# Zone Pricing and Strategic Interaction: Evidence from Drywall

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**Abstract**

Retail chains often set a uniform price for zones that combine very different markets. We call the friction that prevents the expected market-level pricing "spatial menu costs." We develop an empirical model of competitive zone pricing that includes these costs. We apply it to retail drywall, using a rich, original data set for this industry. With structural demand and cost estimates, we estimate prices and profits under different pricing regimes to find bounds on the spatial menu costs needed to induce firms to adopt their existing zone pricing systems. Spatial menu costs are found to be substantial: at least 22.1% of estimated profits, or 2.2% of revenues. Finally, we show that competitive interaction plays an important role in recovering menu costs; abstracting from it leads to an overestimate of profit gains by 32.9%.

**JEL Classifications:** L11, L22, L74
**Keywords:** zone pricing, price discrimination, market segmentation, estimation of equilibrium oligopoly models

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# 1 Introduction

In the empirical industrial organization literature, the standard approach models prices as being set at the *market level*. Competing firms in a particular market each set a specific price for that market, taking as given the prices set by competing firms. In practice, retail firms commonly set prices at the *zone level*. These pricing zones, although usually geographically contiguous, often combine distinct markets that may be hundreds of miles apart and that differ in significant ways. A firm's pricing zone might include urban and rural markets, markets with different degrees of competition, and markets where input costs vary substantially. With these differences across markets, we might expect the firm to set individual prices in each market rather than a common price throughout the zone.

In this article, we develop an empirical analysis of zone pricing under competition. While monopolists can only increase profits by adopting more granular pricing policies, price discrimination theory has shown this is not necessarily the case in markets with competition. When competitors are present, a commitment to not use more granular pricing may allow firms to obtain higher profits. We explore this ambiguity by examining the zone pricing practices of the major home improvement retailers. We explain a number of features of drywall retailing that make it an ideal industry for such a study, and further we are able to construct a unique, rich data set for this industry. We estimate a structural model of supply and demand, which we use to estimate equilibria under alternative pricing regimes. We find profits increase if firms adopt more granular pricing. Since the major retailers have chosen not to adopt these policies, they must face some additional costs. We call these costs "spatial menu costs", and our analysis finds them to be substantial.

The spatial menu costs considered here relate in spirit to the concept of menu costs prominent in the macroeconomics literature. The macro literature documents how prices change infrequently over time, and this inter-temporal price rigidity has potentially significant implications for the macroeconomy. There are also studies that examine the menu costs associated with price changes at the micro level, such as for products within stores (see Levy, Bergen, Dutta, and Venable (1997) for example). Here, the price rigidity is across space – a pricing zone. Many of the key issues from the macro literature apply in our context.

Retail drywall markets have several features that aid analysis of zone pricing. In the mainstream retail sector for drywall, competition is between a few large chains, all of which practice zone pricing. Drywall, also known as wallboard or gypsum board, is costly to transport, so consumers buy from local stores and retailer costs vary geographically. The distribution centers for each major retail chain have known locations, making costs estimable. Some observed pricing zones span multiple, diverse markets, making advertising an unlikely reason for setting such large pricing zones. Some pricing zones also include monopoly markets and markets with multiple stores from each chain. The variation of costs, competition, and demand variables within a pricing region allow us to uncover the role of spatial menu costs in forcing pricing zones.

Our work contributes to the literature on price discrimination, as spatial menu costs are an interesting impediment to price discrimination. Firms have chosen not to set completely uniform prices and so engage in limited price discrimination. We show that without spatial menu costs, drywall retailers would set a discriminatory price in each market. In the standard monopoly setting, limiting the firm to a zone system can only lower profits. However, Holmes (1989) and Corts (1998) show that in environments where firms compete, the effect of being able to price discriminate has an ambiguous effect on profit; impediments to price discrimination limit what a particular firm can do, but it also affects what its rivals are doing. In more recent work, Aguirre, Cowan, and Vickers (2010) and Cowan (2012) explore sufficient conditions on demand for a third-degree price discriminating monopolist to either increase or decrease social welfare and consumer surplus, respectively. Chen and Schwartz (2013) examine the welfare implications of differential pricing in a monopoly setting where there are differences in marginal costs of serving consumer groups. Our empirical model allows for both demand and cost-based rationales for differential pricing, and we quantify the impact of zone pricing to both consumers and firms.

In order to examine the welfare implications of zone pricing in retail drywall, we estimate a structural model of demand and supply using a new data set for the industry.

The two largest retail chains report prices and up-to-date inventory levels; we difference reported inventory levels to derive daily sales. The sales data allow estimation of a discrete-choice demand model. Consumers select between all available drywall products at each nearby store from either chain. We find drywall to be a highly substitutable product, but overall industry elasticity is very low. We estimate the marginal cost of each product in each store by accounting for transportation costs from the warehouse. With these demand and costs estimates, we can estimate profits under the current pricing zones and compare them to pre-menu cost profits in counterfactual equilibria where one or both of the firms instead use market level pricing. Multiple equilibria exist for a given zone configuration. We compare the current regime with a small adjustment in zones to yield unique counterfactual equilibria. Aggregating across markets, we find the spatial menu costs to be 2.2% of current revenues. For the 128 stores in the sample, this equates to roughly \$4.6 million in additional profits for retail drywall annually. Applying a selection mechanism across multiple equilibria on the meta game of zone pricing yields a menu cost of nearly \$2.3 million. The spatial menu costs that would rationalize the chains' decision not to separate stores into their own pricing districts are substantial, though small enough that managerial effort costs (as in Zbaracki, Ritson, Levy, Dutta, and Bergen (2004)) are a likely explanation.

Previous work on zone pricing is relatively sparse in both the economics and marketing literature. Montgomery (1997), Chintagunta, Dubé, and Singh (2003), and Khan and Jain (2005) are important exceptions. They all examine a supermarket chain that practices zone pricing and ask how profits and consumer surplus would change if the chain switched from zone pricing to store-by-store pricing. Marginal costs were assumed to be the same at all stores. Although this is an acceptable abstraction for supermarkets within a city, such an assumption cannot be maintained with drywall. An important difference between our work and the previous literature is that instead of analyzing what is happening to one firm in isolation, holding fixed the environment of the firm as it changes from zone to store-by-store, we take into account how switching regimes can affect the entire competitive interaction. We show the profit gains to using market level pricing are greatly overstated when abstracting from effects of competition, causing the menu costs to be overstated by as much as 32% or over \$2.1 million annually for the stores examined.

This article is organized as follows: In Section 2, we document zone pricing for the home improvement retail industry and describe the data used for this study. In Section 3, we introduce the supply and demand system. In Section 4, we present estimation results and in Section 5, we conduct analysis on alternative pricing regimes.

## 2 Data and Descriptive Evidence

We create a new data set for drywall sales at the largest home improvement warehouse retailers in the United States. We obtain a cross-section of store prices for all drywall products nationally for Home Depot, Lowe's, and Menards. We also construct a panel of daily prices and sales quantities for all drywall products offered at 128 Home Depot and Lowe's stores in the Intermountain West. To obtain sales quantities, we monitor daily inventory levels reported on the retailers' websites; by differencing daily inventory levels, we obtain sales for each product-store pair.

### 2.1 Drywall data

Drywall prices posted on company websites reveal the use of zone pricing by both Home Depot, Lowe's, and Menards. For all three retailers, prices for a given product vary considerably at a national level, but are exactly the same price at all of the chain's stores within contiguous areas. These areas are largely the same for different drywall products within a chain. We define a pricing zone as an area in which stores have exactly the same price on all drywall products offered. We show that although most pricing zones are small, some contain a large number of stores and span a diverse set of markets.

Price levels for regular 5/8" x 4′ x 8′ gypsum board are mapped at every Lowe's and at every Home Depot in Figure 1. Each dot on the map represents a store, and its color represents its price intensity. Nationally this product has considerable price variation, from \$5.98 a sheet to \$20.35 a sheet for Home Depot and \$5.98 to \$18.64 for Lowe's. Menards, the third major home improvement retailer in the United States, only operates stores in the Midwest, but it also uses zone pricing.

In large geographical areas in the United States, such as every store located in Idaho, there is no price variation for both Home Depot and Lowe's. Nationally, Home Depot charges 92 distinct prices for regular 5/8" x 4′ x 8′ drywall across its 1,979 stores whereas Lowe's charges 126 distinct prices across its 1,714 stores. Surprisingly in some areas, such as the Carolina Piedmont, a sharp boundary separates two zones with very different prices. Elsewhere, such as the upper Midwest, prices are similar over a wide area.

