Incentives for Non-Price Competition in the California WIC Program
Job Market Paper

Patrick W. McLaughlin\textsuperscript{a,1,2}

\textsuperscript{a}Department of Agricultural and Resource Economics, University of California, Davis, One Shields Avenue, Davis, California, USA, email: patrickm@primal.ucdavis.edu

Abstract

Institutional details of the California WIC Program’s food assistance component give rise to a retailer who does not compete in price for perfectly price inelastic WIC consumers. A theoretical model of non-price competition hypothesizes that pure non-price competition in brands mimics price competition whereby these retailers carry more and better brands under intense spatial competition; and, that retailers will either minimally or maximally differentiate in horizontal (e.g., physical) space. I use a unique dataset on these retailers’ locations and brand offerings as well as participants’ food benefit redemption patterns to empirically confirm that retailers compete in brands. Namely, retailers carry more and better brands in salient product categories when facing more competitors, which, in turn, reduces attrition and increases market share. The results also suggest that maximal horizontal differentiation prevails, allowing the retailers to minimize costly brand competition.

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1. Introduction

How will firms compete with one another when they have no incentive to compete in price? My paper offers an answer to this question using vendors serving the food assistance component of the California Special Supplemental Nutritional Program for Women, Infants and Children (California WIC Program) as a case study. The WIC Program is a federally funded and state administered two-part health intervention and food assistance program for low-income new and to-be mothers, as well as their infants and young children. The Program is far-reaching nationally, covering one-half of all newborn infants and one-quarter of all children under the age of five in the United States (Davis 2007). Over 1.5 million individuals participated in the California WIC Program in 2012, accounting for roughly one-sixth of all participants nationwide.

The institutional details of food assistance in the California WIC Program render it an ideal yet previously unexplored case study in non-price competition. First, consumers participating in the Program are insensitive to price due to the structure of food benefits distribution. The Program provides food benefits to participants at no cost via redeemable vouchers, or food instruments (FIs), for fixed quantities of food items of specific product categories. For example, FI 6011 allows for purchase of thirty-six ounces of breakfast cereal, one loaf of whole wheat bread and one gallon of low-fat milk. Participants can choose any brands among a Program-approved set, which often includes leading national brands, when redeeming their FI regardless of the price listed on shelves. In this respect, WIC differs from other food assistance programs, such as SNAP, where benefits amount to a direct monetary transfer and participants face budgetary restrictions. WIC participants, on the other hand, have no incentive to choose inexpensive
brands when offered the choice.

My study focuses on the strategic non-price behavior of a subset of retailers who sell WIC food items. FI redemption takes place at state-authorized WIC vendors, a diverse group of over 5,500 private retailers in California, as of 2012, including supercenters (e.g., Walmart), supermarkets (e.g., Safeway), smaller groceries, corner and convenience stores. WIC vendors provide goods specified by individual FIs to participants in exchange for reimbursement by the state up to a pre-specified maximum dollar amount, or maximum allowable departmental reimbursement (MADR) in regulation parlance. Vendors record the prices of the goods sold under the FI to compute the redemption value and have the right to request reimbursement up to the MADR. Additionally, the Program requires all vendors to carry at least one brand of every WIC product category, although virtually all vendors exceed these minimum stocking requirements.

While WIC sales constitute a small fraction of total business for most vendors, they are the primary source of food business for a special class of vendors, which are the focus of this study. In particular, roughly one-sixth of all California WIC vendors are so-called “Above 50%” (A50) vendors, a designation the Program applies to all vendors with WIC sales comprising 50% or more of all food sales. A50 vendors are pivotal in the operations of California WIC, accounting for over one-third of all WIC transactions in the state. Because participants almost exclusively comprise A50 vendors’ food customer base, these vendors have no strategic incentive to lower the prices charged for WIC items to attract WIC consumers due to the perfect inelasticity of their demand. In this sense, my study organically abstracts from price competitive behavior allowing me to observe pure non-price competition in a market setting.
One opportunity for A50 vendors to engage in non-price competition is the quantity and quality of brands that they carry. California WIC authorizes numerous brands, for which some product categories are highly horizontally (e.g., flavors of breakfast cereal) and vertically differentiated (e.g., national versus “off” brands). If WIC participants have strong preferences for particular brands, then A50 vendors have an incentive to craft their WIC brand profile to attract customers. On the other hand, government payments reimbursing vendors are capped, and carrying more and better brands is costly, thus decreasing margins on FI redemptions. Hence, it is unclear a priori that A50 vendors will engage in costly non-price competition, and, if they do, what form it will take.

As the distance between competitors diminishes, or as they become more numerous, A50 vendors’ incentive to strengthen their brand profile increases as a way to attract and maintain WIC customers. The threat of costly brand competition may cause vendors to choose retail locations in order to minimize the intensity of spatial competition. On the other hand, restrictions placed by California WIC on the eligible set of food items may limit the amount of brand competition that vendors can undertake. In this case, vendors can agglomerate in one location without having to succumb to brand competitive measures. Thus, the institutional details of the Program may interact with the strategic behavior of A50 vendors in complex ways that are little understood presently.

To the above end, I develop a theoretical model of non-price competition where vendors choose locations in the tradition of Hotelling (1929) and the quality of brands that they sell. The model is consistent with the idea that the strength of the optimal brand profile increases with the intensity of spatial competition. In general, whether A50 vendors adhere to a principle of minimal or maximal
horizontal differentiation depends upon the strength of the cost restrictions. I show that both strategies are Nash equilibria and develop an empirical approach to uncover which equilibrium persists in a real market setting. The addition of space distinguishes my study from previous work on non-price competition in the airline industry (Douglas and Miller 1974; White 1972) and causes me to arrive at more nuanced conclusions.

I empirically examine the incentives of A50 vendors to engage in brand competition using a unique cross-sectional data source on the location and characteristics of WIC vendors and the redemption patterns of participants. In particular, I observe the brand profile and in-store characteristics of a random sample of A50 vendors; and for all WIC vendors, their geographic location and the FIs redeemed over multiple years with a unique participant identification number. I use the location of WIC vendors to define two variables measuring the intensity of spatial competition that an A50 vendor faces.

First, I find that having more of certain brand types reduces vendor attrition, the rate at which participants fail to be repeat customers. Contrary to the common belief that food assistance-eligible consumers face limited food retail options, I observe that a significant number of participants commit vendor attrition when the proximity of other A50 competitors grows. In such an environment, A50 vendors with more of certain brand types (but not others) experience less attrition, effectively minimizing the intensity of spatial competition. Therefore, one demonstrated incentive for brand competition is to relieve the competitive pressure applied by nearby rival vendors.

Second, I find that vendors who carry more numerous and costly brands of certain product categories have higher benefit redemption market shares, a necessary
condition for the profitability of brand competition. Brand variables positively relate to market share for only a subset of product categories, which is consistent with the first set of findings. Vendors with more and better brands of breakfast cereal claim a higher market share of FI redemptions, a result not replicated for fruit juice brands. These results reflect the brand offerings of A50 vendors: many high-cost, leading brands of breakfast cereal are available on nearly all A50 vendors’ shelves, however the offering of juice brands is much more heterogeneous in this regard. It appears then that A50 vendors may optimally focus brand competition in specific categories rather than improve variety overall when they cannot strategically set prices. Additionally, policymakers looking to reduce Program costs can disallow expensive brands that consumers care little about without significantly impacting welfare.

Last, I empirically model the average wholesale costs of vendors’ brand profiles, a proxy for quality, as a function of the intensity of spatial competition. This approach allows me to test the prediction that more spatial competition leads to increased brand competition while assessing whether vendors tend to minimally or maximally differentiate. Accounting for the theorized endogeneity and spatial autocorrelation in the errors, I confirm that A50 vendors carry more and better brands when they face more competitors. Further, results from estimation are consistent with vendors maximally but not minimally horizontally differentiating, on average (Hotelling 1929; d’Aspremont et al. 1979). I find then that non-price competition is analogous to price competition where firms seek out mutually disparate locations to alleviate the competitive pressures they place on one another. Further, the degree of allowed brand competition enhances access to the California WIC Program by indirectly encouraging more A50 vendor locations compared to
a case where expensive and preferred brands are disallowed. This finding suggests that the competitive structure of WIC FI redemptions can alleviate problems of food access and food deserts.

The contribution of my work to the economics literature is twofold. First, my paper characterizes non-price competition in a context where price competition is irrelevant. My findings differ from previous applications studying non-price competition in several key ways. Second, my work relates the implications of non-price competition to the operations and efficiency to the California WIC Program, a contribution no other study has made to date. In particular, realized non-price competition bears implications for cost-saving measures related to food benefits provision and increased food access in the California WIC Program.

The organization of my paper is as follows. I provide detailed background on the California WIC program in the immediately proceeding section to motivate the incentives vendor and participants face. The next section places my work in the literature. The conceptual framework follows, including a description of the incentives to invest in brand competition in specific product categories and a theoretical model of brand and spatial competition. Then, I describe the vendor survey, participant benefits redemptions and in-store and geographical data in the subsequent section. Then, I provide a preliminary descriptive analysis of the competitive environment and brand profile of A50 vendors to motivate hypotheses. I present three empirical models to test these hypotheses and discuss the results of their estimation. The final section concludes.

2. Background

The federal government funds all WIC Programs and charges states with administering the provision of supplemental food, nutritional counseling, and access to
health-care services. Eligible participant candidates have a household income of at most 185% of the federal poverty line and are often eligible for or receiving Supplemental Nutrition Assistance Program (SNAP; formerly known as Food Stamps), Temporary Assistance for Needy Families (TANF) and/or Medicaid benefits. Participants receive food assistance benefits and other health care and educational resources at local WIC clinics.

State WIC programs provide the supplemental food to the participant at no cost and are responsible for reimbursing state authorized WIC food vendors. The federal government mandates product categories that are beneficial to the well-being of prenatal and postpartum mothers and the healthy development of their newborns and young children. However, it is the responsibility of the individual state to approve specific food brands, package sizes, and types from which WIC participants are allowed to choose (USDA FNS 2013).

The California WIC Program’s criteria for authorizing a food item include that a given food brand or type (a) promotes (or at a minimum, does not detract from) WIC health and nutrition goals, while being a product that participants would want to consume and (b) helps maintain the cost-effectiveness of the Program, while being consistently available on the wholesale market (California DPH 2012a).4 Product categories require either brand specific or non-brand specific approval. For example, the Program subjects individual brands of ready-to-eat breakfast cereal to the approval process but generally allows all brands of oatmeal

3The mandated product categories include infant formula and infant foods, milk, eggs, cheese, dry beans and lentils, peanut butter, breakfast cereal, fruit juice, and whole grain products.
4The approval process for infant formula, on the other hand, is unique compared to all other product categories. The California WIC Program approves a single brand of infant formula by way of a bidding process that selects the manufacturer who offers the highest per unit rebate to the state agency following reimbursement of the WIC vendors (USDA FNS 2013, California DPH 2012a).
provided they have no feature at odds with approval criteria.⁵ In practice, the requirements allow vendors to stock and participants to purchase multiple brands of most product categories to varying degrees.

