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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 rural markets, where firms might otherwise exercise market power. Overall, zone pricing produces higher consumer surplus than finer price discrimination does.

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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, the theoretical literature has shown that price discrimination has an ambiguous effect on both profits and consumer welfare (Thisse and Vives 1988, Holmes 1989, Corts 1998, Dobson and Waterson 2005, Stole 2007).

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. The existing literature on zone pricing has found the potential for large gains in profit by adopting finer pricing; however, due to data limitations, these papers had to abstract from the competitive interaction of firms. The aforementioned theory literature suggests that this abstraction may even yield the incorrect sign on profit and consumer surplus changes when firms price discriminate.

Examples abound of firms segmenting markets based on geography, including grocers (Montgomery 1997, Allain et al. 2017, Eizenberg et al. 2018), online retailers (Seim and Sinkinson 2016),[1] and movie theaters (Dubé et al. 2017). However, little is known regarding how segmenting markets affects both consumers and firms in retail oligopoly.[2] We find that further price discrimination through finer zones exposes some, mostly rural, markets

[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).

to much higher prices, as firms are more able to exercise monopoly power. Finer pricing decreases most prices in larger competitive markets. Consequently, the existing pricing zones shield rural consumers from high prices at the expense of slightly higher prices in urban markets. Strategic complementarity amplifies the price effects in competitive markets, and so ignoring competitive interaction overstates profit gains from finer pricing and understates the extent that zone pricing causes urban to rural surplus transfers. Our results also reveal an asymmetry, as a move by both firms towards finer pricing decreases profits for one chain but increases profits for the other.

We begin by documenting the pricing strategies used by the major home improvement retailers by collecting store-level prices using the retailers' websites. 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 product categories. Some products are uniformly priced, a fact recently documented broadly across retailers (DellaVigna and Gentzkow 2017, Hitsch, Hortacsu, and Xiliang 2017). However, we show 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] Although we cannot disentangle all the motives for designing such a pricing system, we can analyze its impact on firms and consumers.

Next, we create a panel data set of daily prices and sales, which we collect by tracking the firms' daily inventory for drywall products at specific stores. 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

[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.

are used to estimate an empirical model with competition. On the supply side, retailers must use the same price for all stores within predetermined zones. They simultaneously set zone prices for every product. They face store-specific costs, which we derive directly from wholesale prices and transportation costs. For demand, we estimate a nested logit model (Berry 1994), which incorporates preferences for product characteristics and price. We find drywall products to be highly substitutable, which is not surprising because they are not highly differentiated. Our cost data allow us to compare observed prices with calculated equilibrium prices. We find that observed prices are near, but lower than, optimal prices.

Our main analysis comes from calculating equilibria under different zone structures. We consider all combinations of constraining firms to use uniform pricing, use their observed zones, and use market pricing. For each scenario, we calculate equilibrium prices, profits, and consumer welfare. Our analysis yields two main sets of findings.

First, we find market pricing would greatly alter prices and consumer surplus in some markets. As is standard in third-degree price discrimination, we find that finer zones brings higher prices to segments where a firm's residual demand is more inelastic. Here, those segments are mostly rural markets where only one chain is present. Finer pricing decreases most prices in larger competitive markets. Thus, zone pricing yields clear winners and losers that mostly follow urban-rural divide. Finer pricing lowers consumer surplus in noncompetitive, rural markets by $1.5 million annually while increasing consumer surplus in competitive, mainly urban markets by $0.6 million annually. Because these markets have fewer consumers, the per capita impact of zone pricing is ten times greater in monopoly markets. Hence, zone pricing shields mostly rural consumers from high prices at the expense of slightly higher prices in large urban markets.

Our second finding is that there exists an asymmetry across the two chains. Lowe's would benefit from both chains moving to coarser pricing (4.9% higher profits), and Home Depot would benefit if both chains moved to finer pricing (8.4% higher profits). This result is driven by the relatively large number of monopoly stores Home Depot has in this part of the United States. For Home Depot, softening competition through uniform pricing does not outweigh the benefits from exercising market power – a possibility theorized in (Dobson and Waterson 2005). For Lowe's, the opposite is true. However, when we hold the competitor's pricing system fixed, but allow prices to update, we find each firm always do better under finer pricing. As the theoretical literature has shown, this is not guaranteed.

In further 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 an experiment in which one chain switches to market pricing holding the competitor's prices fixed with the experiment where one firm chooses optimal market prices and the competitor optimal zone prices. In the first exercise, the firm lowers price to increase market share in most competitive markets. In the latter exercise, most prices in those markets decrease further due to strategic complementarity. Hence, abstracting from the competitive interaction understates price decreases in competitive markets and overstates the profit gains from price discrimination.

Lastly, we show how decentralizing pricing would affect chain profits. Some chains give local managers the autonomy to decide prices and product assortments. We decentralize pricing at Home Depot and Lowe's by having stores maximize their own profits. This leads to an agency problem, as local stores compete for sales from other allied stores (Brickley and Dark 1987). We find the agency problem in our setting to be large; a move from market pricing increases price dispersion (similar to the findings of Lafontaine (1999) for fast food franchising) and decreases total chain profits by 27-40% in markets where other chain stores are present. This may be the reason that our retailers centralize the firm's pricing activities.[4]

[4]Lafontaine and Shaw (2005) show that company ownership is positively associated with brand value. It may be that Home Depot and Lowe's have higher brand value as compared to the home improvement retailer

2 Data

Home improvement warehouses have grown to have revenues exceeding $130 billion dollars a year.[5] 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.[6] Home Depot and Lowe's are the fourth and eighth largest US retailers by revenue, respectively.[7]

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.[8]

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 of manufacturer, and availability at other local retailers and at online retailers. All of

Ace Hardware. This buyer cooperative has thousands of stores, but does not have centralized pricing.

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

[6]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.

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

[8]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.

these factors may affect the pricing of products. Because all the retailers offer hundreds of products in each category, to keep the collection process manageable, we randomly sample products within each category. In total, we obtain 801,498 prices between 2013 and 2014.

Product category managers working at corporate headquarters - not local managers - make pricing and assortment decisions.[9] Lowe's and Home Depot each have one pricing manager for all drywall products, for example.

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	21.51	24
Insulation	14.48	7	22.50	22	16.53	19
LED	6.23	4	3.02	3	1.62	1
Mosiac Glass Tile	2.08	1	1.66	1	2.07	2
Plywood	3.99	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
Screwdrivers	4.93	5	6.77	3	1.01	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, 130,466, 24,048, 96,959, 100,872, 65,477, 64,839; total: 801,498.

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.[10] For example, the second row corresponds to

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

[10] These statistics are weighted by the number of stores that carry the product. This addresses the fact that

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, consistent with the finding in DellaVigna and Gentzkow (2017) and Hitsch, Hortacsu, and Xiliang (2017) who document that most of the retail chains in the Neilsen Scanner Data utilize near uniform pricing. However, we also see that for some categories, 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.

The significant heterogeneity within and across categories is interesting. Some categories are readily available both online and at most retail stores, such as LED light bulbs, whereas others, such as drywall, are available at far fewer chains. In categories with more competitors providing close substitutes, we would expect a chain's residual demand to be more elastic and its gains from maintaining many zones to be smaller. In addition to possible demand rationales, Table 1 does show that big and bulky products, such as drywall and insulation, tend to have finer pricing than small products, such as screwdrivers and window film (plywood is the notable exception). As pricing is delegated to category managers, managerial ability may also play a role as we and DellaVigna and Gentzkow (2017) hypothesize. Later, we will focus on one of the most finely priced categories to examine the costs and profit gains brought by departures from their observed pricing regimes.

For many of of the categories, the distinct price points are far apart. To gauge the magnitude of price dispersion across stores, we calculate the coefficient of variation (CV).

some products are nationally stocked, and others have a regional presence. Excluding products that have only a small presence does not affect the results.