Figure 2 plots unique prices for a regular 5/8" x 4′ x 8′ gypsum board product available at Home Depot stores in the Western United States. Each dot again represents a store; stores with exactly the same price are the same color. The figure shows geographically contiguous pricing zones. For example, there is a unique price for this drywall product for all Home Depot stores in Oregon. All locations in Utah and Southern Idaho have the same price, although stores in eastern and western Washington have different prices. The unique pricing regions for different drywall products within a chain are often, but not always, the same. Adams and Williams (2015) show this is usually not the case in other product categories. The prices in Figure 2 are only for one product, and there is some variation in the pricing patterns across products. For example, prices for 1/2″ x 4′ x 12′ drywall board exhibit three prices in the state of Washington instead of two, but the two pricing zones in western Washington combine to correspond exactly into the pricing region for 5/8″ x 4′ x 8′ drywall.

We define a price zone as a set of stores where all drywall products have the same price. These pricing zones thus are no larger than the uniform price region for any product. Using our definition of a zone, we determine Home Depot has 165 drywall pricing zones for its 1,979 stores and Lowe's has 129 drywall pricing zones for its 1,714 stores in the US.[1]

Many pricing zones contain only one metropolitan area. Such zone might be justified for marketing reasons or because costs and competition are similar within a city. This would lead to profit-maximizing prices being the same across stores. The drywall pricing zones with the most stores for both Lowe's and Home Depot are in Southern California,

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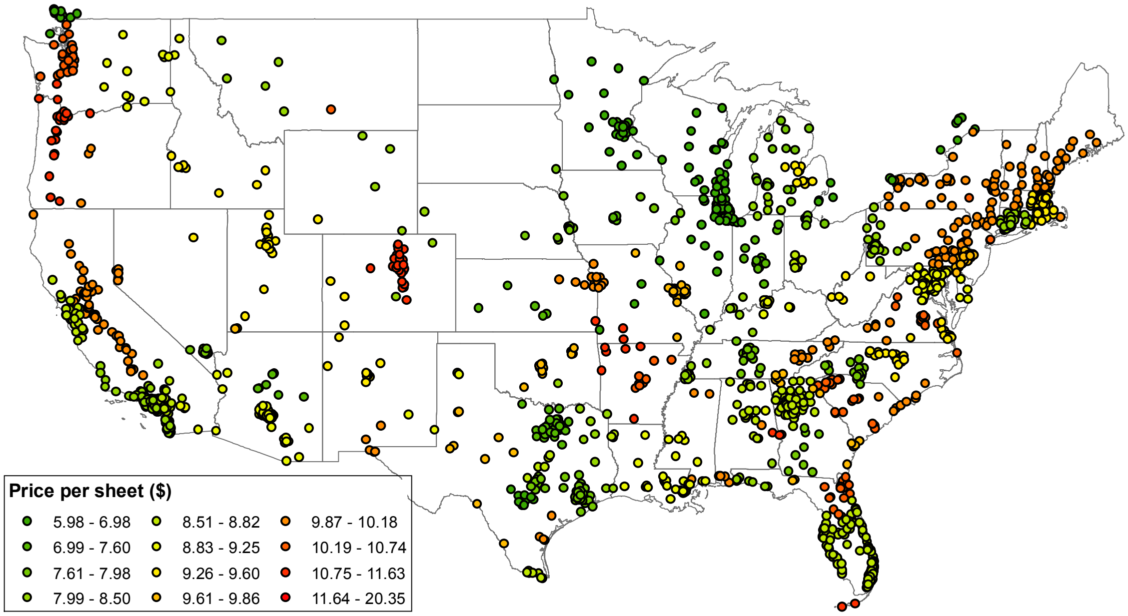
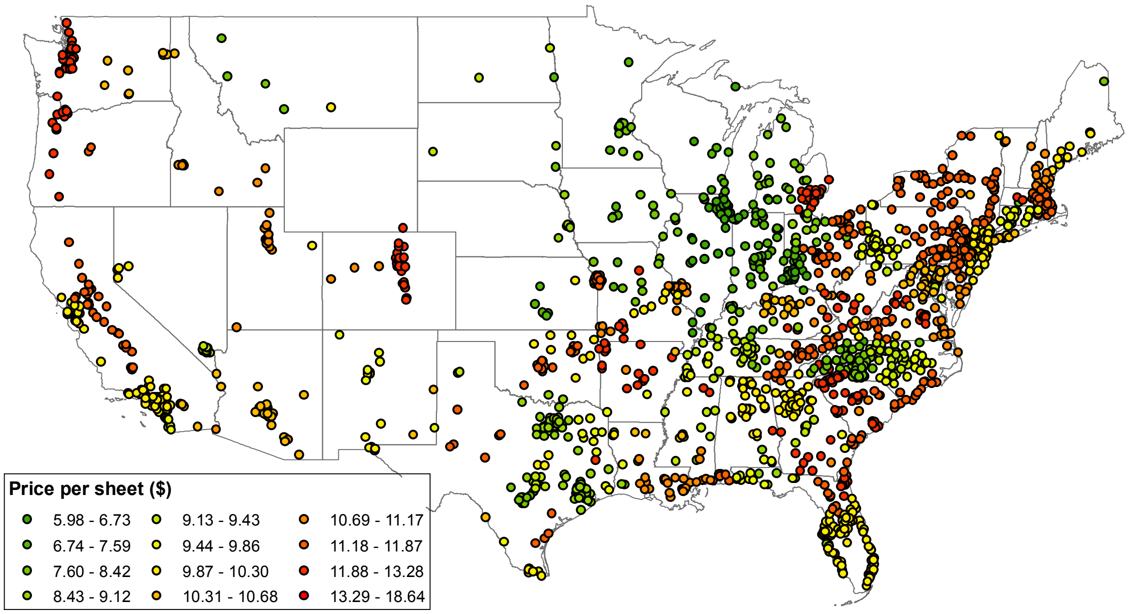
[1] Three pricing zones had the prices for regular 5/8" x 4′ x 8′ sheets that were seen in other zones, hence the 126 distinct prices for that product.

Figure 1: Map of US Lowe's and Home Depot stores. Each point indicates a store location, the color of the point corresponds to a pricing intensity for 4′ x 8′ x 5./8" drywall.



Home Depot Drywall Prices

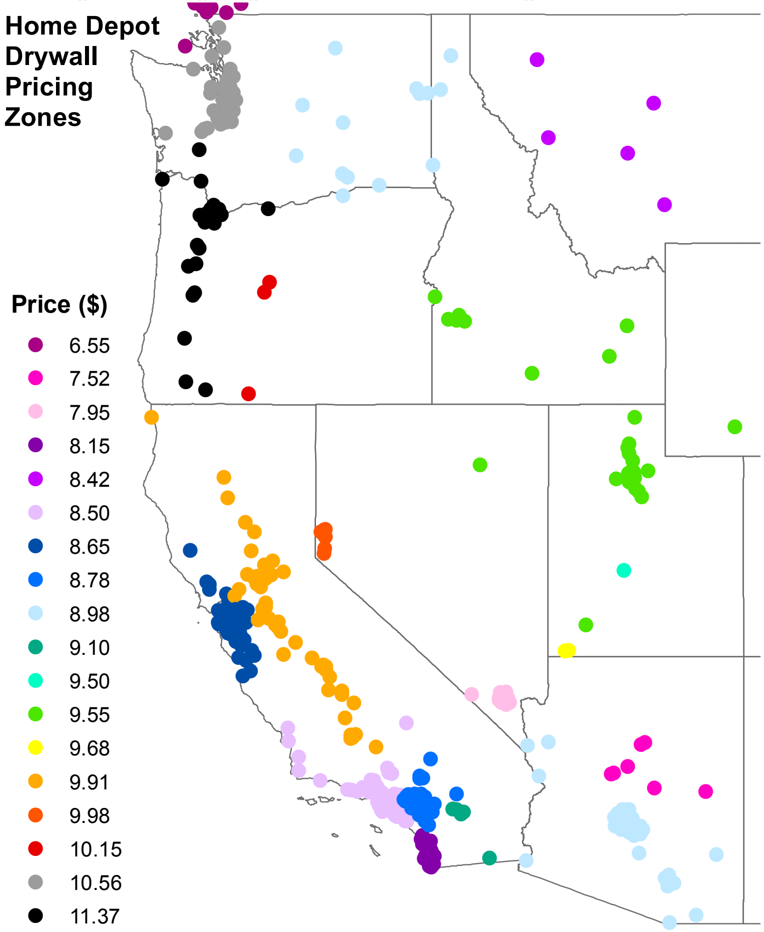
Gold Bond 5/8in x 4ft x 8ft Fire-Shield Gypsum Board Tapered Edge (Model GB99500800), collected 1/8/2013



Lowe's Drywall Prices

Gold Bond 5/8in x 4ft x 8ft Fire-Shield Gypsum Board Tapered Edge (Model GB99500800), collected 1/14/2013 both extending from Los Angeles to San Luis Obispo. Lowe's has 32 pricing zones that span more than 200 miles; Home Depot has 16 such zones. Pricing zones of such size represent multiple consumer markets. Drywall is bulky, making it unlikely that consumers would substitute to stores a great distance away.