The latter criterion of cost-effectiveness ensures that candidate food brands and types are not so costly that they could undermine the ability of WIC to adequately provide benefits. Because WIC is not an entitlement program it must maximize Program benefits under a fixed annual budget constraint, necessitating the requirement for cost control. In California, the Program administration minimizes costs in the non-brand-specific approval process by excluding product types that are premium, luxury or otherwise highly priced compared to related goods.⁶ Nevertheless, the cost of brands eligible for FI redemption varies considerably within and across product categories.

Program participants “purchase” the supplementary food by means of redeemable food vouchers, or food instruments (FIs), for specified bundles of WIC-approved products. Consumers receive FIs monthly for bundles that vary in breadth from a month’s supply of infant formula to a basket of low-fat milk, eggs, cheese, and peanut butter or dry beans. Table 1 describes the top five leading FIs of the California WIC Program in terms of the number redeemed and dollar value. The top three FIs are combination food packages that allow for multiple product categories for purchase. The fourth and fifth leading FIs provide multiple quantities of infant formula for which only one specific brand is approved for purchase.

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⁵For example, oatmeal labeled as organic or produced with added sugar is not eligible for purchase.

⁶For example, the state agency approves many types of cheese (e.g., cheddar) where any brand is permissible; however all brands of more expensive artisan or organic cheeses are excluded (California DPH 2012). For brand-specific product categories, certain brands may not receive approval if they are prohibitively costly even if they meet nutritional requirements, (e.g., organic cold breakfast cereals) (California DPH 2012).
per Program regulations (see footnote 4).

Table 1: Description of Top Five Leading California WIC Food Instruments (FIs), October 2009 - February 2012

<table>
<thead>
<tr>
<th>FI</th>
<th>Description of Prescribed Products</th>
<th>Number Redeemed</th>
<th>Value Redeemed</th>
</tr>
</thead>
<tbody>
<tr>
<td>6012</td>
<td>1 gallon and 1 quart of low-fat milk, 1 dozen eggs, 1 16 oz. package of cheese, and 1 16 oz. package of dry beans, peas or lentils OR 1 16-18 oz. jar of peanut butter</td>
<td>23,153,955</td>
<td>$334,954,013</td>
</tr>
<tr>
<td>6003</td>
<td>1 gallon of low-fat milk, 1 16 oz. loaf of whole wheat bread or tortillas and 36oz. of breakfast cereal</td>
<td>16,065,484</td>
<td>$261,817,965</td>
</tr>
<tr>
<td>6011</td>
<td>Same as FI 6003 except 2 64 oz. bottle of ready-to-drink fruit juice OR 2 11.5-16 ounce frozen juice in place of breakfast cereal</td>
<td>14,871,837</td>
<td>$210,703,857</td>
</tr>
<tr>
<td>1011</td>
<td>4 12.5 oz containers of Enfamil Premium Formula</td>
<td>2,514,895</td>
<td>$175,206,110</td>
</tr>
<tr>
<td>1091</td>
<td>7 12.5 oz containers of Enfamil Premium Formula</td>
<td>1,160,637</td>
<td>$143,869,893</td>
</tr>
</tbody>
</table>

The use of an FI differs from other food assistance programs such as SNAP where participants receive a fixed money amount via electronic benefits transfer (EBT). When redeeming a given FI, participants can choose any WIC approved brands within the listed product categories regardless of the listed prices. Therefore, the nature of FI redemption renders participants’ demand for WIC food products perfectly price inelastic.

Participants can only redeem FIs at authorized WIC vendors, which consist of private food retailers that vary in size, store format, and brand availability. The WIC vendor approval process ensures that a candidate retailer can meet mandated minimum stocking requirements of WIC products and is equipped to
handle FI redemptions (USDA FNS 2013). The minimum stocking requirements amount to vendors maintaining an inventory such that at least one brand of each product category is available for purchase at all times. As later revealed in the data, virtually all WIC vendors exceed the minimum stocking requirements in all product categories. For most vendors, many non-WIC customers also purchase the WIC goods and hence the minimum requirements are likely irrelevant. However, for vendors with a large number of WIC customers and an effectively fixed FI reimbursement payment, the only incentive to carry more and better brands is to compete with other vendors.

There are many WIC vendors in California, presently amounting to over 5,500 food retailers. Figure 1 depicts the number of vendors from October 2009 to May 2012. For most of this time frame, a significant amount of entry occurred, suggesting food retailers see WIC authorization as highly lucrative. The number of WIC vendors leveled off toward the end of 2011, however, as result of a USDA Food and Nutrition Service (FNS) moratorium on new vendor authorization imposed that same year (California DPH 2012b). This number remained stable throughout the early part of 2012, the time period of the in-store product survey that informs the quantity and quality of brands for this study.

WIC vendors include standard food retail outlets such as supercenters (e.g., Walmart), large supermarket chains (e.g., Safeway), and small grocery and convenience stores in low-income neighborhoods. For a vast majority of these WIC vendors, FI redemptions tend to make up a small fraction of total sales. However, I also observe a special class of WIC vendor for which FI redemptions constitute over 50% of total food sales, so-called “above 50%” vendors or A50 vendors, for short. While only 17% of all WIC vendors have A50 status, they account for over
one-third of the number and value of all WIC FI redemptions in California.

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Figure 1: Number of Authorized California WIC Vendors (October 2009 - May 2012)

When a participant redeems a FI, the vendor records the retail value of the goods and submits the dollar amount to the state agency for reimbursement. California WIC reimburses the vendor up to a pre-determined, FI-specific price ceiling—or maximum allowable department reimbursement (MADR). All WIC vendors are
aware of the various MADRs they face, which the Program updates on a biweekly basis. The purpose of the MADR is to control costs by preventing WIC vendors from setting exceedingly high prices for goods purchased by price-unresponsive participants.

The MADR of a given FI varies by peer group, a grouping of vendors defined by store size as measured by number of check-out registers, geographical region and A50 status. Prior to the end of May 2012, California WIC computed the MADR as a twelve-week rolling average of the FI redemption values of a given non-A50 peer group plus a group-specific tolerance factor dependent upon redemption value variance. Presently, new California WIC regulations specify that small vendors with one or two registers (three or four registers) have a MADR of a 15% (11%) markup over the average redemption value of large non-A50 vendors, although data presented in this study do not reflect this change.

Figure 2: A50 Average FI 6003 Redemption Value vs. MADR, October 2009 - February 2012
A50 vendors constitute their own peer group and face a MADR equal to the mean redemption value of a given FI across the entire state. Figure 2 plots the average redemption value for FI 6003 (see Table 1) and the corresponding MADR for October 2009 to May 2012 for the A50 peer group. The average redemption value of FI 6003 and hence the chosen prices of the included goods tends to follow the MADR almost exactly.

While most non-A50 vendors do not redeem FIs consistently near the maximum, A50 vendors virtually always seek reimbursement at or near the MADR. Non-A50 vendors, serve mostly price-sensitive consumers and therefore it is reasonable that the MADR is not universally and consistently a binding constraint. This observation is consistent with the notion that WIC participants are perfectly price inelastic and comprise the core customer base of A50 vendors. Further, if the latter were not the case, then A50 vendors would have an incentive to increase non-WIC food sales as a higher proportion than WIC food sales to receive the more favorable MADR rates of the small non-A50 vendor.7 Hence, I assume that an A50 vendor’s primary food business model is to cater to WIC participants with non-price dimensions as their only means of competition.

3. Previous Work

Attention paid to the WIC Program in the economics literature is small relative to its larger food assistance counterpart, SNAP. Existing studies on WIC tend to fall into one of two categories: market impact of sole-source infant formula contracts (Oliveira, Frazao and Smallwood 2010; Reed and Levedahl 2012; Davis 2012) and the health impact from WIC participation (Arcia, Crouch, and Kulka 1990; Wilde, 7California WIC grants authorized vendors the right to appeal their peer group designation on the grounds that the Program applied established peer grouping criteria incorrectly.
McNamara, and Ranney 1999; Carlson and Senauer 2003). My work departs from both categories by using the WIC program to answer broader questions of non-price competition relevant to food retail, industrial organization, and efficient operation of the WIC Program.

There is a longstanding general interest in the economics of non-price competition. One classic application is in the United States’ airline industry where price was effectively parametric to firms prior to deregulation (Douglas and Miller 1974). The bulk of the literature examines the incentives to compete in advertising (Stigler 1968) and quality as measured by the frequency of flights (Douglas and Miller 1974; White 1972). These authors conclude that (a) non-price dimensions are determined by the level of a fixed price and (b) that costly non-price competition can eliminate rents despite a small number of firms and no free entry. For example, Douglas and Miller (1974) theorize that airlines offer more frequent flights, reducing the distance of scheduled flights to consumers’ ideally preferred times, until profits are exhausted. My context differs from the regulated airline example in two key ways: one, WIC consumers are perfectly price inelastic and hence all price considerations are abstracted from; and, two, the added component of differentiation in physical space gives the opportunity for firms to earn positive rents.

Non-price competition and spatial competition have also long been studied together by economists. In a model of horizontal differentiation, Hotelling (1929) first argued for the principle of minimum differentiation where two profit-maximizing firms choose identical central locations along a segmented line generally interpretable as firm characteristic space.\(^8\) Later, d’Aspremont et al. (1979) proved

\(^{8}\)A horizontally differentiated attribute is one where no value of the attribute ranks higher
that firms instead optimally locate on the end point of the line for some model specifications—or the principle of maximum differentiation. Price-setting firms optimally choose their non-price attributes to limit head-to-head competition, maximizing distance from the competitor to lessen price competition. On the other hand, Hotelling’s result is valid under non-price competition (i.e., if prices are fixed). While the space of “more and better” brands is not horizontal per se, I use this context of the theoretical literature to ask: will firms use their non-price characteristics to distance themselves from competitors even when they do not strategically set prices?