Across all products, the average is 0.039, and excluding uniformly priced products, 0.114.[11] 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 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, such as $6.98-$9.25 as the lowest bin. We plot price ranges instead of unique prices due to the sheer number of prices in the data – in this case, 79 prices. 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 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. These are some of the most finely priced products in the drywall category, as Table 1 shows, the average of 47 and 37 prices for Home Depot and Lowe's respectively.

Figure 3 maps prices for regular 4′ x 8′ x 1/2" drywall in the Western United States. This region is small enough that each unique price is displayed with a separate map symbol/color. 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.

[11] 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.

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

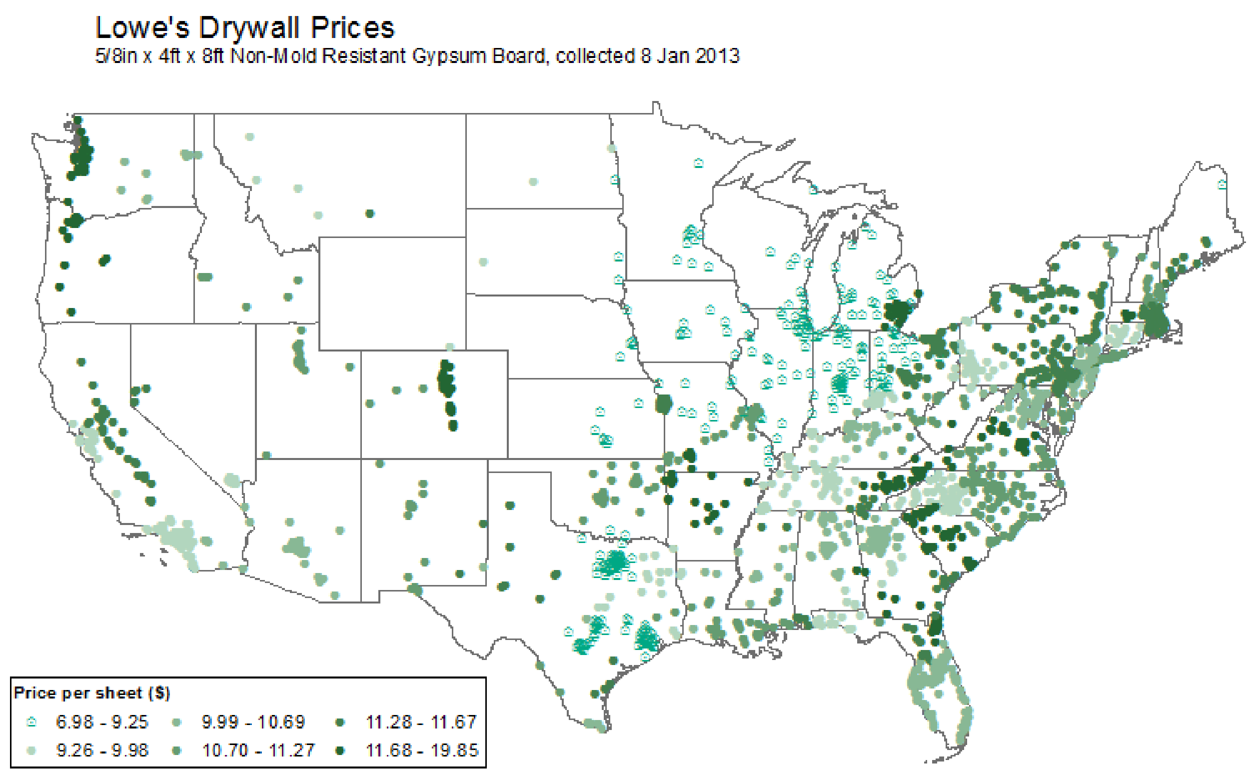


Figure 2: Map of prices for Home Depot 4′ x 8′ x 1/2" mold-resistant drywall.

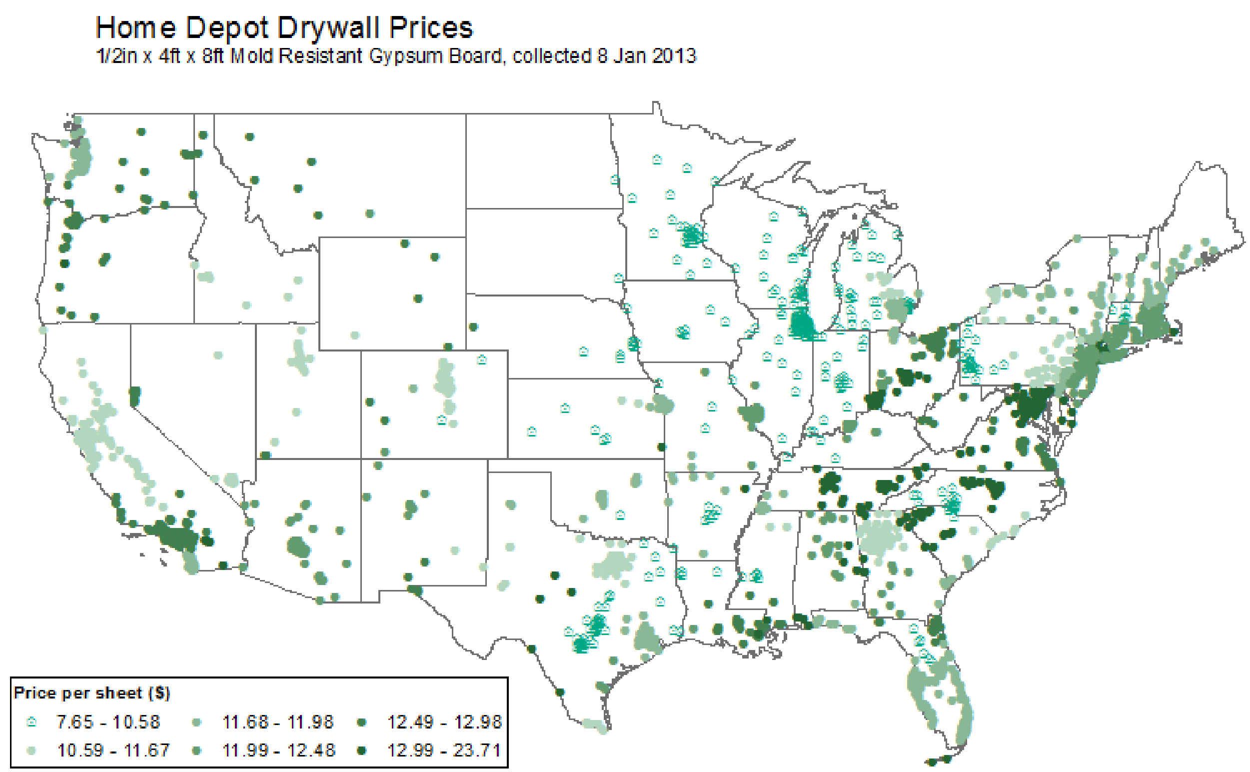
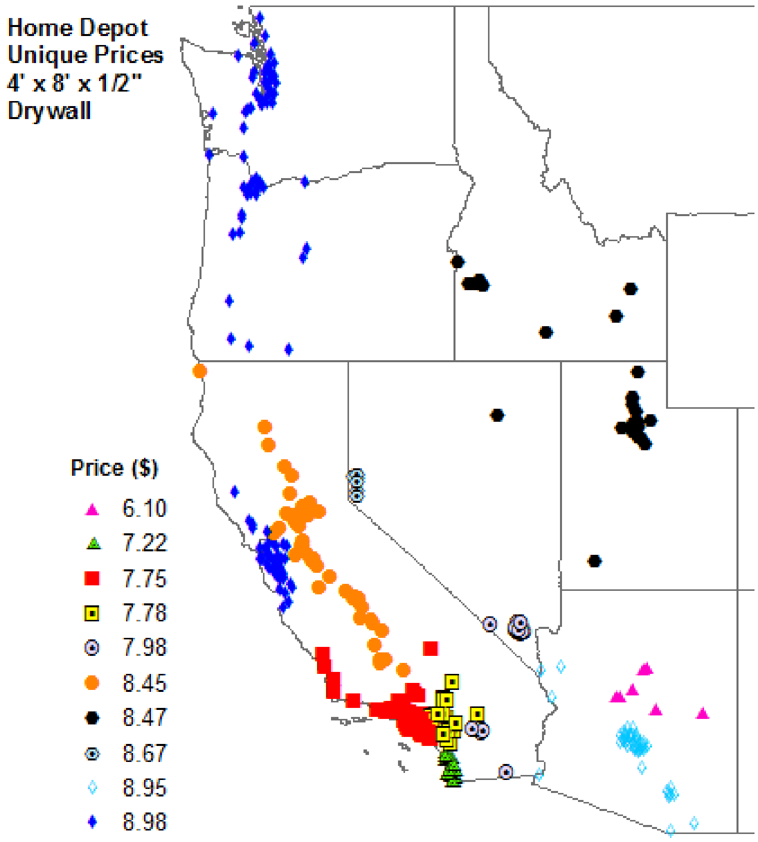


