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By

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ZONE PRICING IN RETAIL OLIGOPOLY

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April 2017‡

Abstract

We quantify the welfare effects of zone pricing, or setting common prices across distinct markets, in retail oligopoly. Although monopolists can only increase profits by price discriminating, this need not be true when firms face competition. With novel data covering the retail home improvement industry, we find that Home Depot would benefit from finer pricing but that Lowe's would prefer coarser pricing. Zone pricing softens competition in markets where firms compete, but it shields consumers from higher prices in markets where firms might otherwise exercise market power. Overall, zone pricing produces higher consumer surplus than finer pricing discrimination does.

JEL Classification: C13, L67, L81

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1 Introduction

Multi-store retailers have the ability to offer different prices based on the geography of their stores. They sometimes do, but often only to a limited extent. This is observed in home improvement retailing, where the large retail chains charge different prices nationally but opt not to set prices store-by-store or even by market. Instead, prices are assigned to zones spanning several markets that differ in significant ways. If these firms were monopolists, this would represent a missed opportunity to price discriminate and increase profits. With competitive interaction, however, price discrimination has an ambiguous effect on both profits and consumer welfare (Holmes 1989, Corts 1998).

The existing literature on zone pricing has found the potential for large gains in profit by adopting finer pricing. However, due to data limitations, the existing literature had to abstract from the competitive interaction of firms. The theory literature suggests that this abstraction may even yield the incorrect sign on profit and consumer surplus changes. In this paper, we evaluate the welfare consequences of third degree price discrimination in retailing, accounting for the competitive interaction. We develop an empirical analysis of retail zone pricing and apply it to new data gathered on the home improvement industry.

Examples abound of firms segmenting markets based on geography, including grocers (Montgomery 1997, Eizenberg, Lach, and Yiftach 2016) and retailers (Seim and Sinkinson 2016).[1] Computational advancements have made it increasingly easy for firms to segment consumers based on geography. However, little is known regarding how segmenting markets affects both consumers and firms in retail oligopoly.[2] By accounting for the competitive interaction, we find that further price discrimination through finer zones

[1]The Staples price discrimination example became well known after a *Wall Street Journal* article noted that prices online reflected the web user's zip code. This article also cites the well known Amazon price discrimination example in which Amazon temporarily charged individual customers different prices. After much backlash, Amazon refunded the price differences. "Websites Vary Prices, Deals Based on Users' Information," Jennifer Valentino-Devries, Jeremy Singer-Vine and Ashkan Soltani, Dec 24 2012.

[2]The ambiguity of third degree price discrimination in oligopoly has been explored in other contexts, such as in negotiated prices (Grennan 2013) and upstream wholesale prices (Villas-Boas 2009).

exposes some markets to much higher prices, as firms are more able to exercise monopoly power. However, prices would decrease in markets in which firms compete. Our results reveal an asymmetry, as a move by both firms towards finer pricing decreases profits for one chain but increases profits for the other. Unlike previous studies, ours finds the aggregate profit and consumer surplus effects to be mitigated, as moves away from the observed pricing zones result in transfers of surplus (up to 66%) across markets.

We begin by documenting the pricing strategies used by the major home improvement retailers. We obtain over 800,000 cross-sectional prices for hundreds of products across nearly 4,000 stores and document that zone pricing is used in many, but not all, of their product categories. There is a significant amount of heterogeneity in pricing across products. Some products are uniformly priced, while others have as many as 100 prices across stores. The magnitude of price dispersion is meaningful, as many products see a range in prices by a factor of two or three nationally. We show that prices are assigned to pricing zones that combine distinct, and sometimes distant, markets, where competition and input costs vary substantially. For example, one Home Depot drywall pricing zone spans 500 miles and includes the stores in metropolitan Salt Lake City, Utah and Boise, Idaho, as well as several stores in small, isolated towns across Idaho, Nevada, and Wyoming.[3]

We combine the pricing data with sales quantity data, which we collect by tracking the firms' daily inventory levels for the drywall. Drywall is a product especially suited to an analysis of zone pricing, because of the size of its zones, the price and cost variations across space, and the detailed information available on its supply. The data are used to estimate an empirical model with competition. On the supply side, retailers set prices in a two-stage game. They first partition their stores into pricing zones. The definition of a zone forces firms to charge the same price for a given product across all stores within the zone. Second, conditional on the chosen pricing zones, firms simultaneously compete on prices. For demand, we estimate a nested logit model (Berry 1994), which

[3]Drywall is sometimes called wallboard, sheet rock, or gypsum board. It is made from gypsum and other additives and is attached to interior wall studs (interior frame). The drywall is then painted.

incorporates preferences for product characteristics and price. We find drywall to be a highly substitutable product (mean product elasticity of -5), which is not surprising because it is not highly differentiated. Industry demand is inelastic (-.7).

Most studies have no direct measure of costs. Instead, they recover costs using the demand system and appealing to optimality conditions on firm behavior (Berry 1994, Berry, Levinsohn, and Pakes 1995). Because we derive marginal costs from wholesale prices and calculated transportation costs, we need not rely on the optimality of both zones and pricing to impute costs. Thus, we are able to calculate optimal zone prices given our demand system estimates and costs. Comparing observed prices with optimal prices, we find that observed prices are, on average, 9% below optimal zone prices, with some prices being too high and a majority of prices being too low.

Our main analysis comes from calculating subgame perfect equilibria under different zone structures. We consider all combinations of firms choosing uniform, (observed) zone, and market pricing. For each scenario, we calculate equilibrium prices, profits, and consumer welfare. Our analysis yields four main findings. First, we find that as pricing becomes more flexible, prices increase greatly in markets where firms have market power, but decrease in competitive markets. For example, a move from zone pricing to market pricing for both firms increases prices in monopoly markets by 27%, but decreases prices in competitive markets by 1.6-3.7%. Our second finding is that, conditional on a competitor's pricing structure (but allowing prices to update), a firm almost always does better under finer pricing. For example, if Lowe's continues zone pricing, Home Depot's profits increase if it goes from uniform pricing to zone pricing and from zone pricing to market pricing (increasing profits by 8.2%). As costs and demands differ, this result is not a foregone conclusion, as it is in the monopoly case. Our third finding is that there exists an asymmetry across the two chains. We find that Lowe's would benefit from both chains moving to coarser pricing (3.9% higher profits), and Home Depot would benefit if both chains moved to finer pricing (1.5% higher profits). Our final important finding is that

aggregate consumer welfare changes are mitigated due to asymmetric price effects across markets. Adjusting pricing zones to increase price discrimination results in decreased consumer welfare, but the net effect is only one third the absolute change. That is, finer pricing allows firms to exercise market power where they do not face competition, but doing so also results in lower prices in markets where firms compete head-to-head.

Following our subgame analysis, we single out the role that competitive interaction plays in estimating the gains from adopting finer pricing. Using the Dominck's Finer Foods data base, Montgomery (1997), Chintagunta, Dubé, and Singh (2003), and Khan and Jain (2005) compare zone pricing to store-level pricing in retail. These earlier analyses abstracted from cost differences between stores and the response of competitors, both of which are important considerations in drywall and many other retail sectors. We compare equilibrium outcomes with a unilateral deviation to market pricing holding competitor prices constant. We find abstracting from the competitive interaction overstates the profit gains from price discrimination by 71% for Lowe's and by 36% for Home Depot.

Lastly, we show how decentralizing pricing would affect chain profits. Some retailers, at least historically, have given local managers the autonomy to decide prices and product assortments. In this exercise, we decentralize pricing at Home Depot and Lowe's by having stores maximize their own profits. This leads to a principal-agent problem, as chain stores are now competitors with other local chain stores. We find the agency problem in our setting to be large; a move from market pricing decreases total chain profits by 23-33% in markets where other chain stores are present. This may be the reason that our retailers centralize the firm's pricing activities.

The rest of the paper is organized as follows. In Section 2, we describe the data that we collect for this study. This motivates the empirical model that we specify in Section 3. In Section 4, we present our demand estimates and compare equilibrium prices with observed prices. All of our counterfactual exercises appear in Section 5. Section 6 concludes.

2 Data

Home improvement warehouses have grown to have revenues exceeding $130 billion dollars a year.[4] They sell products in many product categories, ranging from building materials to small household appliances. The three largest chains are Home Depot, Lowe's, and Menards. Home Depot operates 2,274 stores, Lowe's 1,857 stores, and Menards 295 stores.[5] Home Depot and Lowe's are the fourth and eighth largest US retailers by revenue, respectively.[6]

We create several new data sets with information gathered from the retailers' websites. First, we obtain cross-sections of store prices for all three chains for all products in drywall and a few other categories. Next, we construct a panel of prices and quantity sold for drywall stores in the Intermountain West for a six-month period in 2013. We then combine these data with cost estimates based on wholesale prices and transportation costs. We describe each of these data sets in the following subsections.

2.1 Zone Pricing Practices in Home Improvement Retail

We begin by documenting new facts regarding the magnitude of dispersion and the use of zone pricing for the three main home improvement retailers. The retailers' websites present users with store-specific prices, and we record a snapshot of prices at all stores for products in several categories.[7]

We collect prices for drywall, insulation panels, LED light bulbs, mosaic glass tile, Phillips screwdrivers, plywood, roof underlayment, sanders, stone pavers, and window film. These product categories are chosen because they vary in size, weight, price, location

[4]Home Depot and Lowe's alone exceed $130 billion. Source: 2016 10-Ks.

[5]Home Depot: 2016 10-K ; Lowe's: 2016 10-K; Menards: authors' calculation. Home Depot and Lowe's operate stores throughout the United States and a few in Canada and Mexico. Menards operates only in the Midwest.

[6]Source: National Retail Federation. Top 100 Retailers 2014.

[7]We collect these data by writing a web scraper. For each product, we set our location to each store. This reveals the local product price.

of manufacturer, and availability at other local retailers and at online retailers. All of these factors may affect the pricing of products. In addition, product category managers working at corporate headquarters - not local managers - make pricing decisions.[8] There is one pricing manager for all drywall products, for example. We randomly sample products within each category and obtain, in total, 801,498 prices between 2013 and 2014.