One possibility is that firms will compete in some dimensions but not others. Work generalizing the Hotelling (1929) framework to multiple dimensions finds a mixture of evidence for both the principles of minimum and maximum differentiation. For two or more dimensions, Tabuchi (1994) and Irmen and Thisse (1998) show that two firms will maximally differentiate in one dimension and minimally differentiate in the other(s). In particular, firms maximally differentiate in dimensions where there is the greatest opportunity (i.e., the line is the longest) and the transportation costs in utility terms are the highest. On the other hand, de Palma et al. (1985) show that the principle of minimum differentiation holds in all dimensions when consumers view firms as significantly heterogeneous in some exogenous characteristic. Again, the brand variables are not strictly horizontal; however this literature frames the question of whether non-price competitive firms will choose to compete in all brand or product characteristics, or only a select few to minimize the intensity of spatial competition.

than any other per se in utility term; and consumers have their own ideal preferred value of the attribute (i.e., an address). Examples include different flavors of breakfast cereal or fruit juice and their literal geographic location.
Alternative characterizations of brand competition include the non-address approach to variety competition of Dixit and Stiglitz (1977) and Spence (1976); and the vertical differentiation models of Mussa and Rosen (1978) and Shaked and Sutton (1982). For example, Dixit and Stiglitz (1977) discuss the ambiguity of competitive equilibria producing optimal product variety; however, if two product categories have similar costs, firms will specialize in a product category with a low elasticity of substitution. Shaked and Sutton (1982) characterize oligopolistic competition in vertical differentiation where only firms producing high quality (e.g., carrying more expensive brands) earn positive profits. My work evaluates such predictions in a natural food retail setting where firms do not compete in price.

Second, my work complements the existing empirical literature on non-price competition in food retail. A consistent finding of existing studies is that competing in non-price dimensions can help maintain a relatively price-inelastic customer base, allowing retailers to charge higher prices. For example, Bonanno and Lopez (2009) find that supermarkets tend to increase milk prices to capture consumer surplus when they offer both additional food and non-food services. Richards and Hamilton (2006) find that price and variety of fresh fruit offerings are strategic complements with consumers’ higher willingness to pay. However, the response in variety alone across competing supermarkets is heterogeneous, where variety of one firm responds to some competitors but not others. Matsa (2011) shows that supermarkets under intense spatial competition increase the quality of their stores via reducing the frequency that carried products “stock-out”, a result amplified by the presence highly price-competitive Walmart. To the extent that the confounding presence of price competition drives any of the preceding results, my work
characterizes some of the incentives food retailers have to compete in non-price attributes alone.

4. Conceptual Framework

I present the conceptual foundation of my study in two parts. In each, I assume that the primary function of the A50 vendor is to “sell” FI redemptions, where WIC consumer demand for FI redemptions at a particular vendor is a function of offered brands and location. Given the incentive to compete in non-price dimensions, the first part discusses the incentives to invest in brands of some product categories but not others when optimally choosing the non-price attribute. This section provides an overview of general hypotheses of how A50 vendors respond to the institutional details of the California WIC Program as well as consumer demand for WIC food products. I present a framework where A50 vendors may compete in brands of some product categories but not others.

The second part spells out the incentives to offer more and better brands of WIC goods under intense spatial competition, and characterizes how vendors will locate under such competition. In particular, I revise the analysis of Hotelling (1929) to a setting where price is exogenously fixed and vendors strategically choose a non-price attribute instead. I find that A50 vendors carry more and better brands the closer they are to one another; and, multiple equilibria in strategically chosen geographic location exist.

4.1. Specific Product Category Incentives

A combination of the structure of FIs, the set of goods eligible for redemption and characteristics of consumer demand likely determine the product categories in which A50 vendors will compete. First, consider the FIs themselves, for example
FIs 6003 and 6011, the second and third leading FIs in terms of redemption number and dollar value. FI 6003 allows for one gallon of low-fat milk, one sixteen-ounce loaf of whole wheat bread and thirty-six ounces of breakfast cereal; and FI 6011, which offers the same as FI 6003 except for two sixty-four ounce bottles of fruit juice in place of the breakfast cereal. Participants can purchase, for instance, three 12-ounce boxes or one 36-ounce box under FI 6003; or, redeem two 64-ounce bottles of juice under FI 6011. Vendors may carry multiple brands from these product categories to capitalize on a preference for variety in these product categories if one exists. On the other hand, both of these two FIs allow only one whole-wheat bread purchase, eliminating an incentive to stock multiple brands due to variety preferences.

Vendors may also stock many brands of a highly horizontally differentiated product category regardless of any preference for variety. For example, consider brands of breakfast cereal, a classic and broadly horizontally differentiated good. If different subsets of participants prefer specific brands of breakfast cereal over all other brands on the basis of horizontal attributes then vendors may do well to stock many. As the number of breakfast cereal brands increases, the vendor becomes closer to each group of participant in product space, increasingly obtaining participants’ patronage. However, for relatively homogenous product categories (e.g., low-fat milk) the breadth of horizontal differentiation is limited. Hence, a small number of brands likely will persist for these categories.

Variation in the restrictiveness of WIC product eligibility categories may result in brands proliferating for some types but not others. For example, WIC allows for many different breakfast cereals brands with various grain contents and hence flavors. On the other hand, WIC explicitly limits eligible bread to “100% whole
wheat” loaves with very limited added ingredients. Other cost-reduction-inspired restrictions such as no organic whole wheat bread reduces the set of available bread brands on the quality dimension as well. Hence, the types of bread A50 vendors can stock may be relatively homogenous, incentivizing vendors to stock few brands and seek out the cheapest ones. However, there are comparatively large sets of nationally recognizable as well as less prolific “off-brands” of breakfast cereal and fruit juice brands from which A50 vendors can choose, and hence more opportunities for brand competition.

Even though breakfast cereal and fruit juice vary considerably in terms of horizontal characteristics and potential quality, ultimately the strength of consumer demand for specific brands will impact A50 vendors’ chosen brand profile. In the case of breakfast cereal, studies find that high price-cost margins come mainly from consumers’ high willingness to pay for their most preferred brand (Nevo 2001) to which consumers exhibit strong loyalty (Chidmi and Lopez 2007). This strong preference for specific brands likely carries over to price-inelastic FI redemptions. Consumers in the fruit juice market, on the other hand, do not exhibit strong consumer preferences for brands. For example, Huang, Perloff and Villas-Boas (2006) observe that orange juice consumers are highly sensitive to price and frequently substitute across different brands. Thus having more and better brands in this product category is less likely to have an impact on the number of FIs that a vendor redeems. A50 vendors then may do well to invest in more preferred yet expensive breakfast cereal brands rather than the costly juice ones.

4.2. Brand Competition under a Varying Intensity of Spatial Competition

The following models the optimal combination of chosen brands and location among A50 vendors facing pure non-price competition. I assume WIC participants
face a tradeoff between redeeming FIs for the ideal brands and transportation costs associated with patronizing the corresponding vendors. In particular, a participant with a fixed location \( t \) along a line segment \([0, 1]\) will choose vendor \( i \) among a set of vendors if it maximizes

\[
u(x_i, y_i; t) = x_i - c(y_i - t)^2 \quad i = 1, 2 \tag{1}
\]

where \( x_i \) is the average wholesale costs of vendor \( i \)'s brand profile, \( y_i \in [0, 1] \) denotes vendor \( i \)'s location and \( c \) is a scalar term. Interpreting the non-price dimension \( x_i \) as average wholesale costs follows Mussa and Rosen (1978) where the cost of vertically differentiated good, such as FI redemption, proxies for quality. WIC consumers seek out vendors with the best brands but face quadratic transportation costs in doing so, consistent with the idea that food assistance recipients are unable to travel far for food shopping. \(^9\)

Let vendors 1 and 2 with locations \((a, b) \in [0, 0.5] \times [0.5, 1]\) serve the market. I assume vendors choose an effective price \( p_i \) per FI and \( x_i \) to solve the following problem

\[
\max_{0 \leq p_i \leq \bar{p}} \max_{0 \leq x_i \leq \bar{x}} \pi_i = \left(p_i - x_i\right)q_i(x_1, x_2; a, b) \tag{2}
\]

where \( q_i(\cdot) \) denotes the demand for vendor \( i \) and \( \bar{x} \) refers to an exogenous upper bound placed upon costs by California WIC. In effect, the FI in question is a composite good consisting of the brands of WIC product categories relevant to Program participants. While there are many FIs that provide numerous types of

\(^9\)This assumption also follows d’Aspremont et al. (1979), who imposed this assumption to ensure the existence of a competitive equilibrium in firm-level choice variables.
food categories, in reality, this modeling choice reflects the observation in the data that WIC Program participants with multiple FIs overwhelmingly redeem all at one location.

Note that \( q_i(\cdot) \) is not a function of price because I posit that WIC consumers have a perfectly price-inelastic demand. Hence, vendor profit strictly increases in \( p_i \) and they each optimally choose \( p_i = \bar{p} \), where \( \bar{p} \) is the MADR for the the FI. Rational vendors choose only one value of \( p \), the maximum allowed, and hence I abstract from price competition where pure non-price competition remains. Note that Equation 2 is similar to the models of firm behavior in the price-regulated airline industry literature (Stigler 1968; White 1972; Douglas and Miller 1972) where the non-price strategic variable summarizes voluntarily increasing marginal costs to induce a positive shift in demand.

Assuming that participants are uniformly and continuously located along the line segment \([0, 1]\), I find an expression for \( q_i(\cdot) \) by first finding the location of the indifferent consumer \( t^* \). That is, setting \( x_1 - c(t^* - a)^2 = x_2 - c(b - t^*)^2 \) to obtain

\[
q_1(x_1, x_2; a, b) = t^* = \frac{x_1 - x_2}{2c(b - a)} + \frac{a + b}{2} \tag{3}
\]

\[
q_2(x_1, x_2; a, b) = 1 - t^* = 1 + \frac{x_2 - x_1}{2c(b - a)} - \frac{a + b}{2} \tag{4}
\]

Demand for FI redemption at, for example, vendor 1 increases in \( x_1 \) and with more a central location (increasing \( a \)), generally. However, from 2, clearly a trade-off exists when it comes to raising \( x_i \) between FI profit margin and increasing demand for redemptions. That is, while locating centrally brings the vendors close to many participants, such a location implies intense and costly non-price competition.

The optimal wholesale costs for vendor 1 (vendor 2 follows similarly) come
from the first-order conditions from 2.

\[
\frac{d\pi_1}{dx_1} = -\left(\frac{x_1 - x_2}{2c(b-a)} + \frac{a + b}{2}\right) + \frac{\bar{p} - x_1}{2c(b-a)} \geq 0
\]  

(5)

Depending upon \((x_1, x_2; a, b, \bar{x}, \bar{p})\), the upper bound on \(x_i\) may bind and hence Equation 5 would hold with strict inequality. Assuming that \(x_i < \bar{x}\), the first-order conditions gives the following best-response functions.

\[
x_1(x_2) = \frac{\bar{p} - c(b^2 - a^2) + x_2}{2}
\]

(6)

\[
x_2(x_1) = \frac{\bar{p} - c(b-a)(2-a-b) + x_1}{2}
\]

(7)

Naturally, one vendor responds to an increase of a competitor’s costs by increasing \(x_i\) as well.