Figure 2: Map of unique prices for Home Depot 4′ x 8′ x 5/8" drywall.



A notable feature about the decision to use zone pricing in retail drywall is that costs and market structure vary considerably within a zone. Table 1 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 5/8" x 4′ x 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 stores in Rock Springs and Elko 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.

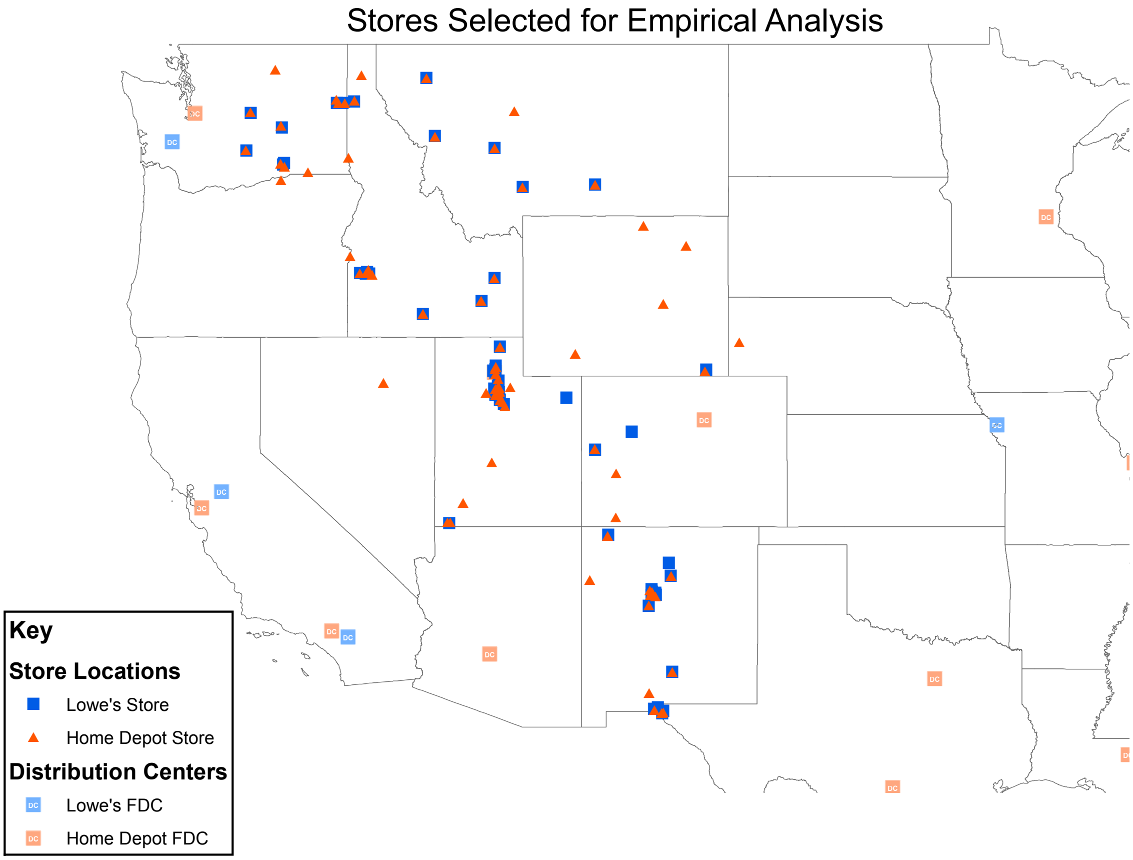
Table 1: Example documenting differences in costs and competition within a zone.

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

To estimate an empirical model of zone pricing with competition, we create an original data set of prices, sales quantities, and product characteristics for all drywall products available at 75 Home Depot stores and 53 Lowe's stores in the Intermountain West. We select this region of the United States as it allows us to capture considerable variation in competition and costs, while keeping the data collection manageable. While pricing strategies do vary across product categories, drywall is the focus of this study for several reasons. Consumer markets are small and relatively well-defined, because buyers are unlikely to transport something as bulky and fragile as drywall far. Because of transportation difficulties, costs will vary predictably across stores. Drywall is rarely used in price promotions or as a loss leader, so category profit maximization is reasonable. Finally, 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.

Figure 3 maps the stores for which we obtained quantity data. Our data set includes all stores in Idaho, Montana, New Mexico, Utah, western Colorado, eastern Washington, and 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). Menards, the third largest home improvement warehouse, operates no stores in this region and so is omitted from the analysis.

Figure 3: Home Depot and Lowe's locations where detailed pricing and sales information was obtained



Our sample includes 14 complete Home Depot pricing zones and 11 complete Lowe's pricing zones. This area contains several single store pricing zones as well as one of the largest pricing zones in the nation. The pricing zone boundaries largely match between chains. Both in the sample area and nationally, the chains often charge the same price in locations where they compete; where chains have stores in the same ZIP code, 89.9% of prices in our sample match exactly.

Matching prices are consistent with models ranging from collusion as well as Bertrand competition with a high substitutable product. Our model will assume chains are maximizing their own profits under competition. Price changes do not occur at the same time. While this data was collected, drywall installers were pursuing a lawsuit alleging price fixing by manufacturers. No similar allegations were made against drywall retailers.

We download prices and inventory levels for individual store stock keeping units (skus) and match these to products. For several products, Lowe's lists several brands on their website as different products, but those skus have identical prices and inventory levels that (with a one day lag) coincide perfectly. We eliminate these duplicates. Using manufacturer model numbers, we match products offered by both chains. In all, we identify 31 distinct products. We record the thickness, width, length, mold resistance, and moisture resistance for each product. We do not use brand identifiers because our site visits found brands frequently mislabeled at both chains.

Net changes in daily inventory levels for each product at each store are used to calculate sales quantities. Decreases in inventory levels give sales quantities. Inventory level increases of more than 20 sheets are classified as deliveries. When deliveries occur, we take the net change in inventory for the day as the volume of the shipment, meaning we assume no sales take place on delivery days. This systematically under-reports sales, but deliveries occur only every 16 days on average.[2] Smaller net increases in inventory levels are counted as returns, or negative sales.

Table 2 provides summary statistics for the data sample, which was collected between 12 February 2013 and 29 July 2013. The sample includes $N = 155,184$ observations. On

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[2] We provide evidence in the estimation section that suggests our results are not sensitive to the possible measurement error in sales.

average, daily inventory decreases by 6.2 and 7.0 sheets per product-store for Lowe's and Home Depot, respectively. Because the sales volume is low, we aggregate to the fortnight level in model estimation. The observed sales quantity would represent a small fraction of drywall used in new construction. We interpret Lowe's and Home Depot to be supplying the market for smaller consumer projects, such as wall repair or room remodeling. Construction contractors and their supply networks are participating in a separate market. Consumers in our model will always have an outside option which will include buying from contractor suppliers.

Table 2: Summary statistics for the sample

| **Means** | Lowe's | Home Depot |
|---|---|---|
| Sales (per product, per day) | 6.19<br>(24.67) | 6.97<br>(19.77) |
| Delivery size (per product) | 200.90<br>(294.76) | 194.11<br>(216.05) |
| # Products (per store) | 8.60<br>(1.13) | 8.97<br>(1.15) |
| Revenue (per store, per day) | $531.87<br>(381.42) | $651.15<br>(305.15) |
| Price (per product) | $10.90<br>(3.04) | $12.04<br>(3.78) |
| Observations | 58,100 | 85,787 |

On delivery days, typically around a hundred sheets are delivered per product-store. The two chains have similar drywall product selection, offering around eight products per store. The price of drywall within a market ranges from just over $5 to over $20 per sheet, depending on the dimensions and features. The total drywall sales revenue for the 128 stores we study sums to $25.4 million per year.