Figure 3: Map of unique prices for Home Depot 4′ x 8′ x 1/2" non-mold-resistant drywall.

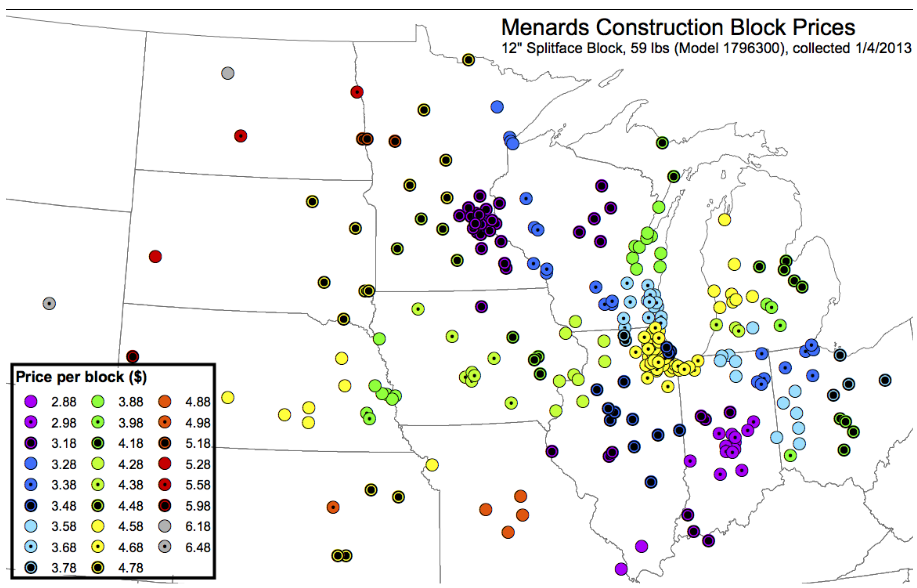


The coarseness of pricing zones varies by product category, but there is also some within-category variation. For example, compare the Home Depot mold-resistant and non-mold-resistant 4′ x 8′ x 1/2" drywall sheets in Figure 2 and Figure 3. In Figure 2, Western Washington and Oregon belong to two pricing 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.[12] For example, the Van Nuys,

[12]Sourced from The Home Depot US Store Listing, July 2010, accessed through the Home Depot supplier portal. The Home Depot Supplier Onboarding Guide, Summer 2013, states: "Each Market is part of a Buying Office (BYO) which was used historically when we operated multiple Buying Offices in the field."

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" 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.

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

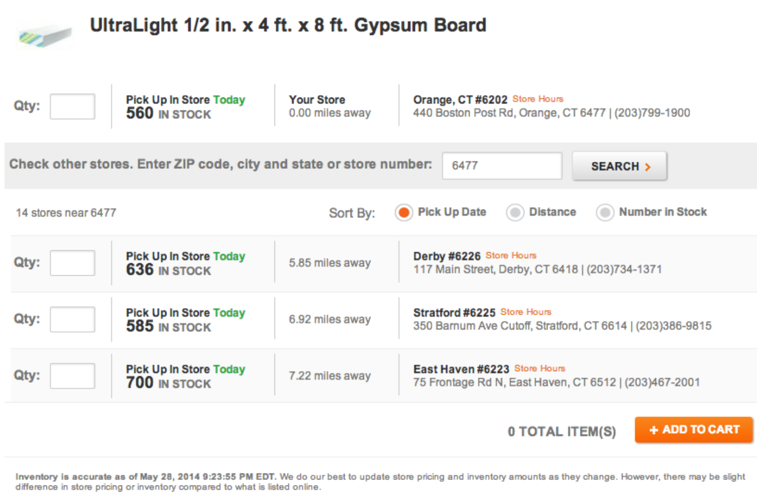


Finally, we note that some pricing zones are quite small. This can be seen in the previous pricing maps and most clearly in Figure 4, which plots prices for a 12" cement block at Menards. For example, Wisconsin is split into four zones and Minnesota is included in five zones. Several zones contain just 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 how prices and pricing strategy vary considerably 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.

Figure 5: Obtaining product inventories from HomeDepot.com.



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[13]; (iii) this region captures considerable variation in competition and costs, while keeping data collection manageable; (iv) consumer markets are small

[13]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,[14] 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.[15]

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). Home Depot, however, has more such locations. Lowe's pursued a national strategy targeting its expansion in larger, metropolitan markets in the early 2000s, when the chains were adding stores in this region.[16]

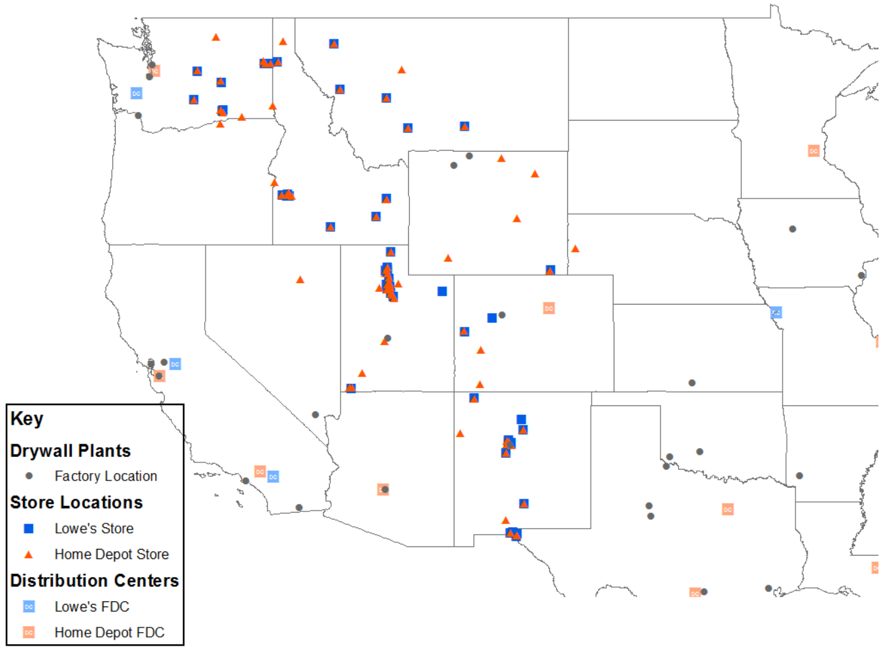
For the purposes of this study, we define a price zone as a set of stores at which all products have the same price. Thus, these pricing zones are no larger than the uniform

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

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

[16]Home Depot first entered this area in 1994. It opened stores steadily until 2008. Lowe's expanded into the region in 1998 with its purchase of Eagle Hardware, which began Washington in 1990 and had expanded into the Salt Lake and Billings in 1994. Lowe's first entered New Mexico in 2000. The 2003-2005 Lowe's Annual Reports describe its metropolitan-focused expansion strategy.