Rearranging Equations 6 and 7 yield unconstrained solution values \(x_i^*\)

\[
x_1^*(a, b) = \frac{\bar{p} - c(b-a)(2+a+b)}{3}
\]

(8)

\[
x_2^*(a, b) = \frac{\bar{p} - c(b-a)(4-a-b)}{3}
\]

(9)

For completely disparate locations \((a = 0, b = 1)\), \(x_i^*\) are minimized. Vendors may want to choose such locations to maximize the profit margin of FI redemptions. But as vendors move to central locations (i.e., \(a, b \to 0.5\)) the optimal average level of wholesale costs increases. Holding the location of vendor 2 constant, as \(a \to 0.5\) both \(x_i^*\) and \(q_1(\cdot)\) increase. In other words, there exists a tradeoff between the strength of the profit margin and consumer demand for the particular vendor. In general, however, the optimal physical locations for vendors depends on the values of market parameters.
It may be that the upper bound on $x_i$ binds. Thus, vendors generally choose their optimal value of $x_i$ according to the following piecewise function.

$$x_i^*(a, b; \bar{x}) = \begin{cases} 
  x_i^*(a, b; \bar{x}) & \text{for } x_i^*(a, b; \bar{x}) < \bar{x} \\
  \bar{x} & \text{for } x_i^*(a, b; \bar{x}) \geq \bar{x}
\end{cases} \tag{10}$$

Equation 10 identifies the restrictiveness of California WIC’s set of approved brands ($\bar{x}$) as key in determining the optimal location strategy. Suppose that for a small $\bar{x}$ $x_i^*(a, b; \bar{x}) = \bar{x}$ for all $a$ and $b$ i.e. WIC allows only the cheapest of brands. Then, vendors would optimally choose to locate at $a = b = 0.5$ (i.e. minimally horizontally differentiate) to maximize market share without having to increase $x_i$. However, if California WIC allows many high quality (and hence expensive) brands such that $x_i^*(a, b; \bar{x}) < \bar{x}$ for a relatively large $\bar{x}$ then each vendor chooses $x_1 = x_2 = x_i^*$ for $i = 1, 2$ and earns zero profit, analogous to Bertrand’s paradox. In this case, vendors can make positive profit as they isolate themselves from each other (i.e. maximally horizontal differentiate) avoiding costly non-price competition. For intermediate values of $\bar{x}$, $x_i^*(a, b; \bar{x}) \leq \bar{x}$ depending upon the relative locations of vendors. In this case, what equilibrium of locations would arise is not readily apparent.

The following Theorem summarizes the equilibrium strategies of vendors in location and $x_i$.

**Theorem.** A unique Nash equilibrium in location and $x_i$ exist for two ranges of $\bar{x}$: minimum horizontal differentiation when $\bar{x} \leq p - c_t$ and maximum horizontal differentiation when $\bar{x} \geq p - \frac{25}{72}c_t$. When $p - c_t < \bar{x} < p - \frac{25}{72}c_t$ both minimum and maximum horizontal differentiation are Nash equilibria.
Proof. See Appendix. \hfill \Box

For the intermediate values of $\bar{x}$ both minimal and maximal horizontal differentiation are optimal strategies. When both vendors choose central locations, each optimally chooses the maximum quality allowed ($x_i = \bar{x}$) and earns positive profits. If, say, vendor 1 deviates and locates as far away as possible ($a = 0$) then this vendor’s market share falls dramatically relative to their chosen value of $x_i$. This deviation is relatively unprofitable despite $x_i^c$ decreasing. The limit on the quantity and quality of brands then intuitively limits the degree to which non-price competition can occur.

On the other hand, vendors can reduce the costs of non-price competition by maximally horizontally differentiating in the first place. Here, they have the same market share as in the minimum differentiation case but higher profit margins as result of mollifying competition in $x_i$. However, theoretically both equilibria can persist in real pure non-price competition settings. The empirical approach of my work seeks to uncover which equilibrium appears to persist.

Nevertheless, sufficiently low values of $\bar{x}$ will induce minimal differentiation in location. Vendors would agglomerate in one place that all participants must travel to in order to redeem their FIs. In effect, a strict low-cost brand policy could impede Program access by reducing the number of locations where A50 vendors exist. Instead, allowing costly non-price competition to take place can induce at least some vendors to maximally horizontal differentiate, perhaps locating in regions where food retailers otherwise do not exist (e.g., food deserts). Further, given a fixed $\bar{p}$, sufficiently high values of $\bar{x}$ increase participant welfare while leaving an incentive for A50 vendors to choose lower values of $x_i$ to maximize reimbursement net of brand costs.
Using the data described in the proceeding section, I develop my empirical approach to test the following hypotheses: (a) vendors have an incentive to compete in brands, i.e., \( q_1 \) is increasing in \( x_1 \); (b) vendors do, in fact, compete in brands i.e. the optimal choice of \( x_1 \) increases as the value of \( b - a \) decreases; and, (c) vendors tend to minimally or maximally horizontally differentiate. While I do not observe participants transportation costs or the upper bound on quality \((\bar{x})\) per se, I do observe all FI redemptions, vendors’ brand profile for select product categories and vendors’ exact physical locations. The responsiveness of market share and average wholesale costs, for example, to key vendor variables both assesses the validity of the model and sheds light on which equilibrium described in the Theorem persists.

5. Data

The three primary sources of data are: (i) an in-store product survey for California A50 vendors, (ii) individual vendor FI redemptions for California, and (iii) information on the precise geographic locations and other relevant information of all WIC vendors in California. Additionally, I use a secondary dataset on the wholesale costs of select WIC goods faced by several large California supermarket chains. The ensuing subsections describe each dataset in detail, followed by a preliminary descriptive analysis to motivate the empirical modeling approach.

5.1. In-store Product Survey and Vendor Characteristics

A one-time in-store product survey of a random sample of California A50 vendors took place from late April to early May 2012. The sampling methodology stratified the sample by vendor size (number of registers) and county population, accounting
for one-third of all A50 vendors in the state. California WIC requested the selected A50 vendors to complete and submit a questionnaire detailing the specific brands carried for a subset of WIC food product categories.

Table 2 contains a list of the surveyed product categories and the number of brands carried therein. Virtually all A50 vendors exceed the minimum stocking requirements of carrying one brand in all product categories.

Table 2: Number of Brands by Product Category of Surveyed A50 Vendors

<table>
<thead>
<tr>
<th>Product Category</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast Cereal</td>
<td>284</td>
<td>12.4</td>
<td>2.64</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>100% Fruit Juice</td>
<td>284</td>
<td>8.0</td>
<td>1.94</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Whole Wheat Bead</td>
<td>282</td>
<td>1.4</td>
<td>0.97</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Infant Fruits and Vegetables</td>
<td>284</td>
<td>3.3</td>
<td>3.30</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td>Infant Cereal</td>
<td>284</td>
<td>4.1</td>
<td>1.09</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Peanut Butter</td>
<td>284</td>
<td>1.7</td>
<td>0.72</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Additionally, I am able to observe the brand profile of sampled A50 vendors, summarized in Table 3 for ready-to-eat breakfast cereal and 100% fruit juice. I define a set of dummy variables that are equal to one if and only if a vendor carries at least one brand by the given producer. For example, a variable corresponding to the presence of General Mills brands is equal to one if General Mills’ Cheerios are present on a vendor’s shelves. The third column of Table 3 describes the

---

In effect, the sampling method prescribes oversampling larger A50 vendors in counties where their numbers are comparatively few vendors while surveying a relatively small portion of vendors in counties where A50 vendors are numerous. For example, in counties with very few A50 vendors, all such vendors are surveyed. On the other hand, in highly populated counties such as Los Angeles County, less than 20% are included. However, A50 vendors in heavily populated counties make up most of the sample vendors.

The survey also includes prices for surveyed product categories that reveal to be consistent with Figure 2, or that A50 vendors set prices to consistently redeem FIs at or near the MADR.
percentage of vendors for which this variable is equal to one.

Table 3: Summary of Average Vendor Brand Profile and Associated Costs for Breakfast Cereal and 100% Fruit Juice

<table>
<thead>
<tr>
<th>Brand</th>
<th>Vendors Carrying Brand (%)</th>
<th>Wholesale Cost per Ounce</th>
<th>Average FI Partial Net Revenue*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breakfast Cereal Brands</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Mills</td>
<td>284 100%</td>
<td>$0.27 $0.04</td>
<td>$7.14</td>
</tr>
<tr>
<td>Kellogg’s</td>
<td>284 98.9%</td>
<td>$0.26 $0.05</td>
<td>$7.61</td>
</tr>
<tr>
<td>Post</td>
<td>284 99.6%</td>
<td>$0.23 $0.04</td>
<td>$8.67</td>
</tr>
<tr>
<td>Quaker</td>
<td>284 91.9%</td>
<td>$0.28 $0.07</td>
<td>$6.84</td>
</tr>
<tr>
<td>Mill Select</td>
<td>284 9.5%</td>
<td>$0.14 $0.01</td>
<td>$11.88</td>
</tr>
</tbody>
</table>

| **100% Fruit Juice Brands** | | | |
| Dole                    | 284 10.21%                 |                          |                                 |
| Golden Crown            | 284 19.4%                  |                          |                                 |
| Hansen’s                | 284 78.2%                  | $0.05 $0.01              | $8.72                           |
| Langer’s                | 284 55.6%                  | $0.04 $0.01              | $9.45                           |
| Minute Maid             | 1.76%                      |                          |                                 |
| Old Orchard             | 284 45.4%                  |                          |                                 |
| Ocean Spray             | 284 < 1.00%                | $0.05 $0.02              | $7.28                           |
| Springfield             | 284 17.6%                  |                          |                                 |
| Welch’s                 | 284 24.6%                  | $0.06 $0.00              | $6.87                           |

*Computed as MADR for the respective FI (6003 for breakfast cereal, 6012 for juice) minus the average wholesale cost per ounce times the quantity allotted per respective FI. Both FIs allow for the same quantities of whole wheat bread and low-fat milk.

Complementing the product survey, are the store characteristics of each vendor summarized in Table 4. California WIC uses the number of working registers in the store to proxy for the size of the vendor. Under this designation, A50 vendors tend to be smaller than the average non-A50 WIC vendor. Some A50 vendors exist as part of chains, many of which exist solely to serve WIC customers.\(^{12}\)

\(^{12}\)For example Mother’s Nutritional Center is a chain of “WIC Only” A50 vendors with over 80 locations in Southern California.
Table 4: Select Vendor Characteristics

<table>
<thead>
<tr>
<th></th>
<th>A50 Vendors</th>
<th>Non-A50 Vendors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample (N=284)</td>
<td>Population (N=902)</td>
</tr>
<tr>
<td># Registers</td>
<td>2.34 (1.51)</td>
<td>1.76 (1.13)</td>
</tr>
<tr>
<td>“WIC-only” dummy</td>
<td>0.81 (0.40)</td>
<td></td>
</tr>
<tr>
<td>Chain dummy</td>
<td>0.58 (0.49)</td>
<td></td>
</tr>
<tr>
<td>Miles to Nearest WIC Clinic</td>
<td>0.78 (1.19)</td>
<td>0.89 (1.40)</td>
</tr>
</tbody>
</table>

Note: A50 vendors in the sample refer to all A50 vendors for which proper survey data on breakfast cereal, fruit juice and whole grains exist. Whether or not a vendor is WIC-Only or part of a chain is only known for sampled A50 vendors. However, many non-A50 vendors are a part of national and transnational chains.

part of a chain or not, California WIC designates A50 vendors who exclusively sell WIC items as “WIC Only”. While most sampled A50 vendors are “WIC Only”, some A50 vendors have a significant non-food sales component to their business (e.g., prepared foods or alcohol).