Both Home Depot and Lowe's operate flatbed distribution centers. These distribution centers provide store locations with lumber and board products.[3] Using distribution

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[3] A Lowe's public document states: "FLATBED DISTRIBUTION CENTERS (FDC) - The purpose is to

center locations, we calculate the closest distribution center to each store, which we utilize in cost estimation. We find the average distance to stores from distribution centers is 318 miles, with a standard deviation of 190. At the extremes, the closest store to a distribution center is three miles, whereas the greatest distance is just over 690 miles. Distribution centers are usually near large markets and often Lowe's and Home Depot distribution centers are near each other. In our sample region, one big difference is Home Depot's placement of a distribution center in northern Utah, whereas Lowe's nearest distribution center is in southern Nevada. Since a sheet of drywall exceeds fifty pounds, we expect distance to be an important driver of costs. Labor costs may also be important. To measure them, we use ZIP code level wages for home improvement retailers from the Quarterly Census of Employment and Wages.

# 3 Model

In this section we introduce the structural model of supply under zone pricing and demand. Competing firms operate stores in multiple markets, and each store sells multiple products. Consumers choose between all the products at stores in their market according to a standard discrete choice setup. Firms set prices in two-stages. First, they partition their stores into pricing zones. Next, they simultaneously chose the price levels of each zone to maximize profits subject to the zones they have chosen. To start, we introduce some notation and our definition of a pricing zone. Next, we describe the consumer's problem. Finally, we detail the pricing game the firms play and show how spatial menu costs determine the selection of pricing zones.

## 3.1 Products, Stores, Markets, and Zones

Each firm operates a networks of stores. Stores, indexed by $s$, each have a location $\ell$. Firms may operate more than one store at $\ell$. Let $S_\ell^f$ be the set of stores operated by firm $f$ at location $\ell$, and let $S_\ell := \bigcup_f S_\ell^f$ be the set of all stores in location $\ell$.

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serve Lowe's stores with lumber, plywood, boards, and other building materials that can be forklift loaded onto flatbed trailers."

Each firm partitions its stores into pricing zones. Let these partitions be denoted by $Z^f$. An element in the partition is comprised of all the stores in the same pricing zone. Conceptually, if firm $f$ (superscript suppressed) operates four stores across two zones, with a single store in the first zone,

$$\begin{aligned} Z &:= \{z_1, z_2\} \\ &:= \Big\{ \underbrace{\{s_1\}}_{z_1}, \underbrace{\{s_2, s_3, s_4\}}_{z_2} \Big\}. \end{aligned}$$

If $s_1$ is in location 1, $s_2$ is in location 2, and $s_3$ and $s_4$ are both in location 3. The same partition could also be described by

$$Z = \Big\{ \underbrace{\{S_1\}}_{z_1}, \underbrace{\{S_2, S_3\}}_{z_2} \Big\}.$$

Zone pricing implies that for every product $j$ in every period $t$

$$p_{jst} = p_{js't}, \ \forall s, s' \in z$$

With the example above, the firm uses store level pricing for $z_1$. However, for all $j \in \bigcap_{i \in 2,3,4} J_{s_i}$, the price is constant for $j$ across $z_2$. Because the product set is allowed to be different across stores, the definition of a zone implies that if a product is offered at at least two stores within a zone, the price is the same across the stores.

Compared to the observed zone structure, alternative pricing regimes are associated with a spatial menu cost $\mu^{Z^f;Z^{-f}}$ that the firm must pay. These menu costs encompass all costs related to changing the zone structure – including reevaluating profits.

In total, there are $J$ differentiated drywall products, where each store offers a subset of these products each period. Let $J_{s,t}$ be the set of products offered at store $s$ in period $t$. The product set may change over time due to inventory or the discontinuation or introduction of a product. The discontinuation, introduction, and overall selection of products is not modeled; however, the product set is mostly constant within a zone so there is little evidence of strategic product placement. Given products, product characteristics, and prices, consumers at each location solve for demands.

A market is a location in time period, $(\ell, t)$. It has a market size of $M_{\ell,t}$.

## 3.2 Demand

Consumers solve a nested-logit discrete choice utility maximization problem. Consider a consumer living at location $\ell$. The choice set facing this consumer is the set of products sold by all stores at $\ell$, that is $\bigcup_{s \in S_\ell} J_{s,t}$ or an outside option. The decision to not purchase a good yields a normalized utility, $\mathcal{U}_{i0t} = \epsilon_{i0t}$. By purchasing product $j$, consumer $i$ receives indirect utility

$$\mathcal{U}_{ijt} = \mathbf{x}_j \boldsymbol{\beta} - \alpha p_{jt} + \xi_{jt} + \zeta_{igt}(\sigma) + (1 - \sigma)\epsilon_{ijt}, \tag{1}$$

where $\beta$ measures preferences over a vector of product characteristics $\mathbf{x}_j$, $p_{jt}$ is price, $\alpha$ is the marginal utility to income, and $\xi_{jt}$ is unobserved (to the econometrician) product quality. The composite taste shock, $\zeta_{ig}(\sigma) + (1 - \sigma)\epsilon_{ij}$, follows a Type-1 Extreme Value distribution among group $g$ – the nesting variable. The outside good is in its own nest. Note when $\sigma = 0$, the composite error term simplifies to just $\epsilon_{ij}$, which yields the standard logit demand system. As $\sigma \to 1$, products within nests are increasingly close substitutes, and in the limit, when $\sigma = 1$, there is no substitution outside of the nest. Each period consumers purchase the good that maximizes their individual indirect utility $U_{ijt}$ or select the outside good if $\mathcal{U}_{i0t} > \mathcal{U}_{ijt}$ for all $j \in \bigcup_{s \in S_\ell} J_{s,t}$.

As shown in Berry (1994), given the logit structure of demand, the log difference in market share of good $j$ compared with outside good $j = 0$ equals

$$\ln(\varsigma_{jt}) - \ln(\varsigma_{0t}) = \mathbf{x}_j \boldsymbol{\beta} - \alpha p_{jt} + \sigma \ln(\varsigma_{jt}/g) + \xi_{jt}.$$

Here, $\varsigma_j/g$ is the market share of product $j$ within group $g$.[4] The demand parameters to be estimated are $\boldsymbol{\theta}^D = (\boldsymbol{\beta}, \alpha, \sigma)$. We address the endogeneity of prices in Section 4.1.

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[4] We use $\varsigma_j$ to denote the purchase probability (market share) instead of the typically seen $s_j$ because we use $s$ to denote a store.

### 3.3 Supply

Prices are set in two stages. First, firms simultaneously partition their stores into zones, selecting $Z^f$ and paying spatial menu cost $\mu_{Z^f}$. After zone partitions are publicly known, firms select zone prices for each product to maximize total firm profits. The second stage price decisions differ from standard multiproduct Bertrand competition only in that firms are constrained for a given product to set identical prices within a zone.

The first stage is a simultaneous move game in which every possible zone partition is a possible action. Payoffs in the first stage depend on the spatial menu costs for the zone partition selected and the pre-menu cost profits that emerge from Bertrand competition in the second stage.

Let $c_{js}$ be the constant marginal cost associated with offering $j$ at store $s$. Given a zone structure chosen in the first stage, the profits accrued to a firm for selling product $j$ in period $t$ are

$$\pi_j^f := \sum_{z \in Z} \sum_{s \in z} (p_{jz} - c_{js}) q_{js}, \tag{2}$$

where $q_{js} := M_\ell \varsigma_{js}$ and $M_\ell$ is the market size corresponding to the location of store $s$. Implicitly, only zones and stores that offer $j$ are included in the sum, and $\varsigma_j := \varsigma_j(\mathbf{X}, \mathbf{p}, \boldsymbol{\xi}; Z, \boldsymbol{\theta}^D)$. Lastly, we assume there are no further fixed costs associated with offering products.

Firms maximize total profits. Total profits are the summation of profits over the products offered by the firm minus the spatial menu costs. Once zones are set, the second stage profit maximization problem involves selecting a price for every zone-product:

$$\max_{\mathbf{p}^f} \sum_{z \in Z^f} \sum_{s \in z} \sum_{j \in J_s} \left(p_{jz} - c_{js}\right) q_{js} - \mu(Z^f; Z^{-f}). \tag{3}$$

Each market share $\varsigma_{jst}$ is a function of the prices in market $(\ell, t)$, including all competitor prices.

The model is quite general and encompasses several cases which are commonly seen in retailing. In the special case of uniform pricing, there is only one zone for the firm and it contains the entire network. Since, $Z \equiv z := \{S\}$, the profit maximization takes simpler form. The first sum in Equation 3 disappears entirely so

$$\max_{\mathbf{p}^f} \sum_{s \in S} \sum_{j \in J_s} \left(p_{jZ} - c_{js}\right) q_{js} - \mu^{\text{uniform}}.$$

Another possibility is that firms operate store-level pricing, or market-level pricing Finally, in the second stage, firms take price zones as given and set prices to maximize profits.