Figure 6: Stores selected for empirical analysis.



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. By comparing prices across time, we note that zone boundaries did not change during the collection period. Nationally, we determine that Home Depot has 165 drywall pricing zones, while Lowe's has 129. The Intermountain West contains several small pricing zones, as well as one of the largest pricing zones in the nation. Further, in this area, 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

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
Demographics			
Median Family Income	\$64,495	\$79,150	\$83,617

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

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.[17] We collect data daily between February 12, 2013 and July 29, 2013.[18] 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

[17]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.

[18]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.

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.

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.

Inventory increases of more than 15 sheets are classified as deliveries. This allows for some returns if excess sheets are purchased. On delivery days, typically a few hundred sheets are delivered per product-store. When deliveries occur, we impute sales for the product as the average sales of the product, store, day-of-week series. However, we note that our empirical analysis is not sensitive to the classification of delivery, nor how imputed sales are handled.[19] The two chains have similar drywall product selections,

[19]For example, counting any small inventory increase as a delivery would only lower estimated mean price elasticity from -5.6 to -5.3. The standard deviations are similar. Not imputing sales or dropping all positive inventory changes also yields similar results.

offering around three products per store.[20] 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.[21] 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 driving 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. Within the stores of interest, we calculate that transportation costs vary by more than \$1 per sheet. Distribution centers are usually near large markets, and Lowe's and Home Depot distribution centers are often near each other, so differences in transportation costs within a market are often smaller. 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 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.

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

[21]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.

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, warehousing costs at the distribution center, checkout transaction fees, and the opportunity cost of store floor space. Our transportation costs are also a lower bound as we assume the source of the drywall is the closest manufacturer. This potentially causes cost estimates to be too low. However, if one of the chains negotiates contract with a wholesale price below the industry average, cost calculations might be too high. For comparison, we also estimate costs using a model of supply in Appendix A.

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 model a pricing game in which chains sell multiple differentiated products across multiple stores, but are restricted to use their observed pricing zones. Conditional on these zones, chains simultaneously choose prices to maximize category profits.

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

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

x_{js} are product characteristics; p_{js} is price; (β, α_ℓ) 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,

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

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) and category shares are mechanically correlated with the error term, but since Equation 3.1 is linear in its parameters, we instrument for these endogenous variables, as discussed in Section 4.1.

3.2 Supply with Zone Pricing

With the demand system defined, we now introduce the pricing game. Firms simultaneously choose pricing on all products, but these pricing choices are constrained to be the same at all of the firm's stores within a price zone. The pricing zones are made outside of the model; section Section 5 investigates equilibrium with alternate pricing regimes.

Let stores of each firm be partitioned in zones, indexed by z. 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^f be the set of all zones for firm f. Let c_{js} denote the marginal cost of product j at store s. There are no fixed costs. The profits a firm accrues by 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.

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

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

Equilibrium prices are such that, given the prices of the other firm, each firm maximizes its total profits subject to the zone pricing constraint.

Our model abstracts from bundles, both in the decision to purchase a basket of goods related to drywall and in the pricing of drywall and complementary products. For example, on the supply side, a chain could set its drywall prices below the level that maximizes drywall profits in order to sell more paint brushes. However, drywall is rarely advertised and it is unlikely to be loss leader.

Analyzing only one product in a potential bundle can cause biased demand estimates (Kim and Kim 2017), which propagate to pricing and welfare calculations. With the data collected, we show that many of the products bought with drywall are uniformly priced. This suggests that price adjustments to products in the basket will affect overall chain preference and current price levels will be absorbed in our coefficient for the overall chain effect. This lowers our concern that abstracting from a basket of goods causes us to overstate market power (Thomassen et al 2017). Nonetheless, if the demand estimates ascribes unmodeled shopping cost considerations to idiosyncratic preferences, then we may overstate the ability of firms to increase prices in monopoly markets, understate price declines in competitive markets, and understate the consumer surplus impact of price changes. Yet, as we will see, our demand system suggests fairly elastic demand and we find substantial switching between products and stores in counterfactual experiments. Finally, we compare optimal prices given our demand system to observed prices. They are close which mitigates some of our concerns that the demand model is misspecified.

4 Estimation and the Observed Zone Pricing Regime

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, seasonality indicators, an indicator for mold-resistance, and a chain indicator for (Home Depot, Lowe's). We allow heterogeneity in demand across locations through market indicators, by interacting price with local family income (α_ℓ), and through the unobservable that varies for each product-store pair (ξ). We aggregate data to the two-week level because we observe zero product sales at the daily level. Price adjustments are not frequent; we observe at most four prices for a product over the sample period. 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 county population to define the outside good share. 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. As we may be concerned that zones are endogenous, the Hausman instrument utilizes far away markets (more than 300 miles) outside the focal zone.

We estimate two versions of the demand model. First, we set $\lambda = 0$ in the nested logit 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 λ =0.878, suggesting high

Table 4: Demand estimation results

	(1) Logit	(2) Nested Logit
Price	-0.301***	-0.110**
	(0.117)	(0.0483)
Income*Price	0.00124	0.000484
	(0.00144)	(0.000569)
Chain	0.424***	0.0474*
	(0.0254)	(0.0252)
Mold resistance	-1.201***	-1.792***
	(0.0920)	(0.0559)
$\mathbb{I}$[length = 10]	-1.698***	-0.0928
	(0.102)	(0.0991)
$\mathbb{I}$[length = 12]	-1.269***	0.0824
	(0.116)	(0.0837)
λ		0.878***
		(0.0551)
Market indicators	Yes	Yes
Month indicators	Yes	Yes
Mean product elas.	-2.513	-5.570
(s.d.)	(0.486)	(2.433)
Observations	5,054	5,054

Robust standard errors in parentheses. Income measured in thousands of dollars per year.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

substitutability within nest. The coefficient estimate on the income variable is small and positive (and statistically insignificant), suggesting income effects are not important. This seems reasonable given the product studied.[22] We estimate statistically significant and negative parameters on the length dummy variables in the logit model; however, these

[22]Removing income from the model yields similar results, and hence, very similar counterfactual predictions.

parameters become insignificant and of mixed sign in the nested logit model. Finally, we estimate a negative coefficient on the mold-resistance indicator, as the additional weight and lower fire-resistance that comes with mold-resistance makes them less desirable for most rooms in a home.

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 -2.5 to -5.6 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. The price insensitivity of drywall consumption is to be expected, as drywall accounts for a small portion of expenditures on almost any project in which it is used. The industry as measured here, however, comprises only Home Depot and Lowe's, and the inelastic demand suggests limited substitution to the contractor suppliers and lumberyards included in the outside good. In other product sectors, competition from other physical and online retailers likely makes chain-specific demand more price elastic, lowering the gains from price discrimination. In Holmes (1989) and Corts (1998) industry price elasticity is a main determinant of whether price discrimination is profitable, so a more elastic demand may be why so many categories other than drywall have uniform pricing or fewer, larger zones.

4.2 Marginal Costs and Optimal Pricing

Our wholesale price and transportation cost data allows the computation of marginal costs without the assumption of optimal pricing. We, thus, can compare observed pricing with optimal prices. To find equilibrium zone prices, 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, 9.2% lower than optimal (median 7.4%). The histogram shows that most optimal prices are between -10% and 20% with observed prices. There are a few outliers, mostly in the direction of prices being too low.