5.2. FI Redemptions

The next data source is the recorded redemption transaction of every FI issued from March 2012 to May 2012, i.e., the general time period of the A50 vendor survey. For each redemption, I observe the exact FI redeemed including the allotted product categories but not individual items purchased; the vendor where the FI was redeemed; and a unique time-invariant participant identification number but no additional information about the consumer. These data allow me to define several key variables that measure the FI redemption patterns of WIC consumers.

The first of such variables is vendor attrition, defined as the percentage of a vendor’s WIC customers who redeem a given FI at the vendor this month but
redeem the same FI elsewhere the following month. Vendor attrition is an important measure of market success in this context, as the overwhelming majority of customers who commit attrition once do not return to the same vendor again. Table 5 summarizes the overall level of vendor attrition, as well as substitution patterns across vendor types for FI 6003. Because participants typically redeem all of their monthly allotment of FIs at one vendor at one time, defining attrition in terms of this one widely redeemed FI captures a representative picture of overall vendor attrition.

Unconditional on vendor type, WIC consumers commit attrition roughly 38.5% percent of the time. WIC participants patronizing an A50 vendor, however, are relatively more loyal, committing attrition for less than 30% of all redemptions at these vendors. For the most part, participants tend to patronize vendors of the same type when they choose to patronize another WIC vendor. However, there is considerable substitution between A50 and large non-A50 vendors, where participants committing attrition at an A50 vendor are about equally as likely to patronize either vendor type. On the other hand, the same participants are about one-third as likely to visit a small non-A50 vendor.

For sampled A50 vendors, I observe that, on average, roughly one-third of all redemptions of FI 6003 result in attrition, only slightly higher compared to the population of redemptions (Table 6). Several vendor outliers exist on both ends of the range. For example, several vendors experience low or no attrition over the study period. These vendors tend to be relatively isolated vendors that are a part of WIC-Only chains, however, one such vendor exists primarily as a liquor

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13The event of a consumer failing to redeem an FI in the following month is not counted towards vendor attrition, as the consumer is not in the market in the given month.
Table 5: Summary of Vendor Attrition by Type for FI 6003, March-May 2012

<table>
<thead>
<tr>
<th>Presently redeeming FI at Vendor Type</th>
<th>Presently redeemed FI at Vendor Type</th>
<th>All Vendor Types (%) of Attrition and Non-Attrition Redemptions (N=284,633)</th>
<th>(%) of Attrition (%) Only (N=109,664)</th>
<th>A50 Vendors Only (%) of Attrition (%) Redemptions Only (N=107,672)</th>
<th>(%) of Attrition (%) Redemptions Only (N=31,269)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A50</td>
<td>Small</td>
<td>1.53%</td>
<td>3.97%</td>
<td>13.62%</td>
<td>14.46%</td>
</tr>
<tr>
<td>A50</td>
<td>Large</td>
<td>4.96%</td>
<td>12.86%</td>
<td>4.30%</td>
<td>45.84%</td>
</tr>
<tr>
<td>Small</td>
<td>A50</td>
<td>1.64%</td>
<td>4.26%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>Large</td>
<td>2.03%</td>
<td>5.28%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>A50</td>
<td>5.20%</td>
<td>13.50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>Small</td>
<td>2.16%</td>
<td>5.61%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Type, Attrition</td>
<td>Subtotal</td>
<td>21.01%</td>
<td>54.52%</td>
<td>11.08%</td>
<td>39.70%</td>
</tr>
<tr>
<td></td>
<td>Subtotal</td>
<td>38.53%</td>
<td>100.00%</td>
<td>29.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Same Vendor, No Attrition</td>
<td></td>
<td>61.47%</td>
<td>n/a</td>
<td>71.00%</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Table 6: FI Market Share and Vendor Attrition of Surveyed A50 Vendors

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI 6003 Redemption Share</td>
<td>199</td>
<td>0.0057</td>
<td>0.0086</td>
<td>0.0000</td>
<td>0.0698</td>
</tr>
<tr>
<td>FI 6011 Redemption Share</td>
<td>199</td>
<td>0.0057</td>
<td>0.0086</td>
<td>0.0000</td>
<td>0.0701</td>
</tr>
<tr>
<td>Attrition</td>
<td>284</td>
<td>0.3293</td>
<td>0.1562</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: FI 6003 and 6011 Redemption Shares refer to the market share relative to all vendors in a given market. The markets include the Los Angeles, Inland Empire, San Francisco, San Diego, Sacramento, Bakersfield and Fresno Areas. Attrition is the percentage of participants to redeem FI 6003 at a given vendor in one month and redeem it elsewhere the next.

store. Three sampled vendors also experience full attrition however maintained positive market share throughout the study period. These vendors are also atypical including a meat market with a fast-food component and a drinking water retailer.\textsuperscript{14} Participants may visit any of these three aforementioned vendors for reasons unrelated to WIC.

Table 6 also summarizes A50 vendors’ share of redemptions of both FI 6003 and 6011 among all WIC vendors in a given market, defined at the Metropolitan Statistical Area (MSA) level. To include a mix of urban and suburban-rural markets, I include the Los Angeles, Inland Empire (Riverside and San Bernardino Counties), San Francisco Bay, Sacramento, San Diego, Bakersfield and Bay Areas. The geographic data described in the next section allow me to match each vendor to a particular MSA and subsequently compute the number of redemptions of an A50 vendor relative to the number of FIs redeemed in a given region. These markets include a mix of urban, suburban and rural-suburban population centers. Most A50 vendors are small relative to their respective market, however some A50 vendors command significant shares. For example, several A50 vendors in the

\textsuperscript{14}Specifically, this A50 vendor does business as a carniceria and taqueria.
Sacramento area have market shares exceeding five-percent of all redemptions in the region.

5.3. Geographic Location of WIC Vendors

The third data source is the exact geographic locations of all California WIC vendors, as well as publicly available information on the locations of WIC clinics. The California WIC Program provided the addresses for both vendors and clinics, which were subsequently geocoded using ArcGIS. Figure 3 depicts the locations of all A50 vendors in the state. Most A50 vendors tend to locate in the urban population centers of the state, especially the Los Angeles Metropolitan Area (Los Angeles and Orange Counties) and the Inland Empire (Riverside and San Bernardino Counties), as well as the San Francisco Bay Area, San Diego and Sacramento. However, a significant number locate in the population centers of the rural Central Valley, for example in the Fresno and Bakersfield areas. In general, A50 vendors tend to locate in areas with a relatively high population of low-income households.

The geographical data allow me to define two types of variables that measure the intensity of spatial competition, or the number or proximity of nearby potential competitors, described in Table 7. The first set of variables describes the distance in miles to the nearest vendor of a given type. This specification is consistent with the intuition of Hotelling (1929) where two firms compete more intensely the closer they are to another. The second set relates the number of vendors of a given type within a three-mile radius. The three-mile cut-off is arbitrary, chosen to capture a broader level of competition than the first set of variables. Following Netz and Taylor (2002) and Kalnins (2003), I test the robustness of estimation that follows with multiple radii.
Table 7: Intensity of Spatial Competition Variables by Vendor Type

<table>
<thead>
<tr>
<th></th>
<th>A50 Vendor</th>
<th></th>
<th>Small Vendor</th>
<th></th>
<th>Large Vendor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>Dev.</td>
<td>N</td>
<td>Mean</td>
<td>Dev.</td>
</tr>
<tr>
<td># Vendors of a Given Type within a Three-Mile Radius</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>898</td>
<td>23.5</td>
<td>9.2</td>
<td>1898</td>
<td>21.2</td>
<td>10.8</td>
</tr>
<tr>
<td>A50</td>
<td>898</td>
<td>5.5</td>
<td>4.0</td>
<td>1898</td>
<td>4.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Small</td>
<td>898</td>
<td>9.6</td>
<td>6.1</td>
<td>1898</td>
<td>9.8</td>
<td>6.9</td>
</tr>
<tr>
<td>Large</td>
<td>898</td>
<td>8.3</td>
<td>4.6</td>
<td>1898</td>
<td>6.9</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Miles to Nearest Vendor of Given Type

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Dev.</th>
<th>N</th>
<th>Mean</th>
<th>Dev.</th>
<th>N</th>
<th>Mean</th>
<th>Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>898</td>
<td>0.27</td>
<td>0.48</td>
<td>1898</td>
<td>0.49</td>
<td>1.10</td>
<td>2721</td>
<td>0.65</td>
<td>0.89</td>
</tr>
<tr>
<td>A50</td>
<td>898</td>
<td>1.35</td>
<td>2.24</td>
<td>1898</td>
<td>1.67</td>
<td>2.69</td>
<td>2721</td>
<td>2.75</td>
<td>3.01</td>
</tr>
<tr>
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<td>0.83</td>
<td>1.66</td>
<td>1898</td>
<td>0.93</td>
<td>1.77</td>
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<td>2.49</td>
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<td>0.62</td>
<td>1.06</td>
<td>1898</td>
<td>1.22</td>
<td>2.08</td>
<td>2721</td>
<td>0.89</td>
<td>1.26</td>
</tr>
</tbody>
</table>

On average, A50 vendors face a higher intensity of spatial competition than non-A50 vendors. For instance, the average distance between an A50 vendor and its nearest competitor of any type is half the average distance between a non-A50 vendor and its closest rival. Further, A50 vendors have more vendors of any type within a three-mile radius. The observation that the average distance to the nearest vendor of any type is less than the average distance to any specific type is indicative of a heterogeneous landscape. For example, some A50 vendors may locate in close proximity to a large vendor, however the distance to any other vendor type is relatively large. Another small group of A50 vendors may locate very close to one another but miles away from small or large ones. In any case, A50 vendors face a high number of nearby potential competitors.