An equilibrium for the game depends on zones and prices chosen amongst the players. Formally, an equilibrium is a set of pricing zones $Z^*$, prices $\mathbf{p}^* \in \mathbb{R}_+^{|Z^*|}$, and market shares $\boldsymbol{\varsigma}^* \in \mathbb{R}^{|J_S|}$ such that

1. Given pricing zones ($Z^*$) and competitor prices ($\mathbf{p}^{*-f}$), $\mathbf{p}^{*f}$ solves Equation 3
2. Given competitor pricing zones $Z^{*-f}$, $Z^{*f}$ is chosen such that

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

3. Given prices $\mathbf{p}^*$, $\boldsymbol{\varsigma}^*$ follows from consumers solving Equation 1

We assume firms play a game of perfect information in pure strategies.

Unfortunately, the equilibria defined for a given zone structure $Z$ are not in general unique. We found dozens of distinct equilibria for each system of zone partitions we examined. Caplin and Nalebuff (1991) proves uniqueness for competition within multinomial logit demand systems for single product firms, but its result does not generalize to the multiproduct firms we see in our data. In particular, there are equilibria in which firms assign high prices to some products to take advantage of the tail consumers with particularly high $\epsilon_{ij}$ draws while shepherding the rest of the consumers into moderately priced products. Different equilibria assign the role of the moderately priced mainstream alternative to different products and vary as to which stores engage in this version of price discrimination.

In order to evaluate the menu costs associated with alternative pricing policies we must ensure that differences we find are due to the policies themselves, and not due to switching between vastly different equilibria. We therefore investigate small deviations from the observed equilibrium, allowing firms to switch to market level pricing one product at a time. By only allowing for adjustments in prices of a specific good in a single market, the result of Caplin and Nalebuff (1991) does guarantee unique equilibria. Hence, in our definition of a Bertrand-Nash Equilibrium, we condition on the zone structure instead of having firms choose zones. We also explore a move to alternative pricing regimes for all products simultaneously. We discuss a metagame of zone choice and pricing, and calculate menu costs after implementing a selection mechanism on equilibrium. All experiments are reported in Section 5.

# 4 Estimation and Results

We proceed by estimating the demand parameters which enter shares $\varsigma$ as well as marginal costs. We run our estimates in two stages. First, we estimate the demand parameters of the nested logit model. Given estimates of the demand parameters, we solve for marginal costs assuming firms are competing in a Bertrand game of zone pricing. As zone pricing is a consequence of solving a constrained optimization problem, we cannot invert the first-order conditions to back out marginal costs. Instead, we parametrize the cost function, and simultaneously recover marginal costs and cost parameters using mathematical programming with equilibrium constraints (MPEC). With our estimates, we calculate observed profits of the current zone structure. Given the presence of multiple equilibria, we use observed prices to calculate current zone profits.[5]

## 4.1 Demand

We invert market shares, as shown in Berry (1994), to obtain $\ln(\varsigma_j) - \ln(\varsigma_0) = \delta_j$, where $\delta_j$ is the mean utility from purchasing product $j$. To account for the endogeneity of unobserved product quality being correlated with price, we pursue both instrumental variable and

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[5] By solving for equilibrium zone prices given observed prices as starting values, we obtain equilibria prices quite close to observed prices. The geometric fit between the two is 93%. This is discussed further in Section 5.

fixed effects approaches. We separate unobserved product quality as

$$\xi_{jt} := \xi_j + \xi_t + \Delta\xi_{jt},$$

where we assume $\Delta\xi_{jt}$ is uncorrelated with price and observed product characteristics. For product characteristics, we use the dimensions of the gypsum board (length, width, height), and whether the drywall is mold resistant and/or moisture resistant. We estimate $\xi_t$ as a market-time fixed effect. We compare this method with an instrument variables approach, where we instrument price by using a Hausman instrument – average prices for a given product in other markets where the product is offered.

We use a product-store hierarchy for nests within markets. The top level of nests denotes the various product types available in the market $(\ell, t)$. We define product types as the grouping of product dimensions. The second nest comprises the various stores in the market that sell that particular product type. The interpretation of $\sigma$ in this nesting structure is the degree of substitutability of a product type across the various stores at location $\ell$ at time $t$. We specify the nesting structure this way because of conversations we have had with home builders, who say that by far, the most important characteristic of drywall is the size, particularly the thickness. Specifically, almost all walls use 1/2-inch boards, but 5/8-inch is necessary on fire walls, such as the walls separating the interior of a house from its garage. If size is the most important characteristic, we would expect that consumers substitute to other stores in the market for a particular drywall type instead of substituting to a different size sheet at the same store. Hence, our nests are at the product type level instead of the store level. We expect to (and do) estimate $\sigma$ close to one, which suggests that a particular product type is highly substitutable across stores within a market.

Identification for parameters in this stage results from the observed purchases of consumers given their choice set, following the standard revealed preference identification for discrete choice demand systems. In every market, all products and their associated prices and characteristics are known. Product indicators and characteristics are constant across all markets. The other products offered vary by market and relative prices vary by zone. The response of sales quantities to these different relative prices and product offerings identifies the price coefficient $\alpha$. Preferences for observed and unobserved product characteristics are revealed through market shares.

We estimate several demand specifications. First, we set $\sigma = 0$ in the nested logit model so that the nests do not matter. This results in the classic logit demand system. We estimate this specification assuming prices are exogenous (using Ordinary Least Squares) and then use a fixed-effects approach to address the endogeneity of prices. We then estimate $\sigma$ along with the demand parameters, again assuming prices are exogenous, and then accounting for endogeneity. Given the nesting structure, all observed product characteristics within a nest are identical, except price which may vary across the stores in the market. Hence, for the nested logit model using instrumental variables, we use store fixed effects to address the endogeneity problem on the group shares. For the nested logit model using fixed effects, the endogeneity problem on group shares is already addressed by having the fixed effects be product-store ("$j$") specific.

We aggregate daily sales so that $t$ denotes a two week period because many drywall products have few daily sales. Observations with zero sales must be dropped, because $\ln(\varsigma_{jt})$ would be undefined[6] At the biweekly level, 5.70% of products exhibit zero sales. Aggregating data across time does not introduce as much measurement error as it might in other applications, because product characteristics are all time-invariant and prices rarely change. Over 127 days of data collection, only 9.4% of product-store combinations exhibit price changes. Of the products to see price adjustments, 88% (77 products) of them experience a single change and 12% (11 products) see two price adjustments.

In order to complete the demand system, we need to specify market size. 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 $\ell$ typically has several stores from both Home Depot and Lowe's. Further, given the structure of pricing regions by both firms, regions overlap into several markets. We take market size to be proportional to the 2010

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[6] See Gandhi, Lu, and Shi (2013) for estimating discrete choice demand systems with products that exhibit zero sales.

CSBA population.[7]

Table 3: Demand estimation results

| | (1)<br>Logit | (2)<br>Nested logit | (3)<br>IV nested logit | (4)<br>FE nested logit |
|---|---|---|---|---|
| Price | $-0.594^{***}$ | $-0.650^{***}$ | $-0.831^{***}$ | $-0.359^{***}$ |
| | (0.0172) | (0.0108) | (0.0129) | (0.0141) |
| Area | $0.130^{***}$ | $0.158^{***}$ | $0.194^{***}$ | $0.107^{***}$ |
| | (0.00404) | (0.00269) | (0.00308) | (0.00639) |
| Mold resistance | $1.167^{***}$ | $1.385^{***}$ | $1.838^{***}$ | $1.555^{***}$ |
| | (0.0667) | (0.0441) | (0.0457) | (0.260) |
| Chain | $0.938^{***}$ | $0.295^{***}$ | $1.719^{***}$ | $0.292^{*}$ |
| | (0.0334) | (0.0231) | (0.176) | (0.116) |
| $\sigma$ | | $0.918^{***}$ | $0.601^{***}$ | $0.831^{***}$ |
| | | (0.00821) | (0.0119) | (0.00887) |
| Thickness indicators | Yes | Yes | Yes | Yes |
| Store indicators | No | No | Yes | Yes |
| Product indicators | No | No | No | Yes |
| elasmean | -6.620 | -55.99 | -17.58 | -15.79 |
| elasmin | -12.92 | -136.7 | -35.87 | -36.57 |
| elasmax | -2.665 | -2.894 | -2.869 | -1.609 |

Standard errors in parentheses.

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

The results of the demand estimation appear in Table 3. Across all specifications, all coefficients have expected signs and are significant across specifications. We estimate that consumers prefer larger drywall sheets and mold resistant panels. The unreported coefficients on drywall thickness are reasonable and show that industry standard 1/2-inch panels are much more desirable than all other thicknesses. We estimate that consumers are price sensitive, with the marginal utility of income $-0.375$ in the fixed effects, nested-logit model (Model 4). Our estimates on price sensitivity do not become more negative when accounting for the potential endogeneity between prices and unobserved drywall

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

quality, which is not what we would expect as high priced items are typically assumed to be positively correlated with unobserved quality. This is true for both the fixed effects and instrumental variables approach. Our interpretation on the price coefficient across specifications is that given any two drywall products with identical (observed) characteristics but different prices, consumers would gravitate towards the cheaper good as the other (unobserved) characteristics are not worth the additional expense. Hence, in our setting, the correlation between unobserved quality and price is negative leading to price sensitivities closer to zero after accounting for endogeneity. We estimate the mean own-price elasticities to be -16 and -18 for the fixed effects and instrumental variables nested logit models, respectively. These values are large in magnitude but not unreasonable given the high substitutability of drywall products, especially within nests. For the final specification (4), we obtain industry elasticities of $-0.03$ to $-0.04$ depending on the market. Finally, we estimate the coefficient reflecting substitutability within nests to be high, at 0.830 in the last specification. This suggests that consumers would rather drive to another store within the market to buy a particular drywall panel than substitute to a different size.[8]

In the following analysis, we use Model (4) – the nested logit model with fixed effects – as our model of consumer demand. Our results are not sensitive to this choice as the nested logit model with instrumental variables yields quantitatively similar answers. Aggregating the data to just the week level also yields similar results.

## 4.2 Recovering Marginal Costs

Marginal costs can typically be recovered using the demand estimates and the first order conditions of each profit maximizing firm. In the single good, market level pricing case, Lerner's index is inversely proportional to the own-price elasticity. With observed prices and an estimated demand elasticity, the marginal cost is identified. A multi-product analog, as seen in Nevo (2001) and Petrin (2002), can be used when firms set prices for all products at the market level. Since firms here set a uniform zone price, the first order condition based on Equation 4 differs from the condition on which the standard approach

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[8] Our model of demand assumes it is costless for consumers to travel to stores within a market.

is based. Each price $p_{jz}$ is obtained from solving

$$\frac{\partial \pi}{\partial p_{jz}} = \sum_{s \in z} \sum_{i \in J_s} (p_{iz} - c_{is}) M_\ell \frac{\partial \varsigma_{is}}{\partial p_{jz}} + \sum_{s \in z} M_\ell \varsigma_{js} = 0. \tag{4}$$

The first-order condition for each price contains marginal costs for all stores within its pricing zone. The supply system yields $|J \times Z|$ first-order conditions of the form in Equation 4. However, there are $|J \times S|$ marginal costs to identify and $|S| > |Z|$. As there are more marginal costs than first-order conditions, no set of first-order conditions can be directly solved to recover marginal costs.

To make progress in recovering marginal costs, we first parametrize costs as

$$c_{jst} = a_j + \kappa d_s + \nu_{jzt},$$

where $a_j$ is a fixed effect for product $j$, and $d_s$ is the distance from store $s$ to the closest flatbed distribution center. The cost shock $\nu_{jzt}$ is an unobserved (to the econometrician) and enters at the product, zone, time level. Let $\theta^S = (\mathbf{a}_j, \kappa)$. Because the cost shock is at the product level, we cannot manipulate Equation 4 to recover costs directly; however, given an objective function on $\nu$, we can simultaneously recover marginal costs and the parameters governing costs. Instead of using a nested fixed-point approach, we proceed with using mathematical programming with equilibrium constraints (MPEC) as seen in Su and Judd (2012). Forming moment conditions on $\nu$ directly, along with the optimality conditions from the firms' zone pricing problems, completes the mathematical program.

Firms want high prices at stores with high costs and at stores with monopoly power. An unconstrained optimum price for a competitive, low-cost store would be lower. When a firm has both types of stores in the same price zone, the optimal price balances these considerations using Equation 4. Only the zone price, market power (through estimated price elasticities), market size, and a few cost variables are observed, but the zone price reveals information on the marginal costs for its stores. Identification effectively comes from how weighted averages of store cost variables are correlated with the zone price. For example, if zones full of competitive stores far removed from a distribution center have a high zone price, then distribution center distance is an important driver of costs.

Our simplification in making the unobserved error term $\nu$ be product, zone, time specific instead of product, store, time specific results in the dimension of the error term being equal to the number of equilibrium conditions. Without this assumption on the cost shock, we would have an unidentified system. Although restrictive, we do account for transportation costs and wages at the store level.

The objective comes from moment conditions on $\boldsymbol{\nu}$. Let $\mathbf{W} := [\mathbf{a}_j, \mathbf{d}]$ be the matrix of covariates on costs. The method of moments estimator is derived from $\mathbb{E}[\mathbf{W}'\boldsymbol{\nu}] = \mathbf{0}$, leading to the sample analogue

$$g_j(\mathbf{W}, \boldsymbol{\theta}^S) = \frac{1}{N} \sum_{i=1}^{N} w_{ji} \nu_i = 0.$$

Letting $\mathrm{FOC}(\boldsymbol{\theta}^S, \boldsymbol{\nu})$ denote the set of equilibrium conditions characterized by the first-order conditions of the firms' problems, the MPEC program is to solve

$$\begin{aligned} &\min_{\boldsymbol{\theta}^S, \boldsymbol{\nu}} g(\mathbf{W}, \boldsymbol{\theta}^S)' g(\mathbf{W}, \boldsymbol{\theta}^S) \\ &\text{s.t. } \mathrm{FOC}(\boldsymbol{\theta}^S, \boldsymbol{\nu}) = \mathbf{0}. \end{aligned}$$

In estimating costs, we obtain a negative, but insignificant coefficient on wage. We drop wage from the model and proceed with estimating product fixed effects and the coefficient on distance. The remaining coefficients are very similar to the model with wages included. Cost estimations are reported in Table 4. We estimate the parameter on distance (per mile) to be \$0.00052. On average, transportation from the distribution center contributes \$0.20 to the cost of a drywall sheet. We find transportation costs for different stores range from \$0.002 to \$0.46. The coefficient on distance is lower than other estimates of transportation costs in similar settings. Miller and Osborne (2014) estimate a transportation cost \$0.30/ton mile for Portland cement. The equivalent cost for a fifty pound sheet of drywall would be \$0.0075/mile, which is over eleven times larger than we find. If, however, other products shipped to stores on flatbed trucks need frequent deliveries, perhaps much of the drywall inventory is shipped on trucks with spare capacity. Indeed, we find that the deliveries for drywall are less than the full capacity of a flatbed trailer.

## 4.3 Observed Pricing Regime

With the observed prices and the marginal costs we estimate, we calculate the sales weighted average markup on a sheet of drywall to be $1.11. With an average price of a sheet of drywall at $10.22, we find the margin on drywall to be around 11.0%. We estimate profits on drywall for the stores of interest to be about $29 million annually. Table 5 details equilibrium zone pricing profits by chain and competition type. Only 3 of the 53 Lowe's stores in our region are in markets where Home Depot is absent. Home Depot on the other hand has 20 of their 75 stores in markets without competition from Lowe's. These twenty account for 38% of Home Depot's revenue. Interestingly, 15 of the 20 Home Depot monopoly stores are in pricing zones with stores that do face competition from Lowe's. A higher price that would extract the most profit in the monopoly markets must be balanced by a lower price needed to maintain market share in competitive markets. Because several of the monopoly stores are in large, lower cost zones, average prices for monopoly markets are slightly below average prices overall. As a consequence, the current zone structure greatly limits Home Depot's effective market power. Indeed, we estimate Home Depot only obtains 16.48% of its profits from monopoly stores

Figure 4 plots a histogram of observed profits, by chain, aggregated by store. The histograms show there is considerable variation in profits across stores. In this region, Home Depot distribution centers are closer to more stores, so our estimates generally find Home Depot stores to have lower costs and higher profits than Lowe's stores. We estimate a majority of the Lowe's stores have less than $1 million in annual profits for drywall, with the maximum profits being nearly $2 million annually. On the other hand, Home Depot operates a few stores that exceed $2 million in annual profits. Both chains operate stores with nearly zero profits from drywall sales.