This may seem problematic; however, the highest equilibrium price is still within \$0.50 with observed prices in the national data. Further, the products that see large price increases do not drive our main results; they account for only 2.6% of total chain profits.[23] For data confidentiality reasons, we cannot report firms' average markups, but markups on individual products range from -0.9% to 38% with observed prices and from 16% to 69% with equilibrium zone prices.[24] The means are similar.

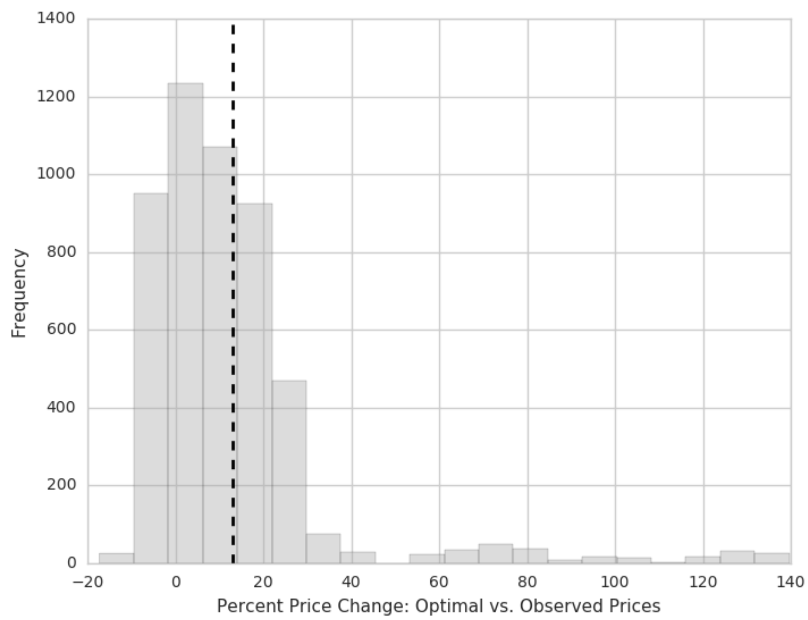


Figure 7: Histogram of differences in equilibrium zone prices with observed zone prices, as percentage

Other studies have found observed prices to be lower than optimal. For example, Nair (2007) finds prices to be slightly lower than optimal in a setting of intertemporal price discrimination. On the other hand, Dubé and Misra (2017) find an online recruiting website charged prices far below optimal. Also, our retailers may have considerations that are not captured in our model. Firms may have fairness concerns as hypothesized in

[23]The outliers are a single product in three of the smallest Home Depot zones.

[24]38 out of 5,054 observations are estimated to have a negative markup using observed prices.

DellaVigna and Gentzkow (2017). Or, firms may have long-run considerations in mind; prices are lower as a consequence of higher elasticities than our model provides.

In many studies, direct measures of costs are absent, and so a common approach is to recover costs by assuming observed prices maximize firm profits. Appendix A extends this procedure to zone pricing, where the standard estimation routines would be underidentified – zone pricing produces only $J \times Z$ optimality conditions to solve for $J \times S$ marginal cost terms. That is, costs vary by store but optimality conditions are specific to a more aggregated level, zones.

In the appendix, we compare the resulting costs with those computed from our wholesale shipping data. The transportation component of costs estimated by the two methods are similar. The overall costs, however, are lower when recovered from optimality conditions, possibly due to our retailers securing lower wholesale prices than the national average. For some products, marginal costs implied by optimal pricing are unrealistic; for these, unobservable components of costs of high magnitudes, both positive and negative, are required to make the optimality conditions hold. This could be because our assumption that firms are choosing the optimal prices in incorrect or because our restrictive assumption needed in order to recover costs does not hold. Therefore, we use the costs described in Section 2.3 in the subsequent sections.

Before turning to counterfactuals, we report additional statistics on profits for the retailers, comparing observed prices with equilibrium zone prices. Table 5 calculates profits by chain and market type under both prices. The most important finding is that the percent of profits attributed to either firm in duopoly and monopoly markets does not change substantially going from observed to equilibrium 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 much higher under equilibrium zone prices than under observed pricing (77% for Lowe's and 40% for Home Depot).[25]

[25]Large gains have been found in other industries. Dubé and Misra (2017) find Ziprecruiter was charging

Table 5: Zone Pricing Profits By Chain and Market Type

equilibrium	Lowe's		Home Depot	
(observed)	% of π	Profits	% of π	Profits
Monopoly	7.39%	0.156	28.46%	1.327
	(8.14%)	(0.097)	(24.28%)	(0.815)
Duopoly	92.61%	1.952	71.54%	3.337
	(91.86%)	(1.094)	(75.72%)	(2.541)
π - equilibrium		$2,107,897$		$4,664,205$
π - observed		$1,190,993$		$3,356,120$

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.

5 Alternative Pricing Regimes

The model parameter estimates allow us to calculate what equilibrium prices 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 combinations that follow from firms choosing between uniform, zone, and marketing pricing. We use the model equilibrium using the observed pricing zones as the baseline model. Hence, all price comparisons are between computed equilibrium prices, not observed prices.

Comparing alternative pricing regimes reveals how the observed zones soften competition in competitive markets and protect consumers in other markets. We first investigate prices of the different combinations in Section 5.1, and then discuss variable profits and consumer welfare in Section 5.2. We discuss the Nash equilibrium of a zone selection 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-level pricing in Section 5.5.

too low for job listings on its platform and optimized prices increased revenues by 81.5%.

For notational purposes, each pricing game we consider is denoted by the pricing methods chains use, with Lowe's method listed first. For example, the (zone, market) denotes a pricing game in which Lowe's uses its current observed zones and Home Depot uses market-level pricing.

5.1 Equilibrium Pricing Under Alternative Pricing Zones

We first consider the (zone, market) counterfactual, in which Lowe's retains its observed zone structure, but Home Depot switches to setting prices market-by-market. As with all the counterfactuals considered, prices are optimal given the specified pricing structure. Relative to the pricing equilibrium for (zone, zone), prices at Home Depot are lower in 77% of markets where it competes with Lowe's and higher in 82% of markets where Lowe's is absent.[26] 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.

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 50% higher, on average, than when both firms utilize zone pricing. In markets with both chains, Home Depot's prices are 3.6% lower and Lowe's prices are 1.8% lower than in the (zone, zone) equilibrium. To respond to a lower competitor price in this scenario, 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 also affords chains the flexibility to post higher prices in places with higher costs or with higher demand. Demands differ across markets due to variation in local-level preferences. Transportation costs differ by store and vary by as much as \$0.65/sheet in some zones. Equilibrium prices for Home Depot are slightly higher in (zone, market) than (zone, zone) in some competitive markets that are far from distribution

[26] In Home Depot's monopoly markets, 16% 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.

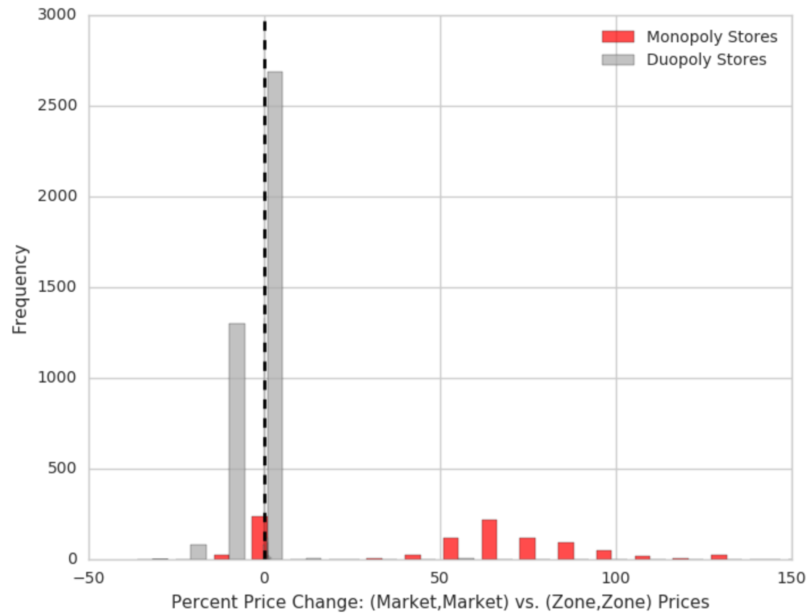
centers. Yet market power considerations have a greater impact on prices. Among all non-mold-resistant panels, for example, the lowest (zone, market) equilibrium price in a Home Depot monopoly market is still higher than at any Home Depot store in a market with a Lowe's store.