15 These two interpretations could hypothetically be biased, as A50 vendors tend to locate in dense urban areas. However, these interpretations are robust to limiting the set of vendors in Table 7 to only those in urban areas.
As of January 2012, the state had 4,679 authorized vendors that derived less than 50% of their food revenues from the WIC Program. FNS regulations specify that at least two criteria must be used for establishing peer groups for such vendors, and one criterion must be geography. Based in part upon recommendations contained in a consultant report, I collected the average wholesale costs per ounce paid for specified packages of various food items from March to May 2012. For each producer brand (e.g., Kellogg’s), I collect the average wholesale costs per ounce paid for specified packages of various sizes. While the cost per weight varies across product sizes, the sizes vary similarly for those sold in A50 vendors and hence the mean yields a measure that is useful to compare across brands. Assuming brands that are “better” in the sense of vertical differentiation also cost more to produce, or that manufacturers charge more for...
goods highly preferred by many consumers, the wholesale costs offer a proxy of
brand quality (Mussa and Rosen 1978).

Table 3 summarizes the mean wholesale cost for several producer brands of
ready-to-eat breakfast cereal and ready-to-drink 100% fruit juice. Within a prod-
uct category, the average wholesale cost per ounce identifies which brands are
“costly.” For example, the three of the top four leading cereal brands in the United
States (General Mills, Kellogg’s and Quaker) have similarly high costs. On the
other hand, the “off-brand” Mill Select costs roughly half as much. For fruit juice,
Welch’s, a well-known brand, emerges as the costlier brand compared to Hansen’s
and Langer’s.

Combining the wholesale costs with the redemption values and the specific
quantities allowed by FIs, I calculate average partial net revenue measures for FIs
6003 and 6011 (Table 3). Specifically, each entry is the MADR of the FI minus the
average wholesale cost per ounce times the number of ounces allowed by the FI.
Whole-wheat bread and low-fat milk are common to both FIs and hence I ignore
their wholesale costs in this calculation. I observe that when consumers redeem
the most expensive brands, the average partial net revenue is similar across FIs.
For example, a consumer purchasing General Mills cereal and Welch’s juice yield
$7.14 and $6.87, respectively, before the costs of the remaining goods. Carrying
more and better brands in either product category thus yields similar FI profit
margins.

5.5. Preliminary Descriptive Analysis

I focus the analysis on the incentives to optimize the brand profile of ready-to-eat
breakfast cereal and ready-to-drink 100% fruit juice. These product categories are
ideal candidates for study for the following reasons: (a) the strength of incentives
for carrying multiple brands of these types of products compared to others, (b) over 50% of California WIC participants redeem FIs containing at least one of these products, (c) the top two FIs carrying these products, FIs 6003 and 6011, are similar in gross profit margin and otherwise similar in product composition and (d) there is significant variation in the wholesale costs of brands within and across each product category. The following combines the exposition of institution-driven incentives from the conceptual framework with the data summary statistics to inform hypotheses on brand competition.

First, it appears that A50 vendors will carry more and better brands of breakfast cereal but not fruit juice. From Table 3, virtually all A50 vendors carry brands of the three leading breakfast cereal producers in terms of sales, namely General Mills, Kellogg’s and Post. Only a small number of vendors do not carry Quaker, the fourth largest brand that also has the highest average wholesale costs. However, less than 10% of surveyed vendors carry Mill Select, an “off-brand” that is almost half the cost of all other surveyed cereal brands. This suggests that A50 vendors are willing to invest in carrying more expensive brands of breakfast cereal despite receiving the same fixed reimbursement payment for the corresponding FI.

A different picture emerges for the fruit juice brands carried by surveyed vendors. While survey data reveals that A50 vendors carry numerous brands, the six listed in Table 3 appear the most frequently on vendors’ shelves. Of these top six brands, Welch’s is the only brand made by one of the three largest commercial juice producers. Despite its national prominence, less than one-quarter of A50 vendors stock this brand. Hansen’s brand, stocked 80% of A50 vendors, is the most prominent, although it is less prevalent than any of the top breakfast cereal
brands. Nevertheless it appears that A50 vendors tend to forgo the high cost fruit juice brands in favor of the lower cost one.

Second, A50 vendors seem to locate in a way that is the most consistent with the principle of maximum horizontal differentiation. For each vendor type from Table 7, compare the average distance of a vendor to their nearest competitors of same and different types. A50 vendors locate roughly twice as far from each other compared to their average distance from any other non-A50 competitor. By comparison, small and large vendors cluster more with vendors of the same type. For example, the distance between a large vendor’s nearest competitor of the same type is less than one mile while the nearest A50 or small non-A50 vendor is over two miles away. Hence, compared to non-A50 vendors, A50 vendors are relatively isolated despite the tendency to exist in dense urban areas.

Figures 4 through 6 map A50 vendors and WIC clinics for three specific geographic locations in California, which give rise to qualitative interpretations of vendor location behavior. The location of the WIC clinics likely influence A50 vendors’ location in a way unrelated to the proximity of competition due to the fact that participants must visit these clinics to obtain their FIs. Figure 4 depicts over ten A50 vendors in a vicinity of Compton, California, a city populated by many low-income households located roughly seventeen miles south of downtown Los Angeles. In the lower portion of the map is Compton Boulevard, which most closely represents the “linear city” of the conceptual framework compared to all other locales. Here, I see that both vendors who minimally and maximally differentiate coexist. For instance, in the immediate vicinity of the clinic, interpretable

16Hansen’s brands are more expensive than Langer’s but cheaper than Welch’s. Without additional wholesale cost data, it is unclear whether or not this brand is “costly” or not.
as the “market center”, two A50 vendors locate in neighboring shopping centers on
the same side of the street. However, as we move away from the clinic it appears
that the distance between vendors increases geometrically, consistent with maxi-
mal differentiation. While both equilibria are realized empirically, I ask whether
or not one particular equilibrium location strategy is prominent throughout the
state.

Looking at broader geographic regions, the principle of maximum horizontal
differentiation seemingly dominates. One example is Boyle Heights, a low-income
neighborhood of Los Angeles located ten miles east of downtown that is populated
predominantly by Latino households, a key WIC demographic. Figure 5 shows
that while a handful of A50 vendors locate very close to one another, most vendors
exist more dispersed compared to those in Compton. The locale of other urban
areas such as the San Francisco Bay and San Diego Areas, as well as the major
population centers of the otherwise rural Central Valley, Fresno and Bakersfield,
look similar to Figures 4 and 5, suggesting most vendors attempt to distance
themselves from one another.
Figure 4: Map of A50 Vendors and WIC Clinics in Compton, CA, Los Angeles MSA
Figure 5: Map of A50 Vendors and WIC Clinics in Boyle Heights, Los Angeles, CA
Figure 6: Map of A50 Vendors and WIC Clinics in the Sacramento MSA
Maximal horizontal differentiation is the most striking, however, in the Sacramento region. Figure 6 shows that the vast majority of A50 vendors locate as close as possible to WIC clinics. Further, few A50 vendors locate nearby to one another. In fact, the nearest A50 competitor to some vendors in Sacramento is over four miles away. Incidentally, these vendors also have the highest FI redemption shares in their respective market among any other A50 vendors in the state.

The observed substitution patterns among vendor types summarized in Table 5 help form hypotheses on which vendors constitute the set of competitors that A50 vendors face. WIC participants patronizing an A50 vendor, however, are relatively more loyal committing attrition for less than 30% of all redemptions at these vendors. For the most part, participants tend to patronize vendors of the same type when they choose to patronize another WIC vendor. However, there is considerable substitution between A50 and large non-A50 vendors, where participants committing attrition at an A50 vendor are about equally as likely to patronize either vendor type. On the other hand, the same participants are about one-third as likely to visit a small non-A50 vendor.

6. Empirical Models

I empirically characterize non-price brand competition in a two-part modeling approach. The first part establishes the incentives to invest in carrying more and better brands for some product categories but not others. This part consists of modeling the conditional mean of vendor attrition and vendor FI market share as a function of brands and the intensity of spatial competition. The second part tests whether or not brand competition increases with the intensity of spatial competition while addressing the endogeneity of vendor location.

The following is relevant for each ensuing model. For vendor \( i \), let \( \textit{brands}_i \) be a
vector of the brand variables i.e., the logarithm of the number of brands of a given product category or dummies for the presence of specific ones; \( ISC_i \) be either set of intensity of competition variable described in Table 7; and \( X_i \) be a vector of controls.

6.1. Incentives for Brand Competition

6.1.1. Vendor Attrition

The empirical model of vendor attrition serves as a first-pass test for the existence of a strong consumer demand response to certain brand variables. Because committing attrition amounts to exercising a costly option to patronize other vendors, it is of considerable interest to test whether or not it is driven by vendors’ brand profile.\(^\text{17} \) Further, when customers commit vendor attrition, they fail to return to the vendor the overwhelming majority of the time. If participants are willing to forgo patronizing a vendor due to an inadequate product offering then there is a strong incentive to improve variety.

In particular, I estimate the parameters of the following Equation

\[
\text{attrition}_i = \alpha_0 + \alpha_1 \text{brands}_i + \alpha_2 ISC_i + \alpha_3 X_i + \epsilon_{1i}
\] (11)

For the brand variables most valued by consumers, I expect that \( \alpha_{1j} < 0 \) where \( \alpha_{1k} \in \alpha_1 = \{\alpha_{11}, \alpha_{12}, \ldots, \alpha_{1j}, \ldots, \alpha_{1J}\} \) and \( J \) is the number of brands. A50 vendors would do well to ensure that their brand profile sufficiently reflects consumer preferences. Finding \( \alpha_{1k} = 0 \) for some variables, however, does not rule out the possibility that consumers value these attributes. Instead, the marginal utility of

\(^{17}\text{Relevant costs likely include (but are not necessarily limited to) transportation costs of visiting a potentially distant vendor, search costs of finding other vendors and risk associated with the possibility that desired brands are not present at the incoming vendor.}\)
certain brand variables could be small relative to the transaction costs of patronizing a new vendor.

Controlling for the intensity of spatial competition is critical. One, as potential competitors become more proximate, transaction costs associated with vendor attrition decrease. Additionally, having more WIC vendors in a given area increases the probability of incidental vendor attrition. For example, the search costs of seeking out A50 vendors decreases when there are many options to choose among. In this sense, an increased level of spatial competition raises the “natural” level of vendor attrition. In either case, I expect the estimated elements of $\alpha_2$ for relevant vendor-type competitors to be greater than zero, where the incentive to invest in a better brand profile subsequently increases.

6.1.2. Vendor FI Market Share

Estimating the responsiveness of vendors’ FI redemption market share offers a second perspective on the incentive to carry more and better brands. As mentioned in the preceding section, consumers’ valuation of some brand variables may be small relative to transaction costs but valued nonetheless. Further, this additional modeling approach allows me to assess the robustness of the results from Equation 11.

The model of vendor FI market share is as follows.

$$\log(share_{i}^{FI}) = \beta_0 + \beta_1 brands_i + \beta_2 ISC_i + \beta_3 X_i + \epsilon_i$$ (12)

The logarithm transformation of market share allows for interpreting coefficients as elasticities or semi-elasticities. The brand variables for which consumers have relatively high utility should have $\beta_{1j}>0$. Further, significant estimated parame-
ters in Equation 11 should constitute a subset of significantly positive estimates in Equation 12. When vendors choose desirable values of brand variable values that induce participants to commit attrition this should also result in higher market shares.