Table 4: Cost Estimates

| | Point Estimates | Std Error |
|---|---|---|
| dist ($\kappa$) | 0.00052 | (0.00016)$^{***}$ |
| | *Product Fixed Effects* | |
| $a_1$ : 8.384 | $a_{11}$ : 11.631 | $a_{21}$ : 12.609 |
| $a_2$ : 7.561 | $a_{12}$ : 12.154 | $a_{22}$ : 11.323 |
| $a_3$ : 2.088 | $a_{13}$ : 10.670 | $a_{23}$ : 14.052 |
| $a_4$ : 7.137 | $a_{14}$ : 10.900 | $a_{24}$ : 18.613 |
| $a_5$ : 7.947 | $a_{15}$ : 12.395 | $a_{25}$ : 13.860 |
| $a_6$ : 7.948 | $a_{16}$ : 12.063 | $a_{26}$ : 9.760 |
| $a_7$ : 9.307 | $a_{17}$ : 8.921 | $a_{27}$ : 9.989 |
| $a_8$ : 14.592 | $a_{18}$ : 11.042 | $a_{28}$ : 15.298 |
| $a_9$ : 7.137 | $a_{19}$ : 11.180 | $a_{29}$ : 10.236 |
| $a_{10}$ : 12.990 | $a_{20}$ : 13.269 | $a_{30}$ : 14.363 |
| | | $a_{31}$ : 14.873 |

Zone clustered standard errors. All FEs significant at 1%

$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$

Table 5: Current Profits by Chain and Market Type

| | Lowe's | | Home Depot | |
|---|---|---|---|---|
| | % of $\pi$ | Annual $\pi$ | % of $\pi$ | Annual $\pi$ |
| Monopoly | 3.28% | \$273,462 | 16.48% | \$3,356,029 |
| Duopoly | 96.72% | \$8,057,492 | 83.52% | \$17,007,531 |
| Total Annual $\pi$ | | \$8,330,954 | | \$20,363,560 |

Duopoly means there is a competitor store in the market (CSBA). Profits are annualized.

# 5 Metagame Analysis

## Pricing and Profits

In this section we explore the metagame in which firms choose to adopt zone pricing or market level pricing. There are millions of zone combinations so we only explore the option of selecting the current zone structure for each firm, or a move to market level pricing for the entire network. We calculate the Bertrand-Nash Equilibrium (BNE) for four pricing regimes: Lowe's and Home Depot keep their current zone structure, Lowe's moves to market level pricing and Home Depot keeps its current zone regime, Home Depot moves to market level pricing and Lowe's keeps its current zone structure, and finally, both firms move to market level pricing. Prices adjust for all products in all periods.

As previously noted, there are multiple equilibria for each of these pricing regimes. We utilize a selection mechanism on the number of products with low sales. Due to the logit error term, high prices yield marginal sales, but the firm may choose to set very high prices so that consumers substitute to other products with better margins. Of the equilibria found, we select the equilibrium for each scenario that has the lowest number of products priced sufficiently high as to yield marginal sales. For example, in solving for equilibria based on the current zone structure, there are equilibria in which the price of a product is such that sales are close to $10^{-6}$ sheets per week. We sum up the number of product-store combinations in which this occurs and select the equilibrium with the lowest number. We gauge the performance of this selection mechanism by comparing the observed zone equilibrium with the calculated zone equilibria. The lowest number of observations with marginal sales is 306. The median difference between equilibrium and observed zone prices is \$0.007 and the mean difference is \$0.11. Lowe's observed annual profit is \$8,330,954 for the 53 stores in the sample. With our selection mechanism, we calculate equilibrium zone profits for Lowe's at \$8,301,573. For Home Depot, we obtain observed and equilibrium zone price profits of \$20,363,560 and \$20,736,293, respectively. Other selection mechanisms, such as the sum of total profits, yields unrealistic equilibrium profits given observed sales.

If both firms choose zone pricing in all markets, in all periods, we must solve for nearly

7,000 prices. The other three possible outcomes have even more prices to solve for. The optimality conditions on firms' problems are highly nonlinear, so we solve for equilibria using state of the art solvers. To search for equilibria, we set 1,000 random starts and solve for the fixed point. On average, around one-third of the starts converge to a fixed point – a BNE for the regime choice.

Since both firms utilize zone pricing, we solve for two parameters of the meta game: a lower point on the menu costs associated with adopted market level pricing. Table 6 provides the payoff matrix associated with the metagame. In the absence of menu costs, both Lowe's and Home Depot would adopt market level pricing; however, in this case, Lowe's obtains lower profits with market level pricing than with zone pricing. This is due to both higher demand for Home Depot products in general, as well as a cost advantage in the stores located around Salt Lake City, where Home Depot has a distribution center, but Lowe's does not. This allows Home Depot to undercut Lowe's and gain market share. This analysis shows that a finer degree of pricing – in this case the ability to discriminate at the market level – does not lead to larger profits, a possibility noted in Holmes (1989). Indeed, additional competition hurts Lowe's, but provides a nearly 14% increase in profits for Home Depot.

Table 6: Metagame of market or current zone pricing

| Lowe's / Home Depot | Zone Level Pricing | Market Level Pricing |
|---|---|---|
| Zone Level Pricing | \$8,301,573, \$20,736,293 | \$7,681,509 , \$21,667,885$-\mu^{HD}$ |
| Market Level Pricing | \$8,705,745$-\mu^{L}$, \$20,937,713 | \$7,818,741$-\mu_{L}$, \$23,632,457$-\mu^{HD}$ |

The zone numbers are equilibrium zone profits instead of observed profits.

Also in the absence of menu costs, we find that moving to market level pricing for a single firm increases profits for that firm. Lowe's sees a 4.8% increase in pre-menu cost profits by moving to market level pricing with Home Depot keeping its zone structure. Home Depot also sees modest gains with this regime at 0.97%. On the other hand, if Home Depot moves to market level pricing but Lowe's keeps its zone structure, Home Depot sees a 4.8% increase in profits, largely due to the ability to discriminate in monopoly markets. However, with this regime, Home Depot's competitive advantages, both in costs and demand, results in a 5.9% decrease in profits for Lowe's.

For zone pricing to be the solution of the metagame in pure strategies, it must be the case that $\mu^{L} \geq \$404,172$ and $\mu^{HD} \geq 2,694,744$. These numbers represent lower bounds on the menu costs associated with adopting market level pricing. These equate to 4.8% and 13.0% of profits for Lowe's and Home Depot, respectively. Together, this yields a menu cost of 10.3% of industry profits, about half the figure calculated using single product deviations. Other market level pricing equilibria exist, some giving much higher profits that match or exceed the menu costs of Section 5. The lower profits in the selected equilibrium could reflect the substitutability between products. Price decreases on one product could prompt the rival firm to discount other products. The increased competition on all products (instead of on only one product) may reduce market share, prompting further rounds of discounting, and lower profits.

Table 7 provides summary statistics at the market level across the various pricing regimes of the metagame. The table also provides a summary of the equilibrium in which firms use uniform pricing. We find Lowe's would earn higher profits under uniform pricing than zone pricing (utilizing our selection mechanism). This is consistent with Lowe's earning lower profits under market level pricing than zone pricing; that is, Lowe's benefits when Home Depot has limited ability to price discriminate. Under zone pricing, Home Depot balances the benefits of discriminating in monopoly markets with its desire to undercut Lowe's in duopoly markets. This allows Lowe's to capture market share in duopoly markets that it would not if Home Depot priced at the zone or market level. With uniform pricing, Home Depot obtains approximately \$18.8 million in profits, \$1.8 million less than when both firms use zone pricing and nearly \$5.0 million less than when both firms use market level pricing.

Since Home Depot operates several monopoly stores as part of larger zones, finer pricing results in monopoly prices in these markets, whereas with uniform and zone level pricing, Home Depot balances discriminating in these markets with competing with Lowe's in other markets. The relationship between zone structure and profits is opposite for Lowe's. With a cost disadvantage in the large Salt Lake City market, lower mean utility overall for products, and few monopoly stores, Lowe's does not capture additional profits from finer pricing. Instead, the chain benefits when Home Depot has reduced ability to discriminate in competitive markets.

Figure 4: Histogram of observed profits, by chain, and aggregated to the store level.