Our first finding is that pricing strategies vary considerably across firms and across categories within a firm. Table 1 computes the mean and median number of unique prices for products at the category-firm level.[9] For example, the second row corresponds to insulation panels. The first column numbers, (14.48, 7), show that Home Depot neither uniformly prices insulation panels nor uses store-level pricing. The average insulation panel has 14.48 price points, and the median number of prices is seven. The difference comes from pricing variation within a category. For example, Lowe's birch plywood has 51 prices, whereas Lowe's underlayment plywood has five prices. Looking within and across columns shows considerable variation in pricing strategies. In several categories, all firms uniformly price almost all products, while in others, such as drywall and roof underlayment, all employ fine pricing. There are also important asymmetries across retailers. For plywood, Home Depot only has 5.4 price points per product, but the number is above 23.6 for Lowe's.

In many of these categories, the distinct price points are far apart. To gauge the magnitude of price dispersion across stores, we calculate the coefficient of variation (CV). Across all products, the average is 0.039, and excluding uniformly priced products, 0.114.[10] The relation between the number of distinct prices and CV is positive through 40 prices, and the CV is above 0.1 when the number of prices exceeds 19. As prices become more

[8] In addition to information from people in the industry, we note that job descriptions for pricing are category-specific. For Menards, some of the positions combine categories, such as paint and grocery.

[9] These statistics are weighted by the number of stores that carry the product. This addresses the fact that some products are nationally stocked, and others have a regional presence. Excluding products that have only a small presence does not affect the results.

[10] Our interpretation is that this suggests significant price dispersion in retailing. The magnitude is less than for prescription drugs (Sorensen 2000). However, Cavallo (2017) notes that prices are identical between offline and online channels 72% of the time across 56 large retailers.

dense, the CV dips slightly to 0.125. Products in categories such as drywall have average CV, but as we will soon see, this translates to significant price variation across stores.

Our second finding is that many products have large, geographically contiguous regions with constant prices. Figure 1 maps price ranges for 4′ x 8′ x 1/2" non-mold-resistant drywall at Lowe's. Each dot corresponds to a store location, and the color of the dot corresponds to a price range. Prices vary considerably across the United States, with the same product having the lowest price of $6.98 and the highest price of $19.85. The factor of three range in prices comes from Lowe's charging 79 distinct prices across stores. The map also shows coarse pricing over large areas of the United States. For example, price dispersion is small or zero in the Upper Midwest and Northeast. Figure 2 shows a similar story for Home Depot's 4′ x 8′ x 1/2" mold-resistant drywall. Nationally, this product has considerable price variation, from $7.65 to $23.71 per sheet, stemming from 93 distinct prices. Again, price dispersion is small or zero for large regions such as in the Midwest and Pacific Northwest. Figure 3 zooms in to the Western United States and maps unique prices for regular 4′ x 8′ x 1/2" drywall. The map reveals geographically contiguous pricing zones. For example, Washington and Oregon form a pricing zone; all stores in Idaho, Utah and Northern Nevada form a pricing zone; and Arizona is split into two zones.

The coarseness of pricing zones varies by product category, but there is also within-category variation. For example, compare the Home Depot mold-resistant and non-mold-resistant 4′ x 8′ x 1/2" drywall sheets in Figure 2 and Figure 3. In Figure 2, Western Washington and Oregon belong to two pricing zones, whereas in Figure 3, these stores combine to form one pricing zone. Information available to Home Depot suppliers offers the likely explanation as to why this occurs: each store is allocated to a division, region, buying office, market, and distribution center.[11] For example, the Van Nuys, California store is assigned as follows: store 6661, market 48, buying office 5, distribution 174, region Pacific Central, and division Western. Zones are determined by pooling "markets"

[11]Sourced from The Home Depot US Store Listing, July 2010, accessed through the Home Depot supplier portal.

together. Within category, the variation is explained by a manager selecting the Western Washington (market 44) market and combining it with the Oregon market (market 54), as in the case of 4′ x 8′ x 1/2" non-mold-resistant drywall. Across-category variation is generally explained by how many markets are pooled together to form a pricing zone.

Finally, we note that some pricing zones are quite small. This can be seen in the previous pricing maps and most clearly in Figure 4, which plots prices for a 12" cement block at Menards. For example, Wisconsin is split into four zones and Minnesota is included in five zones. Several zones contain just a few stores, such as in Northern Indiana and Southeastern Michigan. Further, the price changes are significant, as prices vary by a factor of two nationally.

2.2 Drywall Data for the Intermountain West

The previous subsection shows there is considerable variation in prices and pricing strategy across the main home improvement retailers. We are interested in the effects of these strategies on firms and consumers and, thus, require quantity data in order to conduct an empirical analysis. Fortunately, the chains' websites also provide information to determine product sales. In addition to local prices, these retailers present web users with up-to-date quantity-on-hand information, as shown in Figure 5. We collect this information daily, and by differencing daily inventory, we obtain a measure of daily sales.

Because of data collection limitations, we narrow our focus to products and store locations – specifically, we select drywall products and the Intermountain West. We choose this category and region of the United States for a number of reasons: (i) locations of drywall manufacturers are known, and costs can be estimated; (ii) drywall deliveries to stores are infrequent, minimizing the measurement error associated with using inventory changes to proxy sales[12]; (iii) this region captures considerable variation in competition and costs, while keeping data collection manageable; (iv) consumer markets are small

[12]This is not true for many product categories, such as paint. These products see deliveries every few days making it difficult to infer sales from inventory.

since buyers are unlikely to transport bulky and fragile products over a great distance; (v) drywall is rarely used in price promotions or as a loss leader,[13] so category profit-maximization is reasonable; (vi) drywall pricing zones are large enough to be economically interesting, but small enough that dozens of zones can be studied with a limited number of stores; and (vii) Menards does not operate in this region, reducing the number of major sellers to two.[14]

We create a data set of prices, quantities sold, and product characteristics for 75 Home Depot stores and 53 Lowe's stores. We download prices and inventory levels for individual store stock keeping units (SKUs) and match these to products. For several products, although Lowe's lists several brands on its website as different products, the SKUs have identical prices and inventory levels (with a one-day lag). We eliminate these duplicates. In all, we identify 31 distinct products. We record thickness, width, length, and mold resistance for each product. We do not use brand identifiers because our site visits found brands frequently mislabeled at both chains. Figure 6 maps the stores for which we obtained quantity data. Our data set includes all stores in Idaho, Montana, New Mexico, Utah, Western Colorado, and Eastern Washington, as well as stores in adjacent states needed to complete pricing zones. This region includes locations where only Home Depot operates (for example, Elko, Nevada) and locations where only Lowe's operates (for example, Vernal, Utah).

For the purposes of this study, we define a price zone as a set of stores at which all products have the same price. Thus, these pricing zones are no larger than the uniform price region for any product. Using this definition of a pricing zone, our sample contains 14 complete Home Depot pricing zones and 11 complete Lowe's pricing zones. We do not observe any changes to the zone structure during the collection period. Nationally, we determine that Home Depot has 165 drywall pricing zones, while Lowe's has 129.

[13] We briefly collect local store ads and note that drywall is never advertised.

[14] Menards did not post inventory levels at the time of data collection, although it does now. Therefore, we select a region without Menards stores.

The Intermountain West contains several small pricing zones, as well as one of the largest pricing zones in the nation. Further, in this area of the country, the pricing zone boundaries largely match between chains; however, this is not true in other parts of the country, such as in the Eastern United States.

A notable feature of the decision to use zone pricing in retail drywall is that costs and market structure vary considerably within a zone. Table 2 presents an example from a large drywall pricing zone based around Salt Lake City, Utah. The Home Depot stores in Logan, Utah, Rock Springs, Wyoming, and Elko, Nevada are all in this pricing zone, and, hence, the prices for drywall within these stores are the same – the 4′ x 8′ x 5/8" drywall board is $10.98. The Home Depot in Logan faces competition from Lowe's, located a mile away. The nearest Lowe's to the Rock Springs and Elko stores are 107 and 168 miles away, respectively. Further, at around 50 pounds per sheet of drywall, distance should play an important role in costs. The distance to the nearest distribution center and the distance to the nearest factory both vary by hundreds of miles. Profit-maximizing prices for each of these stores should differ substantially, yet Home Depot places all three stores in the same zone and assigns identical prices.

Table 3 provides summary statistics for the sample.[15] We collect data daily between February 12, 2013 and July 29, 2013.[16] The sample includes 72,092 observations. On average, daily inventory decreases by 11.6 and 14.7 sheets per product-store for Lowe's and Home Depot, respectively. This represents a small percentage of the drywall required to build a house (typically, several hundred sheets). We posit that the sales we record are used for small consumer projects, such as wall repair or room remodeling. General contractors have the ability to purchase in bulk through contractor supply outlets. Thus, new construction and bulk purchasing occur in a separate market.

[15]We exclude products that are not 4′ x 8′/10′/12′ x 1/2". These three dimensions make up over 71% of sales. The excluded products have unique dimensions and/or thicknesses, such as 12" x 12" panels.

[16]While this data set was collected, drywall installers were pursuing a lawsuit alleging price fixing by manufacturers. We note that no similar allegations were made against drywall retailers.

Inventory increases of more than 20 sheets are classified as deliveries.[17] On delivery days, typically a few hundred sheets are delivered per product-store. The two chains have similar drywall product selections, offering around three products per store.[18] The price of drywall within these markets ranges from $6.95 to $15.14 per sheet, depending on the dimensions and features. The total drywall sales revenue for the 128 stores we study sums to $19.4 million per year. If these sales figures are representative of average store performance, drywall sales for Home Depot and Lowe's total over $627 million per year nationally.

2.3 Drywall Cost Data

We create a data set of estimated marginal costs for each product at every store in our sample, based on wholesale prices and transportation costs. Home Depot and Lowe's ship their drywall from manufacturer to store by way of flatbed distribution centers.[19] We obtain locations for these centers from the retailers' websites, and we obtain locations for all drywall manufacturing factories from *Global Gypsum Magazine*. We calculate the minimum distance from any drywall factory to store via a flatbed distribution center. We then convert that distance into a cost estimate by multiplying quoted prices for flatbed shipment per mile and dividing by the number of sheets on a full flatbed truck. Distribution centers are usually near large markets, and Lowe's and Home Depot distribution centers are often near each other. In our sample region, one big difference is Home Depot's placement of a distribution center in northern Utah, whereas the nearest Lowe's distribution center is in southern Nevada.

We estimate the manufacturer's price at the factory gate using confidential Bureau of

[17] When deliveries occur, we take the net change in inventory for the day as the volume of the shipment, meaning we assume that no sales take place on delivery days. This systematically under-reports sales, but deliveries occur only every 10-20 days depending on the product and firm.

[18] Including sizes other than 4′ x 8′/10′/12′ x 1/2", yields roughly eight products per store on average.

[19] We determine this using Google Maps. By examining street views of their flatbed distribution centers (FDC), we note instances of drywall being unloaded. Hence, we assume that drywall is shipped from the manufacturer to FDC, and then to stores.

Labor Statistics microdata. Wholesale price estimates are the only place where we use Bureau of Labor Statistics data; all other data are independently collected. To estimate wholesale prices in a way that preserves confidentiality, we construct a reduced-form regression of price on mold resistance, transaction characteristics, and month indicators. Thus, we generate separate monthly wholesale prices for mold-resistant and regular products, but data limitations and confidentiality concerns force us to ignore wholesale price differences between chains or between manufacturing locations. Within each month, differing transportation distances and product characteristics determine all cost variation. We omit other sources of costs, including labor costs, checkout transaction fees, and the opportunity cost of store floor space.

3 Model of Zone Pricing in Oligopoly

In this section, we introduce the structural model of demand and supply under zone pricing. For demand, we pursue a nested logit demand system (Berry 1994). For supply, we assume that firms sell multiple differentiated products across multiple stores and compete in a two-stage static game. Firms first choose a pricing regime, such as uniform pricing or pricing market-by-market. Then, conditional on the regime choices, firms simultaneously choose prices.

3.1 Nested Logit Demand

Consumers are distributed across several locations, with a generic location denoted ℓ. Consumer i at location ℓ decides to purchase a single product or chooses option 0, which corresponds to not purchasing any of the available products in the market. Let s be a generic store at location ℓ, and let j be a particular product. We suppress the time subscript t for ease of exposition. Each consumer solves the discrete choice utility maximization problem; that is, i chooses j, s if and only if $u_{ijs} \geq u_{ij's'}, \forall j' \times s' \in J_\ell \cup \{0\}$, where J_ℓ denotes the choice set at ℓ.

We pursue a nested logit demand system in which products are partitioned into groups (nests). Let c denote a nest. The outside good, corresponding to $j = 0$, belongs to its own nest. We assume that utility is linear in product characteristics, and equal to

$$u_{ijs} = \delta_{js} + \zeta_{ic}(\lambda) + (1 - \lambda)\varepsilon_{ijs}.$$

In the formulation above, the mean utility of product j at s is equal to

$$\delta_{js} = x_{js}\beta - \alpha p_{js} + \xi_{js};$$

x_{js} are product characteristics; p_{js} is price; (β, α) are preferences over product characteristics, ξ_{js} is unobservable to the econometrician; and ε_{ijs} is an independent and identically distributed (i.i.d.) unobservable having a Type-1 extreme value distribution. The decision not to purchase a good yields a normalized utility, $u_{i\ell 0} = \varepsilon_{i\ell 0}$. Finally, $\zeta_{ic}(\lambda)$ is common to all products in nest c and depends on the nesting parameter $\lambda \in [0, 1]$. Cardell (1997) shows that $\zeta_{ic}(\lambda) + (1 - \lambda)\varepsilon_{ijs}$ has a generalized extreme value (GEV) distribution, leading to the nested logit demand model. As $\lambda \to 1$, products within nests are increasingly close substitutes, and, in the limit, when $\lambda = 1$, there is no substitution outside of the nest. If $\lambda = 0$, the model collapses to the logit demand model. Integrating over the GEV unobservables yields analytic expressions for the purchase probabilities, $\sigma_{js} = \sigma_{\ell c} \cdot \sigma_{js/c}$. Following Berry (1994), the choice probabilities can be inverted to reveal a linear estimating equation,

$$\log(s_{js}) - \log(s_{\ell 0}) = x_{js}\beta - \alpha p_{js} + \lambda \log(s_{js|c}) + \xi_{js}, \tag{3.1}$$

where s_{js}, $s_{\ell 0}$, and $s_{js|c}$ are the empirical counterpart to the theoretical purchase probabilities (σ). Prices may be correlated with the unobserved error term (ξ), but since Equation 3.1 is linear in its parameters, we instrument for price, as discussed in Section 4.1.

3.2 Two-Stage Game of Zone Pricing

With the demand system defined, we now introduce the two-stage game of zone pricing under competition. In the first stage of the game, firms partition their stores into pricing zones. The partition is done with full commitment. In the second stage of the game, conditional on the chosen pricing zones, firms compete simultaneously on prices.

The first stage, or the pricing regime choice, constrains the firms' pricing decision in the second stage. For example, suppose that all firms commit to using uniform pricing. This results in a firm charging the same price for a given product across the entire network of stores. On the other hand, the choice of store-level pricing removes any pricing constraint in the second stage. In this scenario, we may well expect firms to charge a different price at each store, based on market power and costs. We define zone pricing to be a set of partitions across firms between the two extremes of uniform pricing and store-level pricing. Zone pricing implies that for every product j,

$$p_{js} = p_{js'}, \ \forall s, s' \in z, \tag{3.2}$$

where s, s' denote stores belonging to zone z.

Let Z denote the set of partitions for all firms and (Z^f, Z^{-f}) be the zone partition of firm f and competition $-f$. We denote marginal costs c_{js} for offering j at store s. There are no fixed costs. Given a zone structure chosen in the first stage, the profits accrued to a firm for selling product j across the network of stores are

$$\pi_j^f \left(p^f \ ; \ p^{-f}, Z\right) := \sum_{z \in Z^f} \sum_{s \in z} (p_{jz} - c_{js}) q_{js}, \tag{3.3}$$

where $q_{js} = M_\ell s_{js}$, M_ℓ is the market size corresponding to the location of store s, and $s_{js} = \sigma_{js}(X, p, \xi; \theta)$ corresponds to the market share defined in Section 3.1. Implicitly, only zones and stores that offer j are included in the sum. Note, also, the subscript on price (jz)

incorporates the constraint in Equation 3.2. If firm f uses uniform pricing, for example, prices are just p_j and $Z^f \equiv z$. If firm f uses store-level pricing, $Z^f = \left\{\{s_1^f\}, ..., \{s_N^f\}\right\}$ where N is the number of stores operated by the firm.

As firms sell multiple products across stores, total firm profits are

$$\pi^f := \sum_j \pi_j^f \left(p^f \, ; \, p^{-f}, Z\right). \tag{3.4}$$

With demand and payoffs defined, we can now define the equilibrium for the game, which depends on the zones and prices chosen among the players. Formally, an equilibrium is a set of pricing zones Z^*, prices p^*, and market shares σ^* such that

1. given pricing zones (Z^*) and competitor prices p^{*-f}, p^{*f} solves Equation 3.4;
2. given competitor pricing zones Z^{*-f}, Z^{*f} is chosen such that

$$\pi^{*f}\left(Z^{*f} \, ; \, Z^{*-f}\right) \geq \pi^{*f}\left(Z'^f \, ; \, Z^{*-f}\right) \; \forall \; Z'^f; \text{ and}$$

3. given prices p^*, σ^* follows from the demands defined in Section 3.1.

4 Estimation and the Observed Zone Pricing Regime

In this section, we discuss the model estimation, estimated parameters, and estimated markups.

4.1 Demand

We invert market shares, as shown in Berry (1994), to obtain the linear estimating equation in Equation 3.1. This equation relates observed market shares to the mean utility from purchasing product j, s. Included in x are dummy variables for product length, fixed effects for market, an indicator for mold-resistance, and a chain dummy for (Home Depot,

Lowe's). We aggregate data to the two-week level because we observe zero product sales at the daily level. Price adjustments are not frequent. When we observe a price adjustment within the two-week window, we compute the average price weighted by sales.

Three choices remain to complete the demand specification: the definition of the market, the share of the outside good, and the choice of nest. We define a market to be a Core Based Statistical Area (CBSA) over a two-week period. For stores not located within CBSAs, we set the market to be the county in which the store resides. With this interpretation of markets, each location ℓ usually has several stores from both Home Depot and Lowe's, and a consumer, on average, chooses between seven products. Further, given the structure of both firms' pricing zones, zones overlap into several markets; however, in no situations do markets overlap zones. We take market size to be proportional to the 2010 CSBA population to define the outside good share.[20] We nest products by the mold-resistance characteristic. Although drywall is overall highly substitutable, mold-resistance panels are recommended for bathrooms and kitchens. Standard panels are used elsewhere because these panels generally weigh less and are more fire-resistant. Drywall often is trimmed to length, so we expect (and find) 8', 10', and 12' panels to be highly substitutable.

Two sources of endogeneity arise from the inversion of market shares. The first is that unobserved product quality may be correlated with price. The second is that within-group share is naturally correlated with the unobserved error term, ξ. We use an instrumental variables approach to deal with this endogeneity issue. Our list of instruments includes: marginal costs; sum and count of all products and product characteristics at both allied stores in the market and competing stores in the market; and a Hausman instrument – average prices for a given product in other markets where the product is offered. We may also be concerned that zones are endogenous so we also implement the Hausman instrument for distant zones (farther than 350 miles).

We estimate two versions of the demand model. First, we set $\lambda = 0$ in the nested logit

[20] For observations not within CBSAs, we take the population to be proportional to the 2010 Census county population.

model so that the nests do not matter. We then estimate λ along with the demand parameters. The results of the demand estimation appear in Table 4. Across both specifications, we find that consumers are price-sensitive and that the sign on the Home Depot indicator is positive. In the nested logit model, we estimate $\lambda = 0.813$, suggesting high substitutability within nest. We estimate statistically significant and negative parameters on the length dummy variables in the logit model; however, these parameters become insignificant and of mixed sign in the nested logit model. Finally, we estimate the mold-resistance dummy variable to be negative, as these products are significantly more expensive than regular drywall panels and are typically used in only a few rooms of homes.