The expected sign and magnitude of elements of $\beta_2$ are ambiguous. On one hand, for a fixed number of WIC participants in a given area, having more competitors might mean having a smaller market share. However, on the other hand, if vendors subscribe to the principle of maximum horizontal differentiation in terms of geographical location, endogeneity of $ISC_i$ and market share may result in inconsistent estimates. For example, if vendors anticipate having a relatively low market share in a location close to other vendors then they would likely choose a location that distances them from the competition. In this case, estimates of $\beta_2^1$ would be inconsistent although I do not explicitly account for endogeneity concerns in this particular approach.\(^\text{18}\)

6.2. Non-Price Competition and the Intensity of Spatial Competition

Finally, the second part to the empirical approach tests the hypothesis that intense spatial competition results in increased brand competition; and that A50 vendors choose their geographic location to avoid it. The results from the preceding two models inform which wholesale costs stemming from carrying certain brands are relevant and model them as a function of the intensity of spatial competition. In

\(^{18}\)The potential endogeneity of $ISC_i$ is ignored in Equation 12 for the following reasons. One, the associated parameters are not of interest here but those corresponding to $brands_i$ are. Two, the empirical correlation between variables in $brands_i$ and $ISC_i$ is not statistically significantly different from zero, which the empirical model of Equation 13 addresses.
particular,

\[ \text{wholesale}_i = \gamma_0 + \gamma_1 ISC_i + \gamma_2 X_i + \varepsilon_i \]  \tag{13} 

where \( \text{wholesale}_i \) is the mean wholesale costs of a vendor’s brand profile for relevant product categories.

Regardless which equilibrium persists, the true coefficient for the intensity of spatial competition should be consistent with the results of the conceptual model i.e., that facing more competitors results in higher average wholesale costs. For example, when \( ISC_i \) refers to the miles to the nearest A50 vendor it should be the case that \( \gamma_1 < 0 \). However, consistent least-squares estimation of \( \gamma_1 \) depends squarely on which equilibria best describes A50 vendors’ actual location behavior.

First, suppose the principle of minimum horizontal differentiation best describes A50 vendors’ location behavior. This strategy amounts to voluntarily choosing a high intensity of spatial competition, where vendors cluster as much as possible (e.g., \( ISC_i \to 0 \)). Naturally, many deviations from this strategy would arise due to, for example, the availability of suitable retail space in a given geographic location or local zoning restrictions. In general, these restrictions will not systematically relate to the chosen level of wholesale costs except through the level of the \( ISC_i \) variable itself, per the conceptual model.

Further, positive shocks to average wholesale costs (e.g., a competitor with lower costs of acquiring the same goods) should not cause minimally differentiating vendors to increase the distance between themselves and other A50 vendors. Assuming the principle of minimum horizontal differentiation requires that the upper bound on wholesale costs binds for locations at or near competitors. When an A50 vendor locates in such proximity, the binding constraint allows them to
locate ever closer to nearby competitors without increasing their quantity and quality of their brands. Hence, exogenous positive shocks via $3_i$ of model Equation 13 cannot cause deviations from minimal horizontal differentiation. Additionally, negative shocks only increase the profitability of the location where deviating decreases the market share obtained by the vendor. Hence, under the principle of minimum horizontal differentiation, the error term should be uncorrelated with $ISC_i$ and OLS will yield consistent estimates of $\gamma_1$.

Now, suppose that the principle of maximum horizontal differentiation holds. In this case, following the predictions of the conceptual model, A50 vendors choose location and an initial brand profile simultaneously, anticipating intense brand competition when adjoining one another. This anticipated brand competition drives vendors to choose disparate locations to maximize the profit margin of FI redemption. Locating to avoid brand competition, the brand profiles of the past likely partially determine that of today and hence the chosen wholesale costs inferred from the survey data. The implications for estimation are, for example, that $E(ISC_i' \ 3) > 0$ and that OLS yields inconsistent estimates.

Hence, estimation of Equation 13 requires an instrumental variables approach to empirically assess the validity of the predictions of the conceptual model and to examine whether A50 vendors tend to minimal or maximally horizontal differentiate. One plausibly exogenous instrumental variable exists in the data, in particular the distance of an A50 vendor to the nearest WIC clinic. Because WIC participants must travel to these clinics to receive their FIs, it is likely that at least some A50 vendors would choose to locate nearby.$^{19}$ While choosing such a

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$^{19}$In fact, I observe that over half of all A50 vendors in the sample locate within one-half mile from a WIC clinic.
location may reduce the transportation costs associated with FI redemption for some participants, WIC clinics do not necessarily neighbor all participants’ homes. In this case, some A50 vendors may do well to locate away from the clinic and closer to areas densely populated in WIC participants. Consequently, proximity to a WIC clinic does not inherently relieve A50 vendors of the pressure to engage in brand competition. Instead, the distance to the nearest clinic affects the chosen wholesale costs only insofar as it affects the location decision of the vendor.

6.3. Spatial Error Structure

It is likely that shocks in Equations 11-13 are common to neighboring vendors to some extent. For example, heavy traffic along a certain freeway or regional variation in wholesales costs could impact all vendors within a vicinity. The consequences of failing to properly model spatial dependence include inefficient parameter estimates, biased $t$-statistics, and hence incorrect inference (Anselin 2006). To account for the possibility of spatial dependence, I use spatial econometrics to model the error terms of Equations 11-13.

In particular, I assume the $k_i$, $k = 1, 2, 3$, take the functional form of a spatial error model (SEM). That is,

$$k_i = \rho W_{ki} + v_{ki}$$  \hspace{1cm} (14)

where $v_{ki}$ is identically and independently distributed and $W$ is an inverse-distance row-normalized weighting matrix. This functional form allows for spatial dependence of $k_i$ among vendors that dissipates as the distance between two vendors increases.

Empirical model estimation in conjunction with a SEM follows Kelejian and
This approach is a generalized spatial two-stage least squares (GS2SLS) procedure, which follows similarly to Cochrane-Orcutt procedures used in time series econometrics.\textsuperscript{20} First, Equation 13, for example, is estimated by two-stage least squares using spatially lagged exogenous variables as instruments. The purpose of this auxiliary regression is to estimate $\rho$ of Equation 14 and, subsequently, Equation 13 is re-estimated using $\hat{\rho}$ via the generalized method of moments (GMM). Next, a Cochrane-Orcutt transformed version of Equation 13 using the previous estimate of $\rho$ is re-estimated via two-stage least squares. Lastly, $\rho$ is re-estimated using efficient GMM.

In the event that independent variables fail to be orthogonal to the error terms of Equations 11-13, GS2SLS is easily modified to accommodate additional endogenous variables (Drukker, Prucha and Raciborski 2013). In this case, excluded exogenous variables and their spatial lags serve as instrumental variables in addition to the spatially lagged included exogenous variables, as described above. Otherwise, the GS2SLS estimation proceeds normally as outlined in Kelejian and Prucha (1998).

7. Results

The following presents estimation results of the three empirical models. Each subsection interprets findings and discusses the veracity of the results in light of specific issues that arise in estimation. The first two models establish an incentive to compete in brands, while suggesting which types of brands and competitors are salient. These findings motivate the specification and interpretation of the

\textsuperscript{20}It is worth noting that Das, Kelejian and Prucha (2003) find the GS2SLS to be consistent and nearly as efficient as popular maximum likelihood in small sample Monte Carlo experiments. Hence, GS2LS can be relied upon to provide reliable estimates of parameters of interest.
third empirical model of wholesale costs as a function of the intensity of spatial competition.

7.1. Incentives for Brand Competition

The following details the results of the estimated vendor attrition and vendor FI market share models. Additionally, I defend the assumption of exogeneity of key regressors and the implications for results.

7.1.1. Vendor Attrition

Table 8 presents the estimates of the vendor attrition model in Equation 11. The preferred specifications of the vendor attrition model are contained in columns (e) and (f). For specifications (a) and (b), a subset of the control variable are individually and jointly insignificant while correlated with the brand variables. That these variables correlate is unsurprising as, for example, intuitively a “WIC-Only” store should carry more WIC food brands, all else equal. Omitting the offending variables from the model to reduce multicollinearity affects the significance of the coefficient estimates for the brand variables while preserving their magnitudes. Models (c) and (d) remove only the brand variables, revealing the joint insignificance of the select control variables to be robust. Hence, I focus my discussion on the results of specifications (e) and (f) of the vendor attrition model.

The reduction in attrition related to even small increases in the number of cereal brands is dramatically large. Vendors with the lowest number of brands, where unit increases are large in percentage terms, also experience the highest levels of

\[ I = \frac{(\hat{e}_k W \hat{e}_k / S_0)}{(\hat{e}_k \hat{e}_k / n)} \]

where \( S_0 = \sum_i \sum_j w_{ij} \) (Anselin 2006). I fail to reject the null hypothesis of no spatial autocorrelation in the error term (i.e., \( \rho = 0 \)) and hence I do not present SEM results.

\[ \text{52} \]
Table 8: Vendor attrition for FI 6011 as a function of brands and the intensity of spatial competition

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
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<tr>
<td>log(# Cereal Brands)</td>
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<td></td>
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<td>(2.12)**</td>
<td></td>
</tr>
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<td>log(# Juice Brands)</td>
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<td>-0.017</td>
<td></td>
<td>-0.037</td>
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<td>(0.71)</td>
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<td>(0.23)</td>
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<td>(0.87)</td>
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<td>(1.18)</td>
<td>(1.13)</td>
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<tr>
<td></td>
<td>(3.61)**</td>
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<td></td>
<td></td>
</tr>
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<tr>
<td></td>
<td>(0.35)</td>
<td>(0.41)</td>
<td>(0.32)</td>
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</tr>
<tr>
<td>Nearest A50 (miles)</td>
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<td>-0.013</td>
<td>-0.014</td>
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<tr>
<td></td>
<td></td>
<td>(4.41)**</td>
<td>(4.42)**</td>
<td>(4.85)**</td>
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<tr>
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<td>(1.42)</td>
<td>(1.48)</td>
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<td>(1.54)</td>
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<td>(1.82)*</td>
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<td>(1.58)</td>
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<td>0.443</td>
<td>0.755</td>
<td>0.796</td>
</tr>
<tr>
<td></td>
<td>(3.69)**</td>
<td>(3.88)**</td>
<td>(10.67)**</td>
<td>(11.98)**</td>
<td>(4.39)**</td>
<td>(4.65)**</td>
</tr>
<tr>
<td>Market Dummies</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.16</td>
<td>0.16</td>
<td>0.12</td>
<td>0.12</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>N</td>
<td>284</td>
<td>284</td>
<td>284</td>
<td>284</td>
<td>284</td>
<td>284</td>
</tr>
</tbody>
</table>

Note: Asterisks denote significance at the 10% (*), 5% (**) and 1% (***) levels.
attrition. Thus the logarithmic transformation may overstate the average effect of increasing cereal brands. Nevertheless, this coefficient’s sign and statistical significance is robust to estimates forgoing the transformation. No other brand variable is statistically significant in any specification. Participants may still value these brand characteristics, although the strength of the preference is at most weak compared to that for variety of cereal brands.