Next, we consider the (market, zone) counterfactual, in which Lowe's uses market-level pricing, and Home Depot uses its observed zones. We find that 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 81% in Lowe's monopoly markets. In markets where it competes with Home Depot, Lowe's equilibrium prices in this experiment are lower for 72% of products, and its average price is only 2% less than in the (zone, zone) computed equilibrium.

The (market, market) game also has lower prices in most 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 experiments in which it uses market-level pricing; likewise for Lowe's. In markets where the two chains compete, prices are still lower than in the (zone, zone), (market, zone), or (zone, market) equilibria. In the previous experiments, 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 due to strategic complementarity, 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 3.7% lower than in (zone, zone). Prices for particular products are also more dispersed in the (market, market) equilibrium, 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) equilibria. Monopoly stores and duopoly stores have separate histogram bars. A few duopoly prices are much lower under (market, market), but most price changes are within a few percentage points of the average, -3.7%. The average price

Figure 8: Histogram of differences in zone prices and market prices, as percentage



change for monopoly markets is 50% for Home Depot and 81% 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. Excluding these observations, we find that prices increase by 50% or even double in (market, market) pricing, depending on local costs, local demand, and what margins the zone price already includes.

Finally, we run counterfactual experiments 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 when they use uniform pricing; elsewhere, uniform pricing produces higher prices. Prices at Home Depot are 4.8% lower in the (uniform, uniform) equilibrium compared to the (zone, zone) equilibrium. 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) counterfactual equilibrium is only 0.3% higher than in the (zone, zone) pricing model equilibrium. 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 $0.12/sheet higher in (uniform, zone) than in (uniform, uniform) and are $0.32 higher in (uniform, market). Home Depot's equilibrium prices are $0.11/sheet higher in (zone, uniform) than in the (uniform, uniform) and are a $0.26/sheet higher in (market, uniform).

5.2 Firm Variable Profits and Consumer Surplus

With estimated variable costs and equilibrium prices and quantities for each combination of pricing regimes, we can calculate profits minus fixed costs, or variable profits. Table 6 reports annualized variable profits for Lowe's and Home Depot, respectively, for all combinations of the use of uniform, zone, and market pricing.[27]

Table 6: Variable Profits in Different Pricing Regimes

Lowe's / Home Depot	Uniform Pricing	Zone Pricing	Market Pricing
Uniform Pricing	2.215 , 4.522	2.097 , 4.672	1.844 , 5.170
Zone Pricing	2.222 , 4.500	2.108 , 4.664	1.860 , 5.167
Market Pricing	2.325 , 4.344	2.220 , 4.519	1.995 , 5.055

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

Our first finding is that finer pricing increases a chain's own variable profits, holding fixed the competitor's pricing choice. For example, if Lowe's continues in its current

[27] Profit estimates are calculated from Equation 3.3 and Equation 3.4 using the equilibrium prices for p^f, p^{-f} and the estimated costs for c_{js}. Period profits are summed over all 13 fortnights, then doubled to produce annualized totals. These profits are only for the 128 stores in the Intermountain West, which comprise 3% of the chains' national store count.

zones but adjusts prices, Home Depot's profits increase with finer pricing, from $4.500 million/year in (zone, uniform) to $4.664 million/year in (zone, zone) to $5.167 million/year in (zone, market). Note also that finer pricing decreases a competitor's profit as it brings lower equilibrium prices to competitive markets due to strategic complementarity. As Home Depot uses finer pricing, Lowe's variable profits decrease from $2.222 million/year in (zone, uniform) to $2.108 million/year in (zone, zone) to $1.860 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.

Next, we look at the situations where firms choose the same pricing system (the diagonal entries in Table 6). We find that as pricing becomes more flexible, one chain benefits, and one chain is worse off. 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 $1.995 million/year in the (market, market) equilibrium, which is $0.113 million/year, or 5.7%, less than in the (zone, zone) equilibrium. Lowe's losses are smaller than Home Depot's gains of $0.391 million/year, or 8.4%, using the model parameters we estimate. However, the same exercises run with slightly less consumer substitution between stores would have different results. If the nesting parameter λ in the demand system (introduced in Section 3.1) were less than 0.75, instead of its estimated value of 0.88, then finer pricing would bring lower industry profits, a possibility theorized in Holmes (1989).

One of the key drivers of the asymmetry in profit changes is the difference in the number of monopoly stores across firms. For both firms, profits in competitive markets are in aggregate lower in the (market, market) than in the (zone, zone) equilibrium. For Lowe's the difference is $0.261 million/year, for Home Depot it is $0.171 million/year. Home Depot has 21 monopoly markets, in them profits are $0.561 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 $0.148 million/year. Lowe's total profits are lower in the (market, market) game as the benefits of monopoly pricing for only a few stores does not outweigh the profit declines where the firm competes with Home Depot.

Distribution center placement is a modest contributor of the asymmetry. With a distribution center at the center of the large zone in Utah, Idaho, and surroundings, Home Depot has more cost variation within its zones. Home Depot's (market,market) prices depart farther from its (zone,zone) prices, allowing it to gain market share in large, competitive markets in northern Utah.[28]

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

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

where, implicitly, we sum over only the relevant store-products for the particular market and time period. 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 \$0.926 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 \$1.555 million/year lower because of this. Prices are lower in market-level pricing in duopoly markets as residual demand curves are more steep, and so consumers in duopoly markets have a surplus that is \$0.628 million/year higher. Hence, the net decrease in consumer welfare from finer price discrimination is roughly one third the aggregate change.

Even though a move from zone to market pricing has modest effects on variable profits, it nevertheless results in a large redistribution among consumers. (The results are thus

[28] We can isolate the cost impact by calculating equilibrium using costs that assume all drywall panels travel the same distance to reach the stores. For 9.3% of observations, the direction of profits changes of moving to finer pricing change sign without cost heterogeneity. Prices are slightly higher, but less dispersed, without cost heterogeneity. Overall variable profits in the different counterfactuals still follow the same general patterns as in Table 6. Similarly, we can isolate the impact of demand variations by calculating equilibrium after assigning $\delta_{js} = \bar{\delta}$. This also results in the same general patterns of profit changes across pricing regimes.

Table 7: Consumer Surplus and Variable Profit Changes

	Uniform Pricing		Market Pricing	
	Cons. Surplus	Var. Profit	Cons. Surplus	Var. Profit
Monopoly Markets	418,766	-185,268	-1,555,205	709,275
Duopoly Markets	-229,321	150,600	628,984	-432,023
Δ Surplus	189,445	-34,668	-926,221	277,252
Total Δ Surplus	154,777		-648,969	

Notes: Consumer surplus and variable 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.

like those in Miravete, Seim, and Thurk (2014), where a monopolist in Pennsylvania liquor market can achieve small profit gains through finer pricing that have large distributional consequences.) Here, consumers in monopoly markets lose more surplus than the combined surplus gain from consumers in duopoly markets 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, with the effect in monopoly markets being on average ten times greater per person than the impact in competitive markets. Overall, the markets that are harmed by market pricing are small, rural towns, where the population is on average four times lower than markets with two firms. Mean family incomes are similar; however, they are much more dispersed in the rural markets. The main consequence of zone pricing, thus, is to shield small towns from high prices where firms might otherwise exercise considerable market power. Doing so, however, results in slightly higher prices, shared by a considerably larger population, where firms compete.