As Petrin (2002) notes, adding model flexibility greatly decreases the reliance on the unobserved error term. We confirm that finding by noting that the mean product elasticity increases from -2 to -5 from the logit to the nested logit model. This confirms that drywall is a highly substitutable product. We estimate the industry elasticity of drywall to be -0.7.

4.2 Marginal Costs and Model Fit

Often, marginal costs are recovered by imposing optimality conditions on firm behavior. For example, assuming a Nash-Bertrand equilibrium in a single good setting, the markup can be recovered through Lerner's Index. The multi-product analog can be seen in Petrin (2002) and Nevo (2001), among many other papers in the industrial organization literature. With estimates of transportation and wholesale costs, we do not need to impose any firm optimality conditions. We find this advantageous for three other reasons.

One possible optimality condition to impose is optimal zone assignment; we would look at deviations in zone choice as a source of identification. However, this is a difficult problem, and it seems unreasonable to assume that firms (as well as researchers) have solved it. The zone assignment problem outlined in Section 3.2 is a high dimensional object, on the order of 2^{4000}, applied to Home Depot and Lowe's for national drywall pricing. Looking only at the Intermountain West yields a problem of dimension 2^{128}.

Because of the dimensionality of the firms' problems, we cannot impose condition (2) of the definition of the equilibrium. Instead, we will consider a few alternative zone structures.

Marginal costs may also be recovered without assuming optimal zone assignment, but by assuming optimal pricing, conditional on observed zones. We are also hesitant to impose this condition because of the pattern of prices we see in the data. The national pricing maps in Figure 1 and Figure 2 show that sharp boundaries sometimes separate two zones with very different prices. It is difficult to imagine that costs vary substantially within small geographic areas within states. A likely explanation is that pricing is impacted by forces not captured in the model. For example, we know that the government can freeze prices in areas that have been declared disaster areas. If these price freezes persist, then prices will not reflect what the firm would like to charge. Another likely explanation is that retailers use pricing algorithms or heuristics to determine prices. It is unclear how close heuristics are to optimal prices.

Our final reason for not imposing optimal pricing to recover marginal costs is a dimensionality problem. By assuming market pricing, as is typical in the industrial organization literature, there is a one-to-one relationship between optimality conditions and marginal costs. That is, the number of first-order conditions (FOC) is the same as the number of unknowns. By assuming that firms choose zone prices, we no longer have such a relationship. Instead, the number of unknowns is much larger than the number of optimality conditions – each product-zone FOC relates to the number of store-product cost terms within the zone. To make further progress, restrictive assumptions would need to be placed on the cost structure.[21]

We see not imposing optimal firm behavior as an advantage, in that it allows us to compare observed pricing with equilibrium zone prices. To find equilibrium zone prices

[21] A previous version of this paper imposed those conditions. What is required is that the unobservable in the cost equation varies by zone, but not by store. The problem can then be solved using mathematical programming with equilibrium constraints (MPEC), as shown in Su and Judd (2012).

(or any subgame equilibrium), we sequentially solve the best-response functions of the firms, fixing zones, until convergence. Figure 7 plots a histogram of percent differences between observed prices and equilibrium prices. We find observed prices to be, on average, 9.1% lower than optimal. The histogram shows that some prices are too high, by at most 19.8%, but some prices are too low, by up to 109.4%. This may seem problematic; however, the highest equilibrium price is still less than the highest price observed in the national data, by $2.70 or 12.1%. Further, the products that see large price increases do not drive our main results; they account for only 0.96% of total chain profits. For data confidentiality reasons, we cannot report firms' average markups, but markups on individual products range from -5% to 39% with observed prices and from 16% to 64% with equilibrium zone prices. The means are similar.

Before turning to counterfactual analyses of the estimated model, we report additional statistics on profits for the retailers. Table 5 calculates profits by chain and market type under both observed and equilibrium prices. The most important finding is that the percent of profits attributed to either firm in duopoly and monopoly markets does not change under equilibrium or observed prices. This mitigates the concern that the price outliers in Figure 7 determine much of firm profit. Next, we find that a larger percentage of firm profit comes from stores located in Home Depot monopoly markets. This makes sense, as in our sample, Lowe's has 17 fewer monopoly stores than Home Depot. Finally, we note that profits are quite a bit higher under equilibrium zone prices than under observed pricing (40% for Lowe's and 20% for Home Depot).

5 Alternative Pricing Regimes

With our estimated model, we can calculate the equilibria that would result if chains partitioned their stores into different pricing zones. Each set of partitions brings a different Bertrand-Nash pricing game. There are millions of zone combinations, so we explore only the nine subgames that follow from chains selecting their current zone structures, moving

to market-level pricing, or moving to uniform prices for their stores in our region of study. The solutions to these nine pricing games are equilibria for their various second-stage subgames described in Section 3.

Comparing the subgames reveals how the observed zones soften competition in competitive markets and protect consumers in other markets. The profits from the various subgame equilibria are payoffs in the first-stage game, in which chains select their zone structures. We first compare equilibrium prices in each subgame in Section 5.1, and then discuss profits and consumer welfare in Section 5.2. We discuss the Nash equilibrium of the two-stage game in Section 5.3. In Section 5.4, we describe how omitting equilibrium consideration produces inflated estimates of the gains from finer pricing. Finally, we investigate store pricing in Section 5.5.

For notational purposes, we label the subgames by the pair of pricing regimes that chains select, with Lowe's strategies listed first. For example, the (zone, market) denotes the subgame in which Lowe's uses its current observed zones and Home Depot uses market-level pricing.

5.1 Subgame Equilibrium Prices

We first consider the (zone, market) subgame, in which Lowe's retains its observed zone structure, but Home Depot switches to setting prices market-by-market. As with all the subgames considered, prices are optimal given the specified pricing structure. Relative to the equilibrium in the (zone, zone) subgame, prices at Home Depot are lower in 83% of markets where it competes with Lowe's and higher in 85% of markets where Lowe's is absent.[22] The equilibrium price under zone pricing is a compromise between markets where a high price would be most profitable and markets where a low price would be most profitable. Because the pricing zones tie prices in monopoly markets with prices in competitive markets, monopoly power is not fully exercised.

[22]In Home Depot's monopoly markets, 15% of prices decrease in Home Depot's move to market-level pricing. These prices are in zones where most of the stores are in monopoly markets.

With market-level pricing, however, the price in monopoly markets is not constrained by the need to keep customers in a distant, competitive market. Prices in Home Depot's monopoly markets are 27% higher, on average, than in the (zone, zone) equilibrium. In markets with both chains, Home Depot's prices are 3.7% lower and Lowe's prices are 1.6% lower than in the (zone, zone) equilibrium. To respond to a lower competitor price in this subgame, Lowe's must lower prices throughout its zone. The profits from preserving its high prices in its monopoly markets dull the incentives to reciprocate on price decreases.

Market-level pricing affords chains the flexibility to post higher prices in places with higher costs or with higher demand. Transportation costs do differ by store, and costs vary considerably between markets within some zones. The demand model assigns the same price sensitivity to all consumers, but demands differ across markets because of market fixed effects and locally because of product-store (unobserved) quality. Yet market power considerations have a more noticeable impact on prices. Among all non-mold-resistant panels, for example, the lowest (zone, market) equilibrium price in a Home Depot monopoly market is still higher than at any Home Depot store in a market with a Lowe's store.

Next, we consider the (market, zone) subgame, in which Lowe's uses market-level pricing, and Home Depot uses its observed zones. We find that the subgame equilibrium prices follow a pattern similar to that of the previous exercise. Lowe's raises prices in all of its monopoly markets and generally lowers prices elsewhere. Equilibrium prices increase by 57% in Lowe's monopoly markets. In markets where it competes with Home Depot, Lowe's equilibrium prices in this subgame are lower for 67% of products, and its average price is only 2% less than in the (zone, zone) subgame.

The (market, market) subgame also has lower prices in competitive markets and higher prices in both chains' monopoly markets. Chains continue to use the monopoly price in their monopoly markets. Home Depot's prices are the same as in the other subgame, in which it uses market-level pricing; likewise for Lowe's. In markets where the two

chains compete, prices are still lower than in any of the other subgames. In the previous subgames, the chain with zone pricing moderated its response to its competitor's price cuts in order to maintain profits in its monopoly markets. In market-level pricing, each firm's best response is more sensitive to its competitor's price, and the equilibrium prices are, therefore, lower. Average prices in duopoly markets are 2.5% lower than in the (market, zone) subgame, 1.1% percentage points lower than in the (zone, market) subgame, and 3.8% lower than in the (zone, zone) subgame. Prices for particular products are also more dispersed in the (market, market) subgame, as differences in costs and market power are not averaged out within a zone.

Figure 8 shows a histogram of price differences between the (market, market) and (zone, zone) subgames. Monopoly stores and duopoly stores have separate histogram bars. A few duopoly prices are much lower in the (market, market) subgame, but most price changes are within a few percentage points of the average, -3.8%. The average price change for monopoly markets is 27% for Home Depot and 57% for Lowe's, just as in the other subgames. Some prices in monopoly markets are nearly the same in the two subgames; these are for products in small zones comprised mostly of other monopoly markets. Other monopoly prices are 60% to 80% higher in (market, market) pricing, depending on local costs, local demand, and what margins the zone price already includes.

Finally, we examine the pricing in the subgames in which at least one firm uses uniform pricing. Several of Home Depot's zones comprise mostly monopoly markets. The difference between zone and uniform pricing is, therefore, much like the difference between market and zone pricing, in that it ties the prices in monopoly markets to prices in a much larger set of markets with competition. In Home Depot's zone with mostly monopoly markets, prices are lower in subgames in which they use uniform pricing; elsewhere, uniform pricing produces higher prices. Lowe's has fewer monopoly markets, and most of them are in large zones dominated by competitive markets. For Lowe's, uniform prices are similar to equilibrium zone prices. The average price in the (uniform, uniform) subgame

is only 0.6% higher than in the (zone, zone) pricing subgame. The uniform prices that a firm chooses depend on its competitor's prices and pricing schemes, but the response is small. Lowe's prices are $0.11/sheet lower in the (uniform, zone) subgame than in the (uniform, uniform) subgame and are $0.18 lower in the (uniform, market) subgame. Home Depot's equilibrium prices are $0.03/sheet lower in the (zone, uniform) subgame than in the (uniform, uniform) subgame and are a $0.12 lower in the (market, uniform).

5.2 Subgame Equilibrium Profits and Consumer Surplus

Having examined prices, we now turn to firm profits and consumer welfare. The profits earned in each of the subgame exercises are shown in Table 6. Each entry reports annualized profits for Lowe's and Home Depot, respectively. Profits are only for the 128 stores in the Intermountain West, which comprise 3% of the chains' total networks. The payoff matrix reveals that market-level pricing is the dominant strategy for both chains in the first-stage game, which we discuss further in the next subsection. Finer pricing increases a chain's own profit as it takes greater advantage of its monopoly stores. At the same time, finer pricing decreases its competitor's profit as it brings lower equilibrium prices to competitive markets. If Lowe's continues in its current zones but adjusts prices, Home Depot's profits increase with finer pricing, from $4.369 million/year in (zone, uniform) to $4.458 million/year in (zone, zone) to $4.724 million/year in (zone, market). As Home Depot uses finer pricing, Lowe's profits decrease from $2.310 million/year in (zone, uniform) to $2.225 million/year in (zone, zone) to $2.014 million/year in (zone, market). Lowe's gains and Home Depot loses as Lowe's moves from uniform to zone to market-level pricing, but the gains from finer pricing are larger for Home Depot because it has more stores in monopoly markets.[23]

A move from the current (zone, zone) structure to a (market, market) regime would increase industry profits, but it would decrease Lowe's profits. Lowe's earns $2.095

[23]There is one exception to this pattern. Lowe's profits are slightly higher ($2.312 million/year versus $2.310 million/year) in the (uniform, uniform) subgame than in the (zone, uniform) subgame.

million/year in the (market, market) equilibrium, which is \$0.130 million/year less than in the (zone, zone) equilibrium. Lowe's losses are smaller than Home Depot's gains of \$0.170 million/year, as its profits increase from \$4.458 million/year in (zone, zone) to \$4.628 million/year in (market, market).

One of the key drivers of the the asymmetry in profit changes is the difference in the number of monopoly stores across firms. For both firms, profits in competitive markets are lower in the (market, market) than in the (zone, zone) equilibrium. For Lowe's the difference is \$0.220 million/year, for Home Depot it is \$0.135 million/year. Home Depot has 21 monopoly markets, in them profits are \$0.304 million/year higher in (market, market) than in (zone, zone) equilibrium. Thus, profits increase overall for Home Depot when both chains move to finer pricing. In contrast, Lowe's only has four monopoly markets and these stores increase profits by only \$0.091 million/year. Lowe's total profits are lower in the (market, market) subgame as the benefits of monopoly pricing for only a few stores does not outweigh the profit declines where the firm competes with Home Depot.

Given the specified demand system, consumer surplus for a particular market can be calculated as

$$CS_\ell = \frac{M_\ell}{\alpha} \log\left(1 + \sum_{c \in C}\left(\sum_{j \in c} \exp\left\{\frac{\delta_{js}}{1-\lambda}\right\}\right)^{1-\lambda}\right),$$

where, implicitly, we sum over only the relevant store-products for the particular market. Aggregate consumer surplus is simply $CS = \sum_\ell CS_\ell$. Table 7 reports consumer surplus differences between the (zone, zone) equilibrium and the (uniform, uniform) and (market, market) subgame equilibria. Relative to (zone, zone), consumer surplus is \$0.639 million/year lower in the (market, market) subgame. Consumers in markets served by only one chain are exposed to monopoly prices under market-level pricing, and their consumer surplus is \$1.245 million/year lower because of this. Prices generally are lower in market-level pricing in duopoly markets, and so consumers in duopoly markets have a surplus that is \$0.605 million/year higher. Hence, the net decrease in consumer welfare

from finer price discrimination is roughly one third the aggregate change. Consumers in monopoly markets lose more surplus than the combined amount of consumer surplus gains elsewhere and the profit gains to retailers. This is especially remarkable since monopoly markets are each small and there are fewer of them. The per capita effect in these monopoly markets is considerable. The main effect of zone pricing, thus, is to increase welfare by protecting consumers in monopoly markets from retailers exercising their market power.

A move to uniform pricing would have similar but smaller effects. Consumer surplus is \$0.130 million/year higher in (uniform, uniform), a result that nets a larger transfer from duopoly markets to monopoly markets. Consumer surplus is \$0.345 million/year higher in monopoly markets and \$0.215 million/year lower in duopoly markets. Consumer surplus changes are again larger and in the opposite direction from combined retailer profit changes.

5.3 Nash Equilibrium of the Two-Stage Game and Menu Costs

We find market-level pricing to be a dominant strategy, but we observe chains using pricing zones. The cost of maintaining a market-level system could explain why the chains do not pursue the apparently more profitable strategy. If market-level pricing costs Home Depot at least \$0.280 million/year more to implement than zone pricing, and if market-level pricing costs Lowe's at least an additional \$0.061 million, then both chains using zone pricing is an equilibrium of the first-stage game. Such costs could arise from the managerial effort needed to set thousands of prices or from the changes to the technical infrastructure needed to process fine pricing. Levy *et al.* (1997) and Zbaracki *et al.* (2004) document the high cost of price setting in some firms. In macroeconomics, menu costs often are thought to cause price rigidity and departures from what the equilibrium prices would be without such frictions. The spatial price rigidity of pricing zones could result from similar considerations.

5.4 Abstracting from Competitive Interaction

In the previous sections, we analyzed subgame equilibrium prices so a chain's prices reflected the competitor's pricing regime and pricing choices. Ignoring the competitive response would overestimate the gains from finer pricing. We present an exercise in which one chain moves from zone to market-level pricing, while its competitor's zone structure and all prices are kept fixed. This exercise is most similar to the previous literature on zone pricing, which was forced to abstract from the competitive interaction due to data restrictions.

Table 8 compares the profit from this deviation, holding competitor prices fixed with subgame equilibrium profits. Moving from the (zone, zone) equilibrium to the (zone, market) equilibrium would increase Lowe's profit from $2.225 million/year to $2.291 million/year, a gain of $66 thousand/year. If Home Depot's prices were fixed, then, when moving from zone pricing to market-level pricing, Lowe's still raises its prices in monopoly markets, but it also could undercut Home Depot in markets where they compete without provoking a response. Lowe's profits would be $2.338 million/year, an increase of $113 thousand/year over the zone-zone equilibrium. While these changes seem small, recall that our analysis focuses on a small subset (<.05%) of total products over a small proportion (3%) of the chain networks.

In percentage terms, the overstatements are large. For Lowe's, abstracting from Home Depot's response exaggerates the gains from finer pricing by 71.21%. If Lowe's prices were held fixed, then Home Depot's gains from moving to market-level pricing would be 36.47% higher than if Lowe's adjusted its zone prices. Accounting for the competitive interaction greatly reduces the incentive to adjust pricing zones.

5.5 Store-Owner Pricing and an Agency Problem

Some retailers, at least historically, have given local store managers the autonomy to determine prices and assortments. The idea is that local managers may have specialized

knowledge about local market conditions, and their expertise could increase profits for the retailer. On the other hand, with advances in data collection, processing, and analysis, centralizing pricing may offer no loss in terms of revenue, but may allow chains to either decrease labor costs or have local managers focus on other necessary roles.

In this exercise, we simulate store prices and profits if both chains were to decentralize pricing. Specifically, we have each store maximize individual store profits. This would most closely mimic an incentive scheme whereby store managers are rewarded for individual store performance and not overall chain performance. Since managers care only about store profits, this creates a classic principal-agent problem, and store managers now compete for sales with other chain stores located in the same market.

Figure 9 summarizes this exercise and compares it to the results of the previous exercises. It shows average store performance, as measured by two-week profits, for three scenarios. The first panel corresponds to the (zone, zone) subgame. The second panel corresponds to the (market, market) subgame. Finally, the third panel corresponds to the store-owner exercise. For each plot, the horizontal axis corresponds to the average product price at the store and the vertical axis yields store profits. Since our sample contains 128 stores, each panel contains 128 markers (circles or triangles), separated by chain and market structure (triangle is monopoly; circle is duopoly). Color denotes the chain.

The first panel shows that there are several Home Depot monopoly stores in their own zones, so while most of the dots are centered around $12, a few are closer to $18. When chains move to market pricing, all monopoly stores that were originally a part of larger zones are free to exercise their monopoly power. This causes every monopoly store (all triangles) to increase price. As discussed in Section 5.1, the stores in duopoly markets now compete more fiercely. In the figure, the average duopoly store (denoted by circles) decreases price, and profits dip slightly.

The final panel in Figure 9 shows the consequences of moving to store-owner pricing. None of the monopoly stores adjusts price, as there are no monopoly markets where a

chain has two stores in the sample. This means that all changes occur in duopoly markets. There is a significant increase in price dispersion across stores, much more so than when moving from zone to market pricing. There is considerable movement to the left, as the average price drops by almost 9.6%. There is also considerable movement downwards, as the increase in competition due to the agency problem leads to a significant decline in profits. Compared to market pricing, store-owner pricing reduces total profits in markets where other chain stores are present by 23.1% and 32.5%, for Home Depot and Lowe's, respectively.[24] These stores make up a large proportion of the sample, so looking at the overall impact – including stores that see no profit changes – the aggregate decline in industry profits is 13.1%.

6 Conclusion

In this article, we estimate the welfare effects of zone pricing in retail oligopoly. To perform this analysis, we collect novel price and quantity data for the major home improvement retailers, which assign constant prices across large geographically contiguous areas. Pricing zones combine markets that differ in substantial ways, including market structure and costs. We use the data to estimate an empirical model of zone pricing under competition. With our estimates, we calculate the subgame perfect equilibria of different pricing structures, such as a move to a uniform price or further price discrimination to market-level pricing.

Our results highlight the importance of accounting for the competitive interaction in retail pricing. We find that industry profits are higher under both uniform pricing and market pricing, compared to the observed zones. More importantly, our analysis sheds light on which consumer groups are most affected by zone pricing in oligopoly. We find that zone pricing shields consumers in monopoly markets from facing high prices but,

[24] We have also calculated this comparison using optimal store pricing, with centralized pricing. The results are similar to those for the market pricing exercise.

consequently, raises prices in markets where firms compete. The asymmetric price effects of moving to finer pricing result in a transfer of consumer surplus across markets, so the net effect is one third the absolute effect.

Although we bring in new data in order to quantify the welfare effects, both the methodology and data have limitations. As we do not have individual purchase data, we abstract from features that may be important in retailing, such as consumer transportation costs. The selected product category has the benefit of known and differential costs across stores, but the products are not highly differentiated. Hence, the welfare effects of zone pricing in other retail sectors is unclear. Moreover, online versus offline competition is important to much of retailing. We can abstract from it for drywall, but it is likely an important force in other categories.

Finally, we take the choice of zones as exogenous. An exciting area for future research is to examine the origin of pricing zones, as well as why zones differ substantially across categories and firms. This could reflect differences in the competitive landscape, dictated by costs, demand, or contract negotiation. Another possible explanation is managerial ability. Whatever the causes of zone pricing, the consequences include welfare transfers and mitigation of monopoly power.

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7 Appendix

Table 1: Mean and median number of prices for products.

Category	**Home Depot**		**Lowe's**		**Menards**	
	Mean	Median	Mean	Median	Mean	Median
Drywall	46.45	50	37.19	32	24.27	26
Insulation Panels	14.48	7	22.50	22	16.53	19
LED Light Bulbs	6.23	4	3.02	3	1.62	2
Mosaic Glass Tile	2.08	1	1.66	1	2.07	2
Phillips Screwdrivers	4.93	5	1.31	1	1.01	1
Plywood	5.44	1	23.65	21	5.19	4
Roof Underlayment	33.82	32	52.14	38	10.15	3
Sanders	3.30	3	1.31	1	1.50	1
Stone Pavers	8.65	2	12.43	2	6.00	2
Window Film	2.10	1.5	4.53	2	3.42	3

Notes: Mean and median number of prices per product, weighted by store presence. Number of observations per category (in order): 71,360, 49,203, 114,576, 83,698, 100,872, 130,466, 24,048, 96,959, 65,477, 64,839; total: 801,498.

Table 2: Example documenting differences in costs and competition within a zone.

	Home Depot Stores		
	Logan, UT	Rock Springs, WY	Elko, NV
Drywall Prices			
mold-resistant 8'x4'x1/2"	$11.47	$11.47	$11.47
regular 8'x4'x5/8"	$10.98	$10.98	$10.98
Distances (miles)			
Nearest Lowe's	1	107	168
Nearest American Gypsum factory	743	821	491
Home Depot Distribution Center	58	177	251

Notes: Reported distances are closest distances to drywall factory and flatbed distribution center.

Table 3: Summary statistics for the sample

Means	Lowe's	Home Depot
Sales (per product, per day)	11.61 (38.22)	14.69 (28.80)
Delivery size (per product)	298.80 (361.75)	272.63 (263.91)
# Products (per store)	3.28 (0.45)	3.05 (0.32)
Revenue (per store, per day)	$381.12 (335.90)	$443.25 (189.40)
Price (per product)	$11.78 (2.08)	$11.82 (2.10)
Observations	31,333	40,759

Notes: Summary statistics for all 4'x8'x1/2", 4'x10'x1/2", and 4'x12'x1/2" drywall sheets at 128 Home Depot and Lowe's stores.

Table 4: Demand estimation results

	(1) Logit	(2) IV Logit
Price	-0.169***	-0.102***
	(0.0333)	(0.0176)
Home Depot	0.465***	0.0847**
	(0.0262)	(0.0270)
Mold resistance	-1.332***	-1.672***
	(0.116)	(0.0659)
𝕀(length = 10)	-1.787***	-0.155
	(0.124)	(0.114)
𝕀(length = 12)	-1.451***	0.0588
	(0.159)	(0.108)
λ		0.813***
		(0.0579)
Market indicators	Yes	Yes
Mean product elas.	-1.963	-5.094
(s.d.)	(0.369)	(2.031)
Observations	5,078	5,078

Robust standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Zone Pricing Profits By Chain and Market Type

equilibrium	Lowe's		Home Depot	
(observed)	% of π	Profits	% of π	Profits
Monopoly	7.35%	0.163	27.56%	1.229
	(7.96%)	(0.122)	(24.75%)	(0.893)
Duopoly	92.65%	2.061	72.44%	3.229
	(92.04%)	(1.411)	(75.25%)	(2.715)
π - equilibrium		2,224,750		4,458,117
π - observed		1,532,585		3,607,718

Notes: Duopoly means that there is a competitor's store in the market (CSBA). Profits are annualized. Numbers in parentheses are with observed prices and others are calculated with equilibrium zone prices.

Table 6: Payoff Matrix of the Two-Stage Pricing Game

Lowe's / Home Depot	Uniform Pricing	Zone Pricing	Market Pricing
Uniform Pricing	2.312 , 4.391	2.219 , 4.469	2.007 , 4.733
Zone Pricing	2.310 , 4.369	2.225 , 4.458	2.014 , 4.724
Market Pricing	2.373 , 4.246	2.291 , 4.34	2.095 , 4.628

Notes: Profits are annualized and reported as millions of dollars.

Table 7: Consumer Surplus and Profit Changes

	Uniform Pricing		**Market Pricing**	
	CS	Profit	CS	Profit
Monopoly Markets	345,158	-104,550	-1,245,332	395,345
Duopoly Markets	-215,281	124,920	605,621	-355,264
ΔSurplus	129,878	20,370	-639,712	40,081
Total ΔWelfare	150,248		-599,631	

Notes: Consumer surplus and profit changes are annualized. Numbers in left two columns are differences between equilibrium values in the (uniform, uniform) and (zone, zone) subgames. Numbers in the right two columns are differences between the (market, market) and (zone, zone) subgames.

Table 8: Profits Under Deviations to Market Pricing

Firm / Strategy	Equilibrium ($\text{Zone}_i, \text{Zone}_{-i}$)	Deviation to Market_i	Equilibrium ($\text{Market}_i, \text{Zone}_{-i}$)	Profit Overstatement
i =Lowe's	2.225	2.338	2.291	71.21%
i =Home Depot	4.458	4.821	4.724	36.47%

Notes: Profits are annualized and reported as millions of dollars. Deviation profits are found by fixing $-i$'s prices to equilibrium zone and then solving for i's optimal market prices.

Figure 1: Map of prices for Lowe's 4′ x 8′ x 5/8" non-mold-resistant drywall.

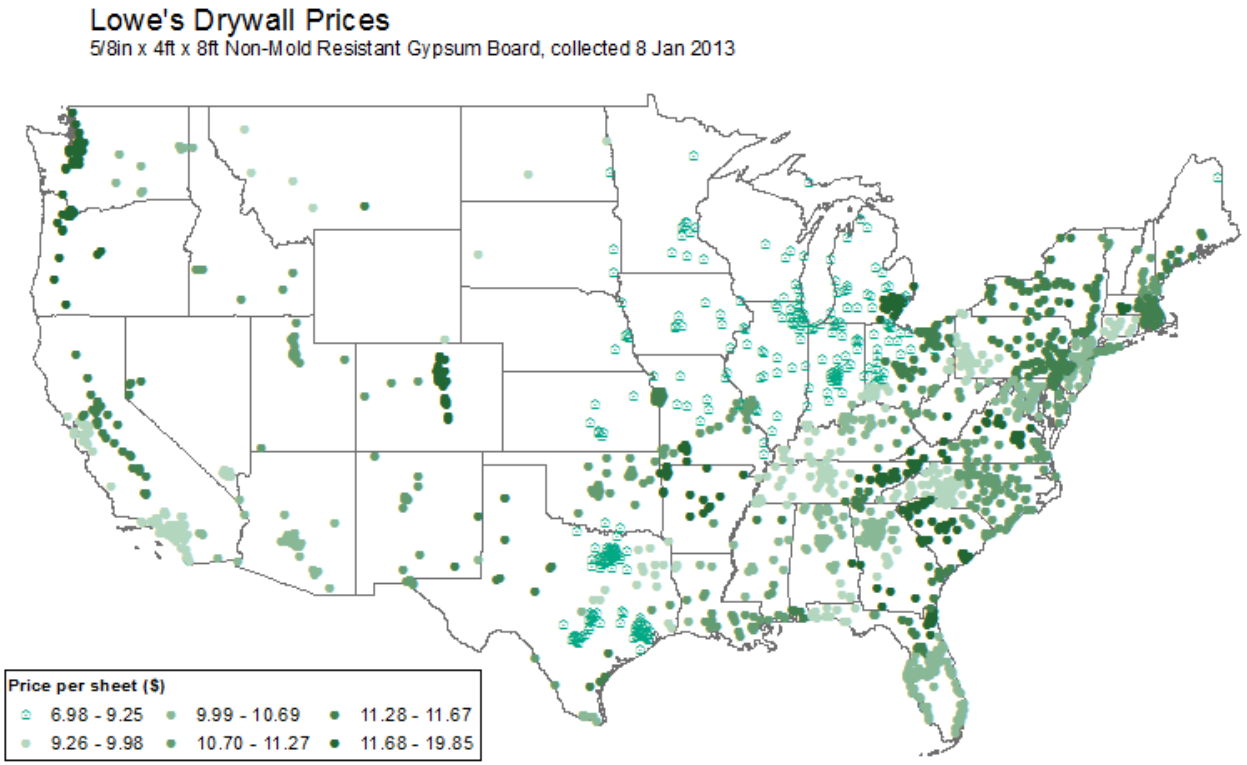


Figure 2: Map of prices for Home Depot 4′ x 8′ x 1/2" mold-resistant drywall.