The incentive to invest in brands predictably grows as potential competitors become more numerous and less distant. Results suggest a high degree of competition between A50 vendors relates to higher rates of vendor attrition. For example, a vendor with an additional A50 competitor within a three-mile radius sees a 1.4% increase in attrition, on average. Naturally, when two competing vendors are nearby one another the cost of going to one versus another is relatively small. The effect of the intensity of spatial competition with other A50 vendors is small, however, compared to the estimated coefficient for the logarithm of the number of breakfast cereal brands.

The proximity of large vendors, on the other hand, appears to have no effect, indicating A50 vendors are not directly competing with large traditional retailers. Additionally, I exclude spatial variables pertaining to small non-A50 vendors due to the relatively little level of substitution between these and A50 vendors observed in Table 5. However, the results of Table 8 are unchanged by including small vendors although point estimates for their effects on vendor attrition are statistically insignificant. Lastly, despite the fact that participants must physically obtain FIs from local WIC clinics, a vendor’s distance to them has a limited effect on attrition. This finding may be due to the fact that vendors tend to locate near clinics anyway and hence the relevant variable predicting attrition behavior is the
intensity of spatial competition.

7.1.2. Vendor FI Market Share

I use two definitions of the dependent variable to test whether the results in Table 9 are specific to the FI for which share is measured.22 FI 6003 allows for 36 ounces of breakfast cereal while FI 6011 has two 64 ounce bottles of fruit juice, and over 50% of all WIC participants receive at least one of these FIs. Coefficient estimates are nearly identical across both market share definitions, indicating the observed incentives for competition apply broadly to a vendor’s market performance and are not idiosyncratic to specific FIs.

Consistent with estimates in Table 8, the number of breakfast cereal brands relates positively to higher market shares of all FIs (Table 9). The share of FI redemptions is relatively elastic to the number of cereal brands, indicating a strong incentive to increase variety. Likewise, the number of juice brands has no statistically significant relationship with any measure of market share. Thus, there is seemingly no strong incentive to compete in variety of brands other than breakfast cereal.

Somewhat in departure from estimates in Table 8, vendors who carry varieties of the Quaker brand of cereal, but not Mill Select, tend to have higher shares. With respect to breakfast cereal brands, vendors see an increase in market share when they invest in carrying expensive brands (e.g., Quaker) rather than the cheapest ones (e.g., Mill Select). This finding is reflected in the average brand profile of A50 vendors where the overwhelming majority of such vendors carry high wholesale cost brands.

22Likewise in the vendor attrition model, I find no evidence of spatial autocorrelation.
Table 9: Vendor FI 6003 and 6011 Market Share as a Function of Brands and Intensity of Spatial Competition

<table>
<thead>
<tr>
<th></th>
<th>log(FI 6003 redemption share)</th>
<th>log(FI 6011 redemption share)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
</tr>
<tr>
<td>log(# Cereal Brands)</td>
<td>1.475</td>
<td>1.462</td>
</tr>
<tr>
<td></td>
<td>(2.93)**</td>
<td>(2.89)**</td>
</tr>
<tr>
<td>log(# Juice Brands)</td>
<td>-0.087</td>
<td>-0.014</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Quaker (dummy)</td>
<td>1.042</td>
<td>1.027</td>
</tr>
<tr>
<td></td>
<td>(2.30)**</td>
<td>(2.28)**</td>
</tr>
<tr>
<td>Mill Select (dummy)</td>
<td>0.196</td>
<td>0.177</td>
</tr>
<tr>
<td></td>
<td>(0.60)</td>
<td>(0.55)</td>
</tr>
<tr>
<td>Hansen’s (dummy)</td>
<td>-0.31</td>
<td>-0.327</td>
</tr>
<tr>
<td></td>
<td>(1.79)*</td>
<td>(1.93)*</td>
</tr>
<tr>
<td>Welch’s (dummy)</td>
<td>-0.04</td>
<td>-0.068</td>
</tr>
<tr>
<td></td>
<td>(0.22)</td>
<td>(0.37)</td>
</tr>
<tr>
<td># A50 in 3-mile Radius</td>
<td>-0.025</td>
<td>-0.025</td>
</tr>
<tr>
<td># Large in 3-mile Radius</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>Nearest A50 (miles)</td>
<td>-0.009</td>
<td>-0.013</td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(0.38)</td>
</tr>
<tr>
<td>Nearest Large (miles)</td>
<td>-0.217</td>
<td>-0.209</td>
</tr>
<tr>
<td></td>
<td>(1.31)</td>
<td>(1.26)</td>
</tr>
<tr>
<td>WIC Only (dummy)</td>
<td>0.670</td>
<td>0.645</td>
</tr>
<tr>
<td></td>
<td>(2.68)**</td>
<td>(2.53)**</td>
</tr>
<tr>
<td>Chain (dummy)</td>
<td>0.652</td>
<td>0.625</td>
</tr>
<tr>
<td></td>
<td>(3.66)**</td>
<td>(3.51)**</td>
</tr>
<tr>
<td>Registers</td>
<td>0.199</td>
<td>0.208</td>
</tr>
<tr>
<td></td>
<td>(3.08)**</td>
<td>(3.26)**</td>
</tr>
<tr>
<td>log(NearClinic)</td>
<td>-0.07</td>
<td>-0.058</td>
</tr>
<tr>
<td>(log-miles)</td>
<td>(3.01)**</td>
<td>(2.48)**</td>
</tr>
<tr>
<td>Constant</td>
<td>-10.591</td>
<td>-10.729</td>
</tr>
<tr>
<td></td>
<td>(10.30)**</td>
<td>(10.95)**</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.76</td>
<td>0.76</td>
</tr>
<tr>
<td>N</td>
<td>199</td>
<td>199</td>
</tr>
</tbody>
</table>

Note: Asterisks denote significance at the 10% (*), 5% (**) and 1% (***) levels.
Fruit juices, on the other hand, see no such positive relationship between carrying either the expensive or inexpensive brands with share. In fact, carrying Hansen’s brand juice—the low cost brand—correlates to a decrease in market share. This may suggest that carrying only cheap brands of any product category is undesirable. Nevertheless, vendors have no strong incentive to invest in stocking the higher cost juice brand. These findings are consistent with the average fruit juice brand profile of A50 vendors where no one brand clearly dominates and expensive brands are carried infrequently. Hence, I find strong evidence of vendor’s incentive to compete in brands only for the product categories most valued by consumers.

Another striking result is that no measure of the intensity of spatial competition significantly relates to vendor FI market share. This finding is consistent with the fact that many A50 vendors tend to locate in regions dense with WIC participants and experience high market share as a result. Instead of reducing a vendor’s share of a likely relatively fixed amount of WIC business, intense spatial competition is a zero-sum game where participants are more likely to shop around as opposed to shift their patronage permanently. On the other hand, vendors with few competitors may also have comparatively few WIC clients and, thus, the impact of the intensity of spatial competition on market share is limited. The importance of the vendor attrition variable, then, is to capture the degree of customer loyalty an A50 vendor experiences.

Estimated coefficients of other control variables take on the expected sign. For example, it is unsurprising that WIC only stores, who are the most likely to excel in unobserved store experience characteristics, on average have a higher FI redemption share. Larger vendors that are part of a chain also redeem more FIs perhaps due to greater inventory and more effective management. Additionally,
vendors closer to local WIC clinics where participants receive FIs also tend to have a slightly higher market share.

7.1.3. Exogeneity of Key Regressors

The assumption that brand and spatial variables are exogenous in the empirical framework requires defense. The brand variables especially necessitate such a discussion, as I argue that vendors will choose non-price characteristics strategically. This modeling choice follows much of the discrete choice literature where the treatment of the endogeneity of prices is the main concern (Nevo 2000). In essence, I argue that the brand and intensity of spatial competition variables are not updated on a continuous basis and are predetermined with respect to the measured market outcomes. The following discusses the veracity of these findings in light of several specific issues of endogeneity.

First, vendor-specific omitted variables potentially correlated with WIC brands could bias estimates of the respective parameters of brands in Equations 11 and 12. Specifically, none of the included regressors will fully capture store experience, such as cleanliness, ease of shopping experience and good customer service. Nearly all consumers of all types rank such characteristics as nearly as important as prices and variety in choosing their primary food retail outlet (Progressive Grocer 2010). It may be that price inelastic WIC participants shopping at A50 vendors have a stronger preference for store experience, as they forgo the greater variety of the large vendor. Additionally, I do not observe certain qualities of other product categories not considered in this analysis. For example, the expiration dates of milk or the freshness of fruits and vegetables sold independent of FIs could correlate to the quantity and quality of other brands.23

23Participants may receive cash value vouchers (CVVs) in addition to FIs to purchase fresh
The consequences of such omitted variables bias would still be consistent with the idea that vendors will engage in non-price competition when they cannot compete in price. Further, the variance in magnitude of hypothetical estimate bias across product categories manifests in a way that is consistent with the interpretation that carrying more and better brands is more important for some product categories than others. However, there is still reason yet to believe that brand variables rather than omitted store experience ones drive the results of the brands parameters. In particular, improving the quality of store experience is likely less costly than improving the vendor’s brand profile. Increasing overall selection of goods requires incurring significant fixed costs (Ellickson 2006) and managing inventory to ensure brands are consistently available is costly as well (Matsa 2011). Improving the consumer shopping experience of A50 vendors would then likely precede any investment in increasing the quantity and quality of brands. If true, then the correlation between brand variables and omitted store experience variables—and hence the error term—would be relatively small.

Second, codetermination between the attrition and brand variables may persist. A vendor who competes in brands would likely improve his brand profile in response to an observed increase in attrition. However, the presence of this type of endogeneity is likely unproblematic for the following reasons. Vendors responding positively in brands to an upward shock in attrition would only serve to attenuate key results. Further, if vendors tend to maximally differentiate geographically, fruits and vegetables. The CVVs differ from FIs in that participants have a fixed cash amount to spend.

24In other words, if the bias affects each brand variable equally I reject the null hypothesis that each parameter is the same. If the bias varies by brand variable then my original explanation remains valid.

25The interpretation of results would also remain the same by the same argument of the previous footnote.
then it is likely that brands are not updated on a continuous basis. Instead, an initially modest brand profