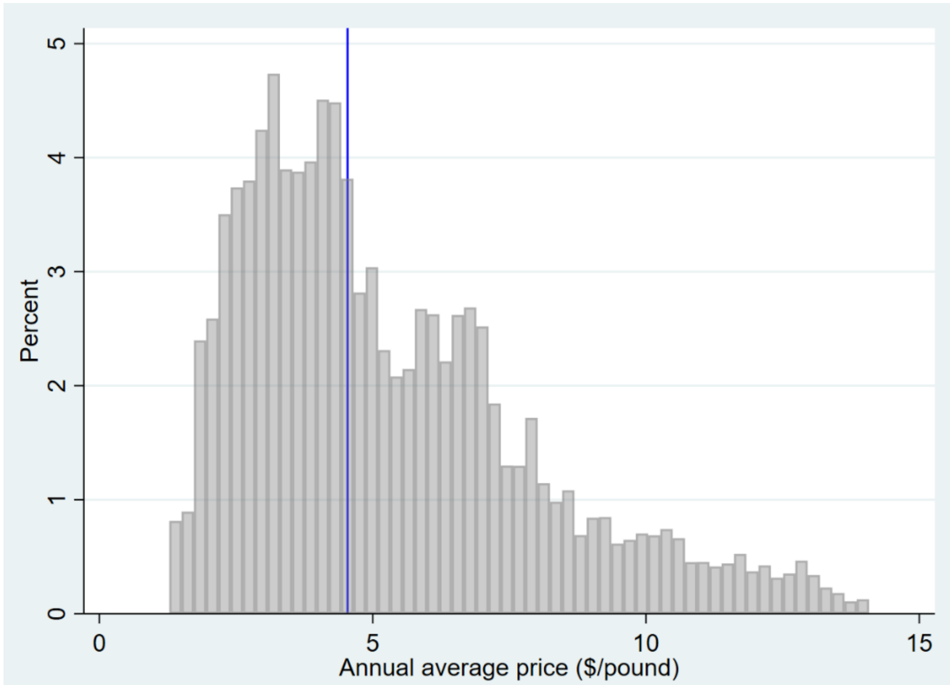
FIGURE 3: Evolution of Jaffe Index NB-PL over Time



Note: The figure depicts the Jaffe index for NBs against the PL over time. Other notes are the same as Figure 2.

Source: Nielsen Retail Scanner Data.

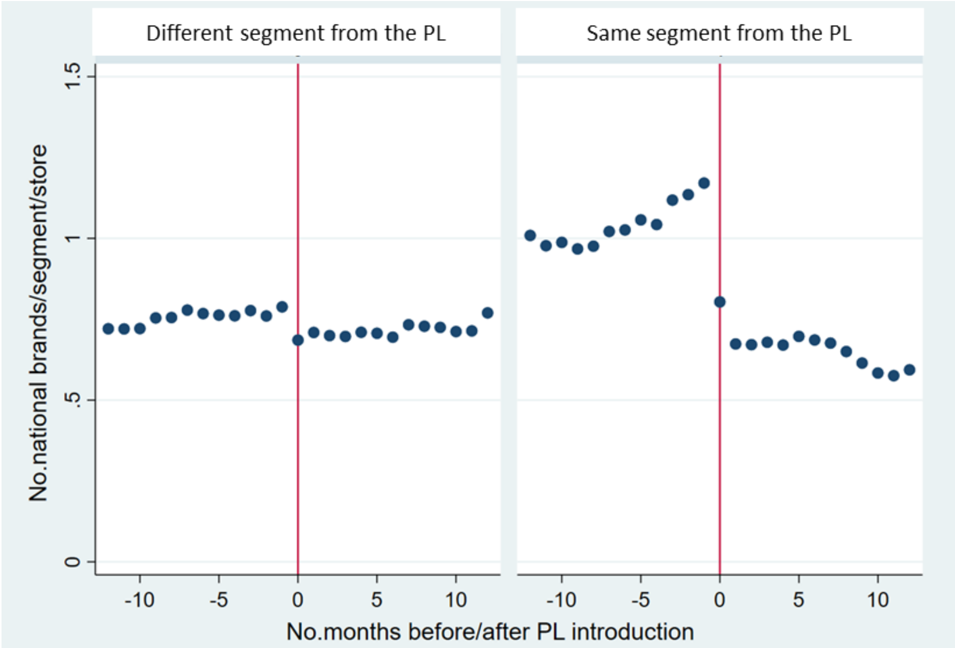
FIGURE 4: Distribution of Store-Level Brand Prices



Note: The figure shows the distribution of store-specific, annual average prices of all brands 2006-2016. The vertical line indicates the median of all prices. The upper and lower one percentiles of the price distribution are excluded.

Source: Nielsen Retail Scanner Data.

FIGURE 5: Number of National Brands over Time

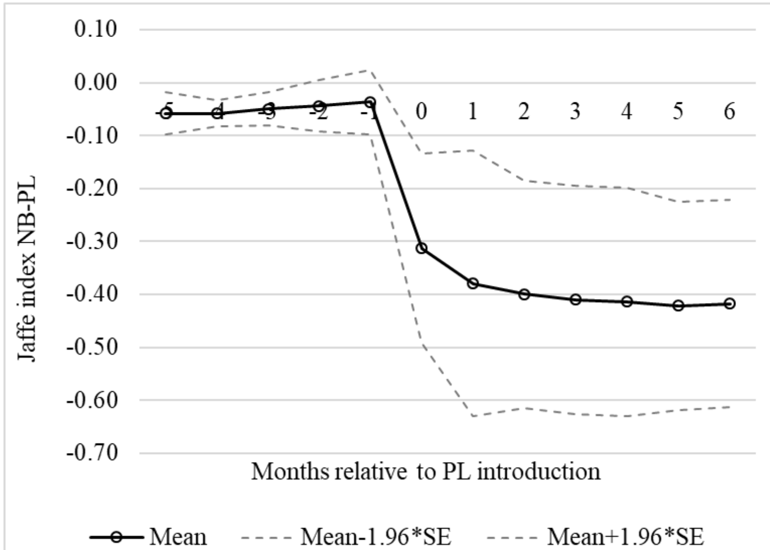


Note: The left panel depicts the average number of NBs in the different price segment compared with the PL. The right panel depicts the average number of NBs in the same price segment with the PL. Other notes are the same as Figure 2.

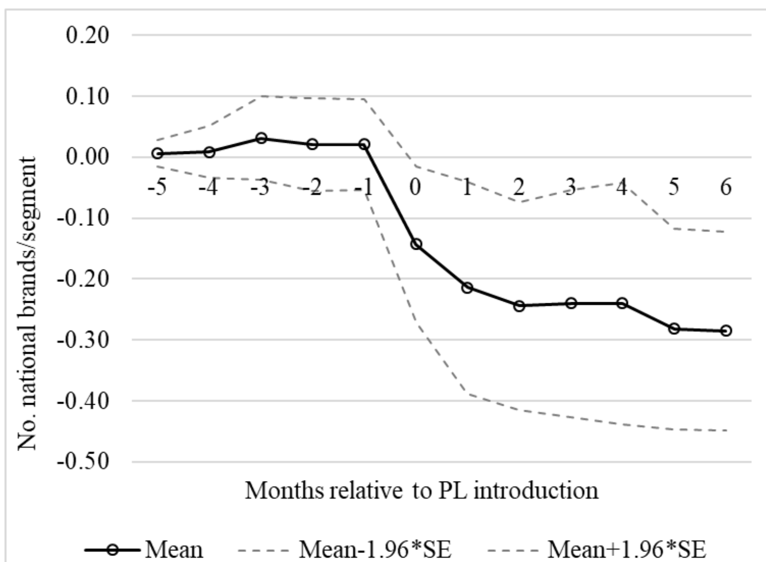
Source: Nielsen Retail Scanner Data.

FIGURE 6: Evolution of Brand Proximity and Brand Numbers

Panel A: Evolution of Jaffe Index NB-PL

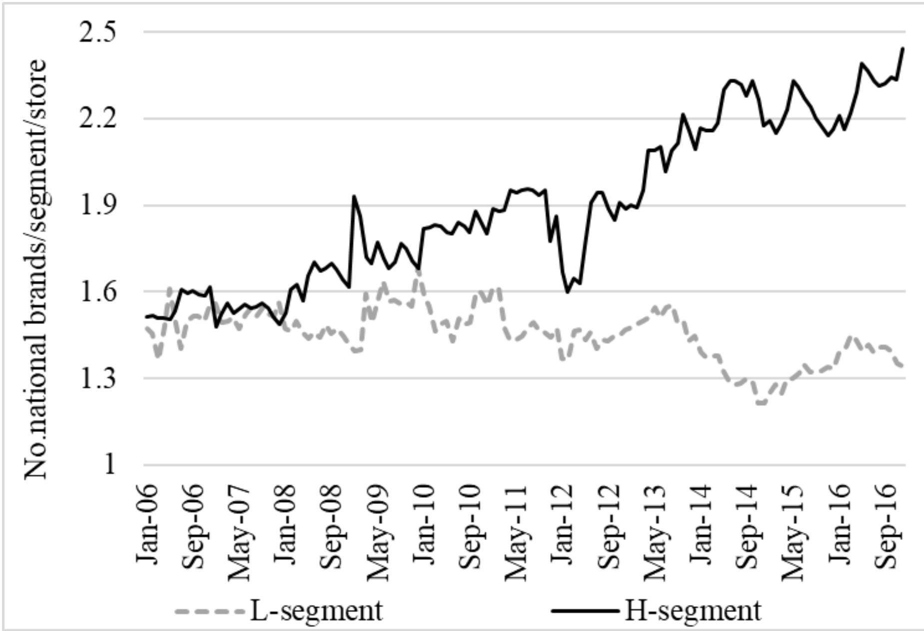


Panel B: Evolution of Number of National Brands in a Segment



Note: The two figures summarize the evolution of the estimated PL effect. Points along the upper dotted curve equal the point estimate plus 1.96 multiplied by the corresponding standard error of the point estimate, while points on the lower dotted curve equal the point estimate minus 1.96 multiplied by the standard error. The dotted curves generate a 95% confidence interval for each point estimate.

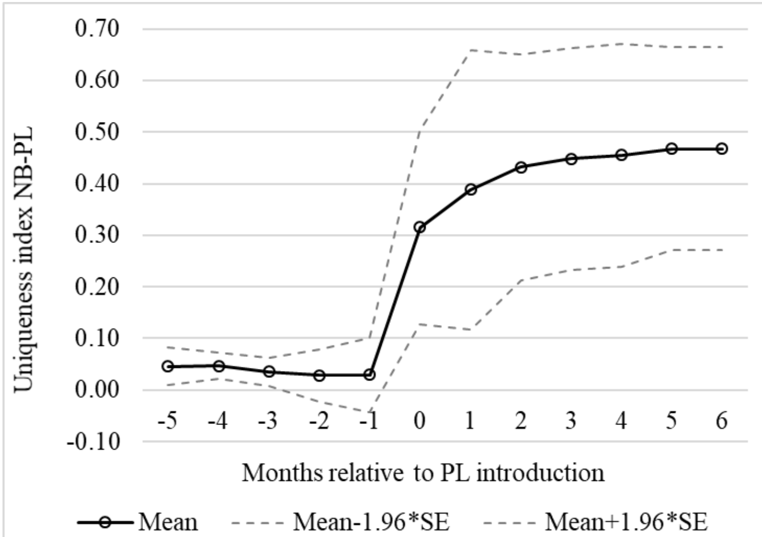
FIGURE 7: Number of National Brands by Segment and Store over Time



Note: The figure draws the number of NBs in L- and H-segments of a store over time.

Source: Nielsen Retail Scanner Data.

FIGURE 8: Evolution of Brand Uniqueness Index



Note: The figure depicts dynamics in the estimated PL on the uniqueness index. Other notes are the same as Figure 6.

Appendix 1. Beef Market Overview

The US beef market contains a large number of national beef brands. Table A1 shows the top NBs and their corresponding market shares by volume (in %) over the years. Tyson has been consistently one of the three largest NBs. Several NBs lost market shares after 2012, which echoes the rapid expansion of PLs in the market during that period.

TABLE A1: Market Shares by Volume for Top National Beef Brands

	Tyson	Excel	Laura's Lean	Cargill	Moran's
	Brand Market Shares by Volume (%)				
2006	5.67	5.89	6.06	2.88	4.87
2007	5.29	6.23	6.16	3.00	4.80
2008	6.29	5.15	5.89	3.49	3.31
2009	6.22	6.45	2.51	3.59	2.79
2010	6.50	6.05	1.90	3.88	1.93
2011	6.17	5.70	1.81	4.19	1.13
2012	5.85	6.44	2.06	4.71	0.26
2013	4.29	4.85	2.74	3.38	0.21
2014	3.86	2.83	3.02	2.61	0.10
2015	4.76	0.71	3.13	0.57	0.10
2016	4.43	0.76	2.70	0.23	0.11
Average	5.39	4.64	3.45	2.96	1.78

Note: The table reports volume market shares of major beef NBs in each year. All months from 2006 to 2016 are included to generate the statistics.

Source: Nielsen Retail Scanner Data.

Appendix 2. Varieties of Beef Products

TABLE A2: List of Beef Varieties and Summary Statistics

	Cut	Size	Avg. Price	UPC share	Revenue share	Volume share	Notes
1	Beef rolls	≤ 3 lb.	3.39	0.3	0.03	0.03	
2	Beef rolls	> 3 lb.	2.63	0.2	0.07	0.10	
3	Ground, fat	≤ 3 lb.	3.29	35.0	53.36	56.28	Lean ≤ 85%
4	Ground, fat	> 3 lb.	2.23	4.7	13.17	20.52	Lean ≤ 85%
5	Ground, lean	≤ 3 lb.	4.96	15.2	19.85	13.91	Lean > 85%
6	Ground, lean	> 3 lb.	2.86	0.3	0.23	0.28	Lean > 85%
7	Others	≤ 3 lb.	2.32	0.9	0.16	0.24	Sliced sirloin, tripe, etc.
8	Others	> 3 lb.	2.77	0.6	0.03	0.03	Sliced sirloin, tripe, etc.
9	Pattie, fat	≤ 3 lb.	4.30	18.9	6.57	5.31	Lean ≤ 85%
10	Pattie, fat	> 3 lb.	3.45	1.5	0.35	0.35	Lean ≤ 85%
11	Pattie, lean	≤ 3 lb.	5.57	4.4	1.79	1.12	Lean > 85%
12	Pattie, lean	> 3 lb.	5.03	0.1	0.01	0.01	Lean > 85%
13	Roast	≤ 3 lb.	7.57	0.5	0.04	0.02	Bulk, round, etc.
14	Roast other	≤ 3 lb.	8.37	1.2	0.15	0.06	
15	Roast tndl.	≤ 3 lb.	5.20	1.1	0.21	0.14	Tenderloin pieces for roast
16	Steak fillet	≤ 3 lb.	10.63	4.6	2.06	0.67	
17	Steak other	≤ 3 lb.	6.16	1.8	0.57	0.32	Flank, skirt, round, chuck, cube, etc.
18	Steak ribeye	≤ 3 lb.	9.46	2.1	0.16	0.06	
19	Steak sirloin	≤ 3 lb.	8.66	2.6	0.76	0.30	Top sirloin steak included
20	Steak slice	≤ 3 lb.	4.55	1.9	0.25	0.19	Shaved and diced steak included
21	Steak strip	≤ 3 lb.	12.22	2.1	0.18	0.05	Shortloin steak included

Note: The table summaries all beef varieties recorded in the Nielsen database. There are 1,117 unique UPCs in the data over all years. The prices are measured in the unit of real 2015 US dollars per pound.

Source: Nielsen Retail Scanner Data.

Appendix 3. Interactive Fixed Effects Model

We provide more information on the Interactive Fixed Effects (IFE) estimator developed by Liu et al. (2020), which enables us to address potential endogeneity concerns on the introduction of PLs. This estimator builds upon a generalized synthetic control approach (Xu, 2017). Below, we summarize the key steps and defer readers to Xu's original article for further details.

In period $t \in \{1, \ldots, T\}$ after PL introduction, each "treated" store (here store that sells a PL) has an unobserved potential outcome that relates to the untreated event, $n_{gst}(0)$, and is used to obtain the causal effect of the treatment (i.e., selling a PL). The counterfactual number of NBs in segment g needs to be computed. The actual outcome value of the store is denoted by $n_{gst}(1)$. A set of period-specific, latent factors are f_t. Observed control variables are denoted by Y_{st}. The identification condition is:

$$\{n_{gst}(1), n_{gst}(0)\} \perp PL_{st} | Y_{st}, f_t,$$

where PL_{st} is the PL indicator and equals 1 if the PL has been introduced. The IFE specification is given by:

$$n_{gst} = \theta_{st} PL_{st} + \Lambda Y_{st} + \lambda f_t + \epsilon_{gst},$$

where λ refers to the unknown factor loadings.

First, we estimate the counterfactual outcomes for each "treated" store, $\widehat{n_{gst}(0)}$, using the control stores (i.e., stores never selling PLs from 2006 to 2016). Next, we compute the treatment effect by:

$$\widehat{\beta_{gst}} = n_{gst}(1) - \widehat{n_{gst}(0)}, \ \forall t \geq t_s,$$

where t_s is the first month of selling PL for store s. The average treatment effect in period t can be computed by taking the average across all stores:

$$\widehat{ATT}_t = \frac{1}{N_t} \sum_s \widehat{\beta_{gst}}\,,\ \forall t \geq t_s,$$

where N_t is the number of treated stores in period *t*.

To apply the IFE estimator, we need to sort out treated as well as control stores that are observed continuously over a series of months. It turns out that less than 8% of the stores provide information in all months from 2006 to 2016. To avoid dropping the majority of stores in the database, we separate the 10-year period from 2007 to 2016 into five 2-year windows: 2007-2008, 2009-2010, 2011-2012, 2013-2014, and 2015-2016. In each window, 60-80% of the stores are observed for at least 20 months.

Given the existence of L- and H-segments, we effectively have four PL effects to estimate and need four subsamples in each 2-year window: the effect of selling the L-segment PL on the L-segment NB number (the LL subsample), selling the L-segment PL on the H-segment NB number (the LH subsample), selling the H-segment PL on the L- as well as H-segment NB numbers, respectively (the HL and HH subsamples, respectively). The LL subsample, for instance, includes treated stores that sell PL in the L-segment for at least one month or and control stores that never sell PL. Similarly, we find stores appropriate to include in the other three subsamples.

In total, the four subsamples provide over one million observations to conduct the estimation. Summary statistics of the subsamples are displayed in Table A3 and show no significant differences compared with the statistics of the full dataset (see Table 2).[8] Estimation is performed for each subsample and 2-year each window. Combining the estimated individual

[8] When using the IFE, the exact number of unobserved factors is determined by a cross-validation procedure. The procedure relies on the information on the control group as well as the treatment group in the pretreatment periods (Xu, 2017). We perform the procedure whenever feasible. When we do not have a sufficiently large number of pretreatment observations in a certain subsample, we set the number of unobserved factors to what the cross-validation suggests in other subsamples. In the LL and LH subsamples, the cross-validation tests suggest that the number of unobserved factors is 2. In HL and HH subsamples, the cross-validation tests suggest that the number of unobserved factors is 1. Changing the number of unobserved factors makes little impact on the outcomes.

effects, we obtain the full set of outcomes covering 2007 to 2016 and all treated stores. The full set of outcomes are used for estimating equation (5).

TABLE A3: Summary Statistics of the Subsample

	Mean	SD	Min	Max
L-Segment PL				
No. NB/Segment/Store	0.98	1.11	0	10
PL Introduced (1, if yes)	0.33	0.47	0	1
No. Observations	1,053,336			
H-Segment PL				
No. NB/Segment/Store	1.20	1.13	0	12
PL Introduced (1, if yes)	0.27	0.44	0	1
No. Observations	1,054,508			
No. Observations Never PL	490,932			

Note: The table reports summary statistics of observations used for estimating the IFE model. “No. NB/segment/store” is the number of NBs in one segment and a store. “No. Observations Never PL” is the number of observations of stores that never sell PL and is the same for all subsamples. The upper panel includes observations of subsamples for the L-segment PL, while the lower panel is for the H-segment PL.

Source: Nielsen Retail Scanner Data.

Appendix 4. Robustness Tests

In Table A4, we report the estimation results of several robustness tests. First, instead of using observations in the window of one year around PL introduction, we shorten the window to half a year, which potentially avoids more unobserved confounders that also affect NB assortment. The results are shown in Table A4, columns 1 and 2, which correspond to and are statistically indifferent from columns 1 and 2 in Table 3. Table A4, columns 3 and 4 outcomes rely on observations of stores that sell positive numbers of NBs within one year before the PL is introduced. Nearly 90% of the stores sell NBs before selling the PL. The size of the alternative sample is hence only slightly smaller compared with the one used in our baseline regression. The signs and magnitudes of the estimates are consistent with columns 1 and 2 in Table 3. Specifically, the store reduces the proximity between NBs and the PL after the PL is introduced, and the number of NBs decreases.

We also perform a placebo test on PL introduction using stores that never sell PLs from 2006 to 2016. The test is constructed in a two-step randomization procedure. First, we randomly select 50% of the stores never selling PLs and set them as the fake PL selling stores. Next, we randomly assign the month of PL introduction to each fake PL seller between the first and last months that a store appears in the Nielsen dataset. In the meantime, we let each PL randomly fall in the L- or the H-segment. With the fake PL selling observations, we re-estimate equations (3) and (4). Table A5 shows no significant effect of the fake PL introduction on the number of NBs, which confirms that effects identified in our original regressions are driven by the actual introduction of PLs instead of any unobserved trend or random shock in the database.

TABLE A4: Robustness Tests on PL Effects on NB Assortment

Dependent Variable	*Jaffe index NB-PL* (1)	*No. NB /Segm.* (2)	*Jaffe index NB-PL* (3)	*No. NB /Segm.* (4)
PL Introduced (PL)	-0.33***	-0.26***	-0.28**	-0.24***
(1, if yes)	(0.10)	(0.08)	(0.11)	(0.09)
No. Brands/Cmp Store	-0.004		0.002	
	(0.003)		(0.002)	
No. Brands/Cmp Store		0.09		0.08
Same Segm		(0.06)		(0.05)
No. Brands/Cmp Store		-0.003		-0.01
Diff Segm		(0.05)		(0.04)
Store Ever Selling PL		0.052		0.03
(1, if yes)		(0.07)		(0.06)
Constant	0.34**	0.63**	0.34**	0.14
	(0.15)	(0.21)	(0.15)	(0.21)
Control Variables	Y	Y	Y	Y
Retailer/Market/Time FE	Y	Y	Y	Y
R^2	0.76	0.43	0.83	0.48
No. Observations	156,910	1,199,356	254,225	1,403,854

Note: This table reports the estimation results of the robustness tests. "Segm." refers to segment, and "cmp" stands for competitor. Stores that introduce PLs before November 2006 or after February 2016 are excluded to ensure at least 10 months of observations before and after PL introduction. *** p-value<0.01, ** p-value <0.05, * p-value <0.10.

TABLE A5 Placebo Test on PL Effects on NB Assortment

Dependent Variable	*No. NB/Segm.*		
	All PL	*L-Segm. PL*	*H-Segm. PL*
	(1)	(2)	(3)
PL Introduced (PL)	-0.001	-0.02	0.03
(1, if yes)	(0.01)	(0.01)	(0.02)
PL Introduced Interacted with		0.05	-0.04
Same Segm. (PS)		(0.03)	(0.03)
No. Brands/Cmp Store	0.10	0.08	0.10
Same Segm	(0.08)	(0.06)	(0.07)
No. Brands/Cmp Store	0.002	0.02	-0.02
Diff Segm	(0.06)	(0.05)	(0.05)
Store Ever Selling PL	0.01		
(1, if yes)	(0.01)		
Constant	-0.07	-0.62***	0.94***
	(0.20)	(0.17)	(0.18)
Control Variables	Y	Y	Y
Retailer/Market/Time FE	Y	Y	Y
R^2	0.39	0.49	0.46
No. Observations	584,042	74,442	78,434

Note: This table reports the estimation results of the placebo test. “Segm.” refers to segment, and “cmp” stands for competitor. Stores that introduce PLs before November 2006 or after February 2016 are excluded to ensure at least 10 months of observations before and after PL introduction. *** p-value<0.01, ** p-value <0.05, * p-value <0.10.