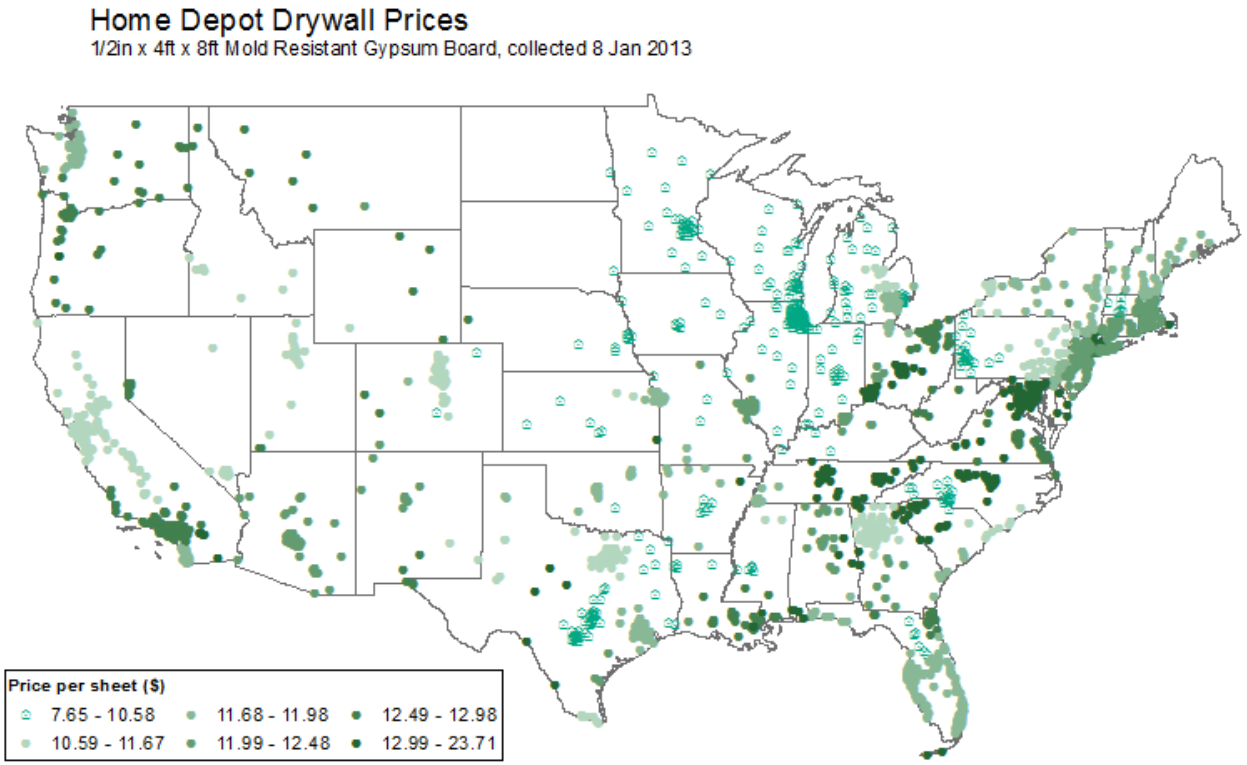


Figure 3: Map of unique prices for Home Depot 4′ x 8′ x 1/2" non-mold-resistant drywall.

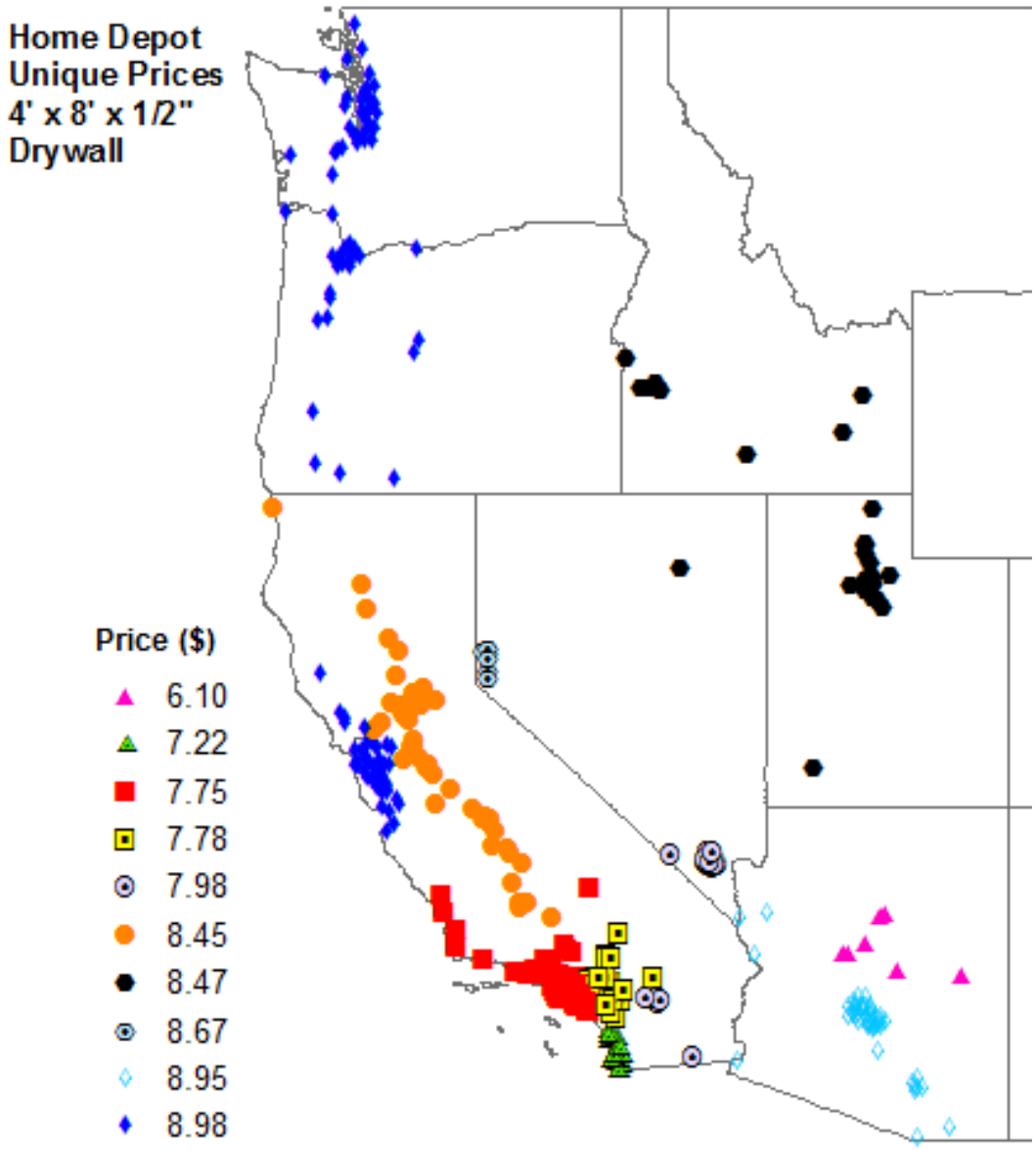


Figure 4: Map of prices for Menards Cement Block, Model 1796300.

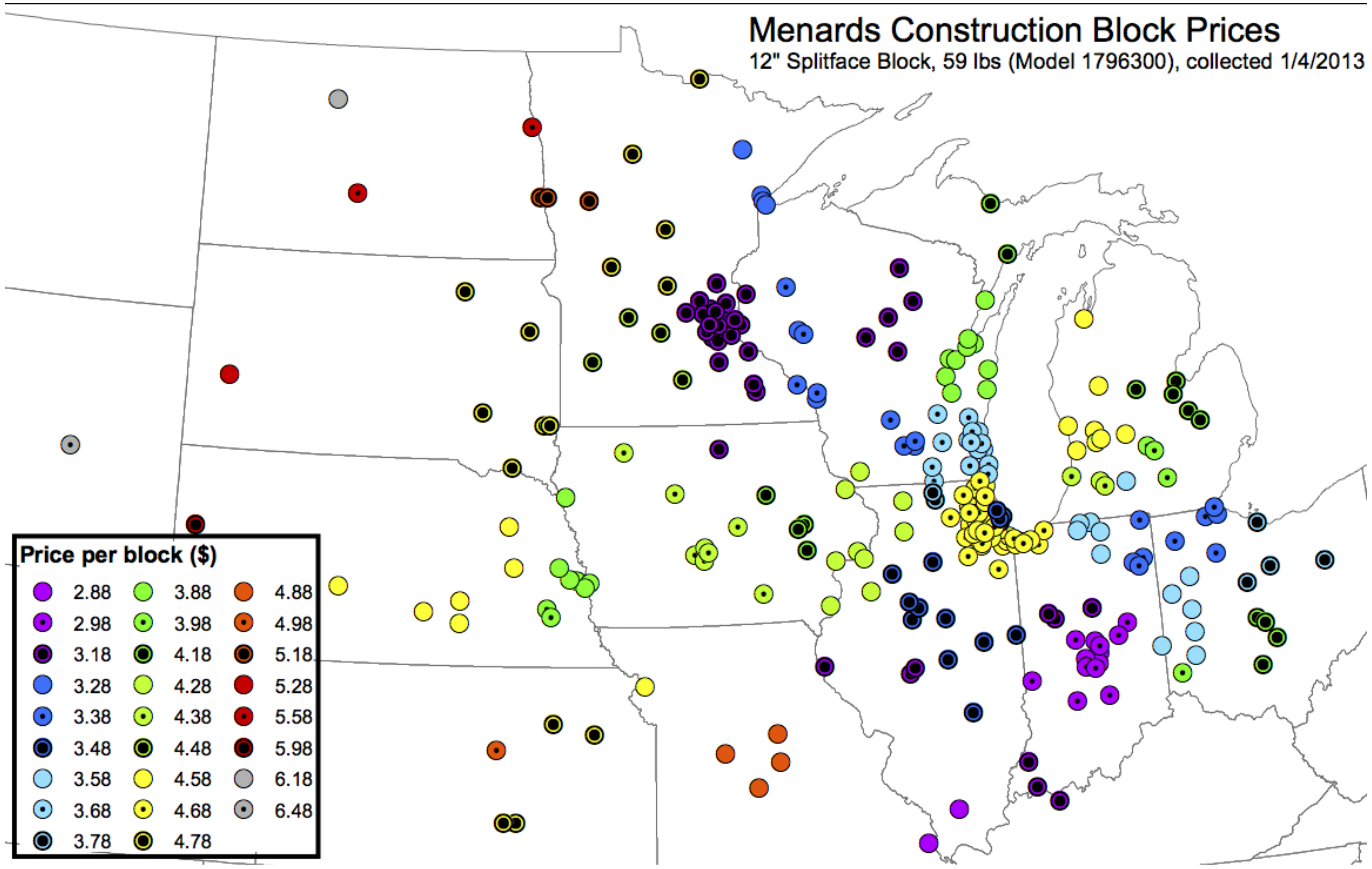


Figure 5: Obtaining product inventories from HomeDepot.com.

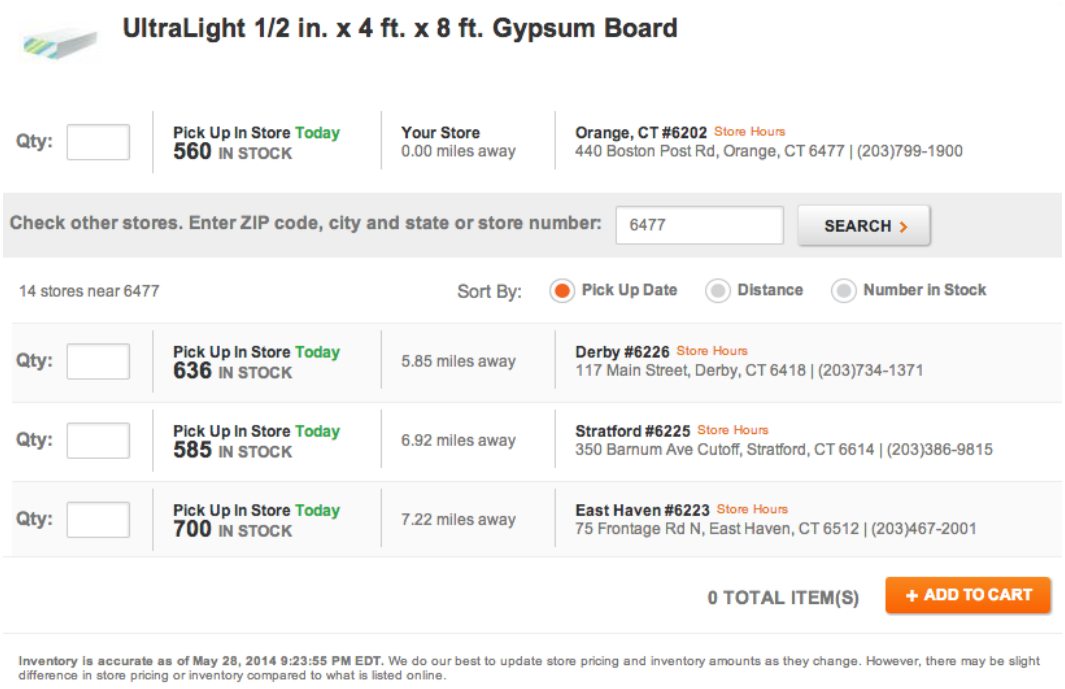


Figure 6: Stores selected for empirical analysis.

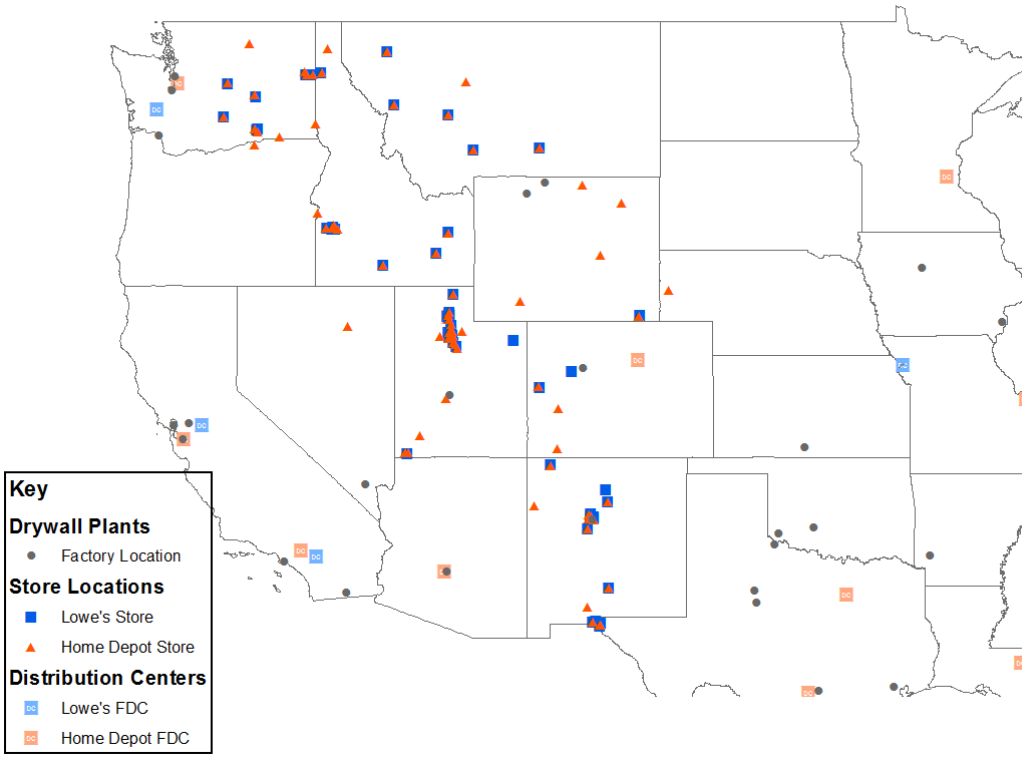


Figure 7: Histogram of differences in equilibrium zone prices with observed zone prices, as percentage

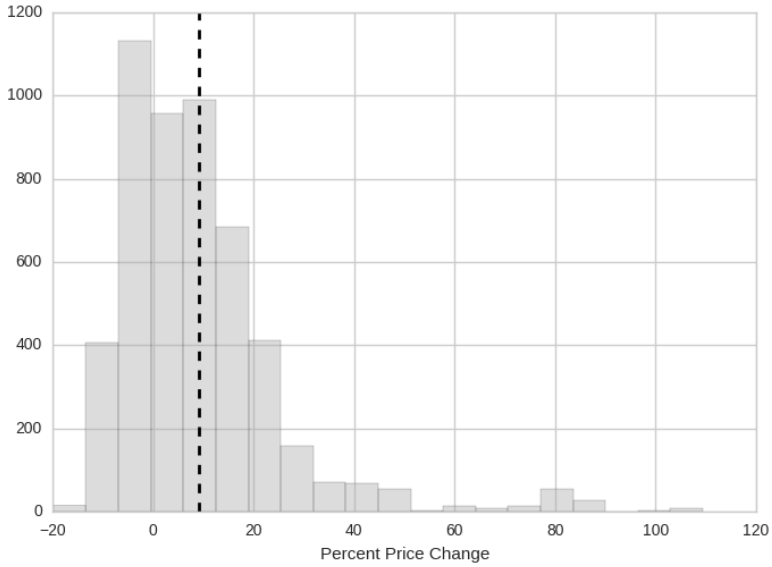


Figure 8: Histogram of differences in equilibrium zone prices with equilibrium market pricing, as percentage

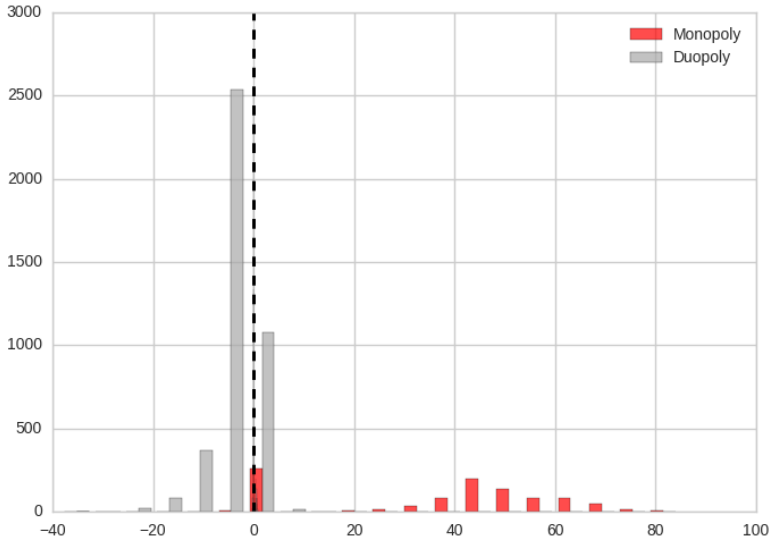
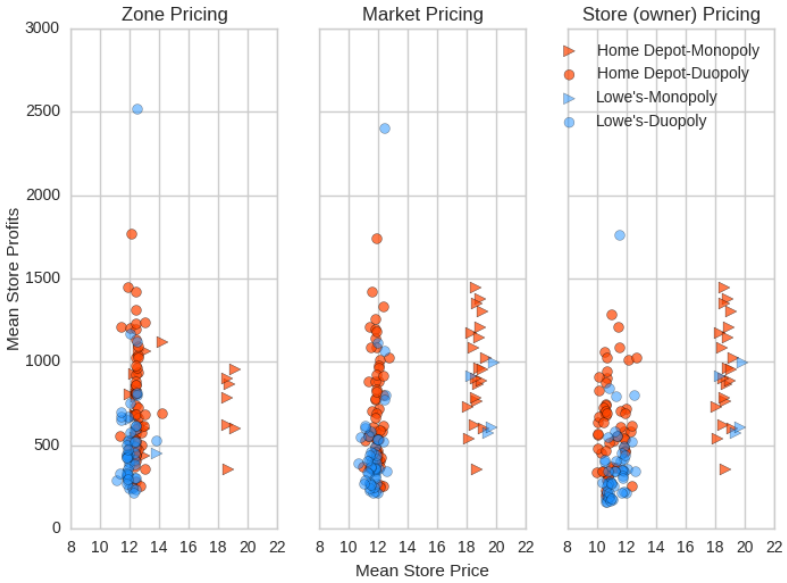


Figure 9: Comparison of counterfactual prices and profits across stores



Notes: Results reported per store, averaged over time. Colors and shapes correspond to chain and market structure, respectively.