Table 7 also shows the consequences of moving to uniform pricing would. We find a similar pattern, but with smaller effects. Consumer surplus is $0.189 million/year higher in (uniform, uniform), a result that nets a larger transfer from duopoly markets to monopoly markets. Consumer surplus is \$0.418 million/year higher in monopoly markets and \$0.229 million/year lower in duopoly markets. Consumer surplus changes are again larger and in the opposite direction from combined retailer profit changes.

5.3 Pricing Regime Choice and Menu Costs

In Section 5.1 and Section 5.2, chains take price regimes as given. In reality, chains are free to adopt uniform pricing or market pricing. They chose their current pricing zones, and even here, there are millions of possible combinations (or more precisely, there are over 2^{128}). We cannot examine such a large game, but we can analyze payoffs presented in Table 6 as a regime selection game. The strategies available to each chain are uniform pricing, using the observed zones, or market-level pricing. We assume firms choose their pricing systems simultaneously.

In the theoretical literature, Thisse and Vives (1988) establish conditions under which market segmentation through zones may lead to a prisoner's dilemma, where both firms opt to price discriminate but receive lower profits than under uniform pricing. Table 6 shows market-level pricing to be the dominant strategy for both firms, and so (market, market) is the pure strategy equilibrium of the regime selection game. Due to the asymmetries across our retailers, most notably in where they operate as monopolists, we find that the equilibrium of the regime selection game only lowers profits for one chain. Yet, neither firm has adopted market-level pricing.

Thus far, our model has assumed prices are set costlessly. The cost of maintaining a market-level system, therefore, could explain why the chains choose their observed zones over the dominant strategy of market-level pricing. 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.

We can bound such costs by adding parameters to the payoff matrix in Table 6 to account for them. In Table 8, both Home Depot and Lowe's face a menu cost μ associated with choosing a pricing system. The superscript denotes either uniform, zone, or market pricing and the subscript denotes the firm. To bound the them, we adjust the parameters such that (zone, zone) becomes an equilibrium of the game.

Table 8: Payoff Matrix with Menu Costs

L / HD	Uniform	Zone	Market
Uniform	$2.215 - \mu_L^U, 4.522 - \mu_{HD}^U$	$2.097 - \mu_L^U, 4.672 - \mu_{HD}^Z$	$1.844 - \mu_L^U, 5.170 - \mu_{HD}^M$
Zone	$2.222 - \mu_L^Z, 4.500 - \mu_{HD}^U$	$2.108 - \mu_L^Z, 4.664 - \mu_{HD}^Z$	$1.860 - \mu_L^Z, 5.167 - \mu_{HD}^M$
Market	$2.325 - \mu_L^M, 4.344 - \mu_{HD}^U$	$2.220 - \mu_L^M, 4.519 - \mu_{HD}^Z$	$1.995 - \mu_L^M, 5.055 - \mu_{HD}^M$

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

Lowe's will select zone pricing over market-level pricing only if If $\mu_L^M - \mu_L^Z > 0.112$ and over uniform pricing only if $\mu_L^M - \mu_L^U < 0.011$. Likewise, zone pricing is Home Depot's best response to Lowe's using zone pricing only if $\mu_{HD}^M - \mu_{HD}^Z > 0.503$ and $\mu_{HD}^M - \mu_{HD}^U < 0.164$.[29]

If the costs of implementing zone pricing μ^Z were a little larger relative to uniform pricing, then (uniform, zone) or (uniform, uniform) would emerge as the equilibrium of the regime selection game. In other categories, such as mosaic glass tile or power sanders, that is what is observed.

5.4 Abstracting from Competitive Interaction

In the previous sections, we analyzed equilibrium prices so a chain's prices reflected the competitor's pricing regime and pricing choices. Nash-Bertrand games are games of

[29] If chains choose pricing regimes sequentially instead of simultaneously, then the difference in menu costs needed to rationalize the observed zone choices differ. If Home Depot is a first mover, then $\mu_L^M - \mu_L^Z > 0.135$ and $\mu_{HD}^M - \mu_{HD}^Z > 0.391$ are necessary for Home Depot to choose zone pricing over market-level pricing.

strategic complements, so ignoring the competitive response overstates the gains of finer pricing. Specifically, a firm would prefer to undercut the competition to divert sales, but in equilibrium, competition will also adjust price downward. 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, such as Chintagunta, Dubé, and Singh (2003), which was forced to abstract from the competitive interaction due to data restrictions.

Table 9 compares the profit from this deviation, holding competitor prices fixed along with profits accounting for the competitor response. Moving from the (zone, zone) equilibrium to the (zone, market) equilibrium would increase Lowe's profit from \$2.108 million/year to \$2.220 million/year, a gain of \$112 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 \$2.685 million/year, an increase of \$577 thousand/year over the zone-zone equilibrium, in this later scenario. Although these changes seem small, in percentage terms, the overstatement in gains is very large.

Table 9: 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	2.108	2.685	2.220	5.15x
i =Home Depot	4.664	5.298	5.167	1.26x

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.

The second row conducts an analogous exercise – a move by Home Depot to market-level pricing holding Lowe's prices fixed and then allowing them to adjust. We find the overstatement in gains for Home Depot to be 26%. The number is substantially lower because our sample area contains several Home Depot monopoly stores that are shielded from competitor response. Even so, the overstatement may also be large in absolute dollars as our analysis focuses on a small subset (<.05%) of total products over a small proportion (3%) of the chain's networks. Although we do not have the data to conduct a national analysis, we posit that the gains would be overstated to a larger extent in a national level analysis due to the sheer number of competitive markets elsewhere in the country.

Another way of interpreting the profit overstatement in Table 9 is as an overstatement of menu costs that we calculated in the previous section. The previous literature on zone pricing necessarily found gains from finer pricing and forwarded menu costs as a likely friction explaining why firms were not utilizing such pricing. Ignoring competition estimates a lower bound on menu costs that is 1.26-5.15 times too high.

5.5 Store-Owner Pricing and an Agency Problem

Some chains give local store managers the autonomy to determine prices and assortments. This is especially true in franchising, and its presence varies both within and across industries (Lafontaine and Shaw 2005). The practice of allowing local managers the autonomy to choose prices is also observed in retail home improvement, notably at Ace Hardware.[30] Home Depot and Lowe's have chosen to centralize pricing, although historically, we know Home Depot operated regional buying offices that oversaw activities in local markets.[31] Our aim is to quantify how centralizing pricing affects the chains.

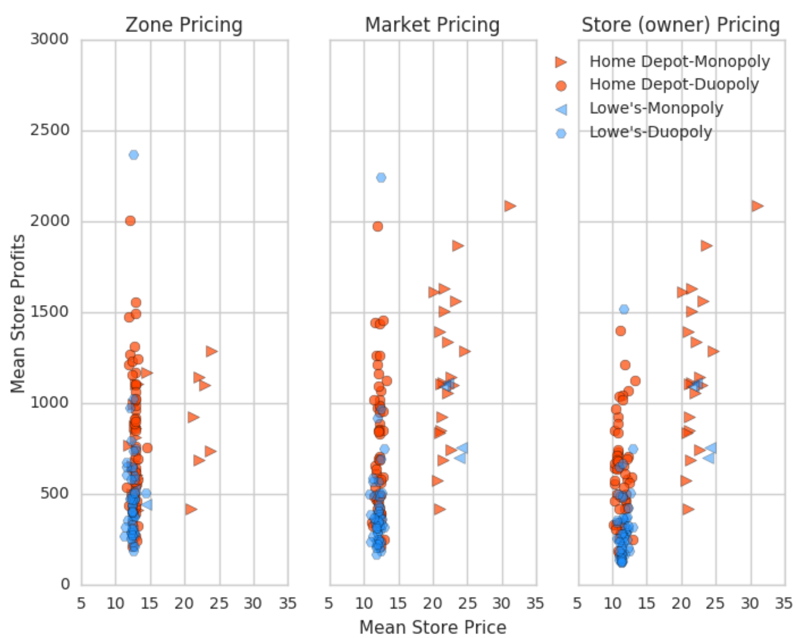
We simulate store prices and profits if both chains were to decentralize pricing. Specifically, we have each store maximize individual store profits. This would most closely mimic an incentive scheme whereby store managers are rewarded for individual store performance and not overall chain performance. Managers care only about store profits, creating an agency problem as store managers now compete for sales with other chain stores located in the same market (Brickley and Dark 1987).

[30] Ace Hardware is a retail cooperative with over 4,700 stores (Ace Hardware 2016 Financial Report). Their stores are considerably smaller than Home Depot, Menards and Lowe's. They sell products in many of the same categories as Home Depot and Lowe's; however, they do not sell drywall.

[31] Source: Home Depot Supplier Onboarding Guide, Summer 2013

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 variable 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.

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.

The first panel shows the base case of zone pricing. 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 $22. When chains move to market pricing (second panel), 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 and store profits increase. For these stores, there is a shift to the upper-right going from panel one to panel two. As discussed in Section 5.1, the stores in duopoly markets now compete more fiercely due to strategic complementarity. In the figure, the average duopoly store (denoted by circles and hexagons) decreases price, and profits dip slightly (4.4%). Relative to panel one, there is a movement in these stores to the bottom left.

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. Hence, the profit gains and consumer surpluses are identical to those under market-level pricing. This means that all changes occur in duopoly markets. There is a significant increase in price dispersion across stores (Lafontaine 1999), much more so than when moving from zone to market pricing. There is considerable movement to the left, as the average price drops by 4.6%. 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 39.6% and 27.1%, for Lowe's and Home Depot, respectively. These stores make up a large proportion of the sample, so the aggregate decline in industry profits is 14.7%. Out of all our counterfactual exercises, this one has the highest increases of consumer surplus in duopoly markets and also the highest aggregate consumer surplus. Profits are the lower than in all other counterfactuals. This may be the reason our retailers have decided to centralize pricing.

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 equilibrium pricing under 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. Further, our analysis sheds light on which consumer groups are most affected by zone pricing in oligopoly. There are clear winners and losers of retail chains using zone pricing. We find that zone pricing shields consumers in monopoly markets from facing high prices, but raises prices in markets where firms compete. We estimate the aggregate profit effects to be small due to the asymmetric price effects of moving to finer pricing.

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 and the set of products offered as exogenous – we observe no changes to the pricing zones over the sample period. There may be important interactions between the commitment to use zone pricing and product variety or the entry of stores within and across chains. We also do not have the data to disentangle 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 in some markets.

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A Estimating Marginal Costs under Zone Pricing

The main results use cost estimates calculated from wholesale prices and transportation costs. An alternative approach is to recover costs by imposing optimality conditions on firm behavior. Here, we show how this approach can be extended to a model with zone pricing.

When competing firms set prices at the store level, there is a one-to-one relationship between optimality conditions and marginal costs. For example, in a single good setting, the markup can be recovered through Lerner's Index. The multi-product analog can be seen in Nevo (2001) and Petrin (2002), among many other papers in the literature. If, instead, firms choose zone prices, then each zone pricing decision generates a first order condition that contains possibly several unobserved cost terms. Therefore, the number of unknowns is possibly much larger than the number of optimality conditions (we have $\dim(J \times Z)$ optimality conditions to estimate $\dim(J \times S)$ costs).

In order to estimate store-specific costs for firms using zone pricing, we assume marginal costs can be written as

$$c_{js} = w_{js}\theta + \nu_{jz},$$

where c_{js} is marginal cost of product j in store s, w_{js} are observable cost variables, such as distance traveled from the manufacturing plant, and ν_{jz} is the unobservable component of marginal costs. This parameterization of costs differs from what is typically found in the literature, because the unobservable is constant within a pricing zone. That is, we assume ν_{jz} instead of ν_{js}.

To see the advantage of this approach, suppose the only variable affecting costs is the distance between factory and store. Given a guess of the distance coefficient, costs will vary by store. The remaining components of marginal costs, that are assumed to not vary within a zone, can be inferred by solving the system of first order conditions (the dimensionality of ν is equal to the dimensionality of the first order conditions). Hence, our restriction on ν allows us, in a restricted way, to estimate $\dim(S \times J)$ costs with only

$\dim(Z \times J)$ first order conditions.

Given any guess of θ, we can solve for ν. To estimate θ, we write the problem using mathematical programming with equilibrium constraints (MPEC) following Su and Judd (2012). Let $\mathcal{M}(\theta; c, w)$ be a minimum distance estimator given the parameterization of c_{js}, such as using least absolute deviations or least squares. The MPEC problem is to solve

$$\min_{\theta, c} \ \mathcal{M}(\theta; c, w)$$
$$\text{s.t. FOC}(c, \theta\,;\, w, x, p) = 0.$$

Critically, we must specify the components entering w as this is the only way to incorporate store-level covariates into the estimation routine. This is in contrast with most of the literature, where store-level costs are first recovered and then regressed on covariates. With our drywall data, we include: driving distance from the closest plant via chain distribution, local retail wages, and product-specific intercepts.[32]

Table 10: Marginal Cost Estimates

	Coef.	Std. Error
Distance	0.0024	0.0019
Retail Wages	0.0000	0.0004
Product-Chain Indicators	✓	†
Marginal Cost IQR	[3.66, 9.93]	

Notes: Distance is computed as the driving distance to the store via the closest chain distribution center. Retail wages are weekly retail wages computed from BLS Occupational Employment and Wages. Standard errors computed using block bootstrap with 1,000 repetitions. †: All products but two are significant at the 1% level; average fitted value from $w\hat{\theta}$ is 6.54.

Table 10 shows the results of estimation. We estimate the transportation coefficient to

[32]We have also estimated specifications including time fixed effects; the time coefficients are similar to each other. We exclude any optimality conditions that involve a product observation with a demand elasticity greater than -1 that are found in 4% of observations.

be positive at 0.0024 per sheet/mile. While not significant (significant only in one-sided test at 10%), this estimate is close to the shipping component of costs calculated with our wholesale pricing data provided by the Bureau of Labor Statistics. The wage coefficient is close to zero and is not statistically significant. Combining with prices, we estimate the interquartile range of marginal costs to be between \$3.66 and \$9.93, and markups between, \$3.05 to \$6.72.

The cost estimates are reasonable for most products, but for others the ν required to make the optimality conditions hold are of sufficient magnitude to make the overall cost estimates unreasonable. In 6.5% of observations, marginal costs estimates are negative, all because of large negative ν terms. Large positive ν terms are also present; ν is more than \$5 in 3% observations, leading to unrealistically high cost estimates.

These large residuals may be because either: 1) the assumption of profit maximization is not satisfied, 2) the restrictive assumption that the unobservable does not vary within a zone is unreasonable. Finally, we note that while transportation costs closely follow our wholesale price data, the overall estimated costs are on average \$1 lower than those calculated from wholesale prices. Our expectation is the opposite, as the wholesale calculations omit labor and opportunity costs. On the other hand, estimated costs could in fact be lower if Home Depot and Lowe's obtain wholesale prices significantly below the national average. The wholesale quotes do not seem to be characterized by extreme price dispersion, however.