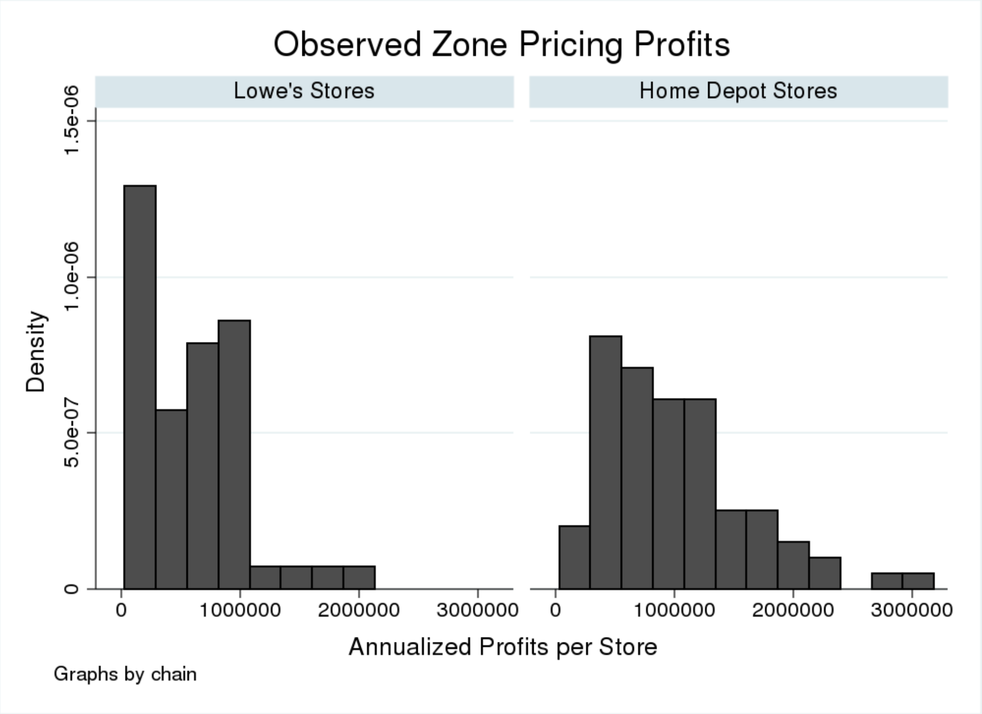

Table 7: Chain Performance Across Pricing Regimes, summarized across markets

| | | (1) Zone BNE | (2) Market BNE | (3) Uniform BNE | (4) HD Dev. BNE | (5) Lowe's Dev. BNE |
|---|---|---|---|---|---|---|
| **Lowe's** | | | | | | |
| | mean | 276,719 | 260,625 | 290,048 | 256,050 | 290,192 |
| | median | 135,203 | 120,247 | 132,386 | 120,634 | 124,887 |
| | lower quartile | 51,632 | 57,659 | 61,037 | 63,012 | 64,053 |
| | upper quartile | 333,312 | 283,439 | 349,276 | 277,780 | 270,362 |
| | min | 39,470 | 26,298 | 50,449 | 42,432 | 25,423 |
| | max | 1,650,275 | 1,496,118 | 1,777,272 | 1,500,762 | 1,714,356 |
| | total profits | 8,301,573 | 7,818,741 | 8,701,427 | 7,681,509 | 8,705,745 |
| **Home Depot** | | | | | | |
| | mean | 441,198 | 508,721 | 401,253 | 461,019 | 445,483 |
| | median | 243,045 | 274,062 | 176,794 | 262,462 | 241,781 |
| | lower quartile | 142,205 | 196,623 | 125,986 | 191,048 | 149,604 |
| | upper quartile | 435,670 | 496,624 | 382,818 | 418,650 | 438,875 |
| | min | 50,292 | 23,443 | 55,720 | 49,148 | 71,889 |
| | max | 2,979,718 | 2,906,893 | 2,868,559 | 2,842,305 | 2,916,245 |
| | total profits | 20,736,293 | 23,909,881 | 18,858,886 | 21,667,885 | 20,937,713 |

Results are annualized and aggregated to the market level.

## Consumer Surplus

Finally, we investigate how consumer surplus changes across pricing regimes. Given the nested logit demand system, the change in consumer surplus across pricing regimes for consumer $i$ at location $\ell$ can be written as

$$\mathbb{E}[\Delta CS_{i,\ell}] := \frac{1}{\alpha}\left[\ln\left(1+\sum_g D_g^{1-\sigma}(Z')\right) - \ln\left(1+\sum_g D_g^{1-\sigma}(Z)\right)\right],$$

where $D_g = \sum_{j \in J_g} \exp(\delta_j/1-\sigma)$, $Z'$ represents prices under counterfactual zones, and $Z$ represents prices under observed zones. Multiplying $\mathbb{E}[\Delta CS_{i,\ell}]$ by $M_\ell$ yields the total change in consumer surplus for a single market. We then aggregate across markets to calculate the total change in consumer surplus.

Table 8 quantifies the change in consumer surplus across four counterfactual scenarios. In the aggregate, we find that equilibrium uniform pricing results in the highest consumer surplus, increasing consumer surplus by nearly \$500,000 annually for the 128 stores in the sample. Market-level pricing results in higher prices for consumers and decreases consumer surplus by close to \$1 million. The move for one chain to adopt uniform pricing while the competitor sets optimal zone pricing under observed zones has varying impact. If Lowe's moves to uniform pricing, we find consumer surplus goes down by nearly \$100,000 annually; however, if Home Depot moves to uniform pricing, consumer surplus goes up by nearly \$300,000. These figures reflect both the estimated Home Depot costs advantage and that Home Depot operates many more monopoly stores in the sample.

Table 8: Consumer Surplus Across Pricing Regimes

| Regime Change | Agg. $\mathbb{E}[\Delta CS]$ | $\min_\ell(\mathbb{E}[\Delta CS_\ell])$ | $\max_\ell(\mathbb{E}[\Delta CS_\ell])$ |
|---|---|---|---|
| Zone → Uniform | \$473,762 | -\$135,721 | \$181,456 |
| Zone → Market | -\$965,073 | -\$196,841 | \$12,354 |
| Zone → Lowe's Uniform | -\$94,488 | -\$95,082 | \$39,646 |
| Zone → HD Uniform | \$285,748 | -\$46,164 | \$69,625 |

Consumer surplus numbers annualized. These numbers are for the 128 stores in the sample.

The direction of consumer surplus changes under uniform and market-level pricing are opposite of what they are for firms; however, the magnitudes differ substantially. After accounting for the change in profits under different regimes and zero menu costs, we find uniform pricing lowers total surplus by $1,003,791 annually, whereas market level pricing increases total welfare by $1,725,683 annually.

## 6 Conclusion

In this article, we document the prevalence of zone pricing in home improvement retail stores. Although product categories such as drywall and lumber have sizable price variation nationally, within regions there can be no price variation within firm. The size of zones, including the number of stores and the number of markets per zone, varies from product category to product category. We find some product categories with hundreds of zones, and for other categories, a single firm, or uniform pricing, is pursued by a firm. Having different zone structures by product category is not surprising given that retailers have separate marketing managers for different product categories. The choice of the zone structure reveals how firms balance discrimination and competition across markets. We postulate that the use of zone pricing, instead of a finer grade of pricing, such as by market or by store, is the result of firms facing a friction – “spatial menu costs". These spatial menu costs have induced firms to set a constant price over multiple markets.

To provide a measure of the spatial menu costs needed to rationalize the use of zone pricing, we estimate a structural model of consumer demand on a detailed data set of retail drywall. We find that consumers consider the products of competing chains to be close substitutes, but the industry elasticity for drywall is inelasitic. Assuming firms are engaged in Bertrand price competition, we back out marginal costs to find that transportation costs are a small, but significant, component of costs.

Given our estimates on supply and demand, our menu costs are calculated by comparing the observed profits in zone level competition to the equilibrium profits in which firms adopt market level pricing. Since firms are offering multiple products, priced uniformly across several markets, multiple equilibria exist. To obtain menu cost estimates, we investigate small deviations in the current zone structure which result in unique counterfactual equilibria. Finding the equilibria for these alternative pricing regimes yields a lower bound on the spatial menu costs at 2.2% of current revenues or 22% of observed profits. While the previous literature on zone pricing has determined menu costs may be large, these articles have not taken into account the competitive interaction of firms. We find that ignoring competitive effects by fixing opponents prices implies much larger gains from market level pricing which overstates the spatial menu costs by upwards of 32%, at 3.3% of observed revenues.

Spatial menu costs force firms into a price zone system that prevents them from abusing their market power. In an industry like drywall with high transportation costs and inelastic demand, menu costs and zone pricing protect consumers in monopoly markets. The elimination of the menu costs would prompt a new level of strategic competition in the duopoly markets, but according to our estimates would still leave the retailer more profitable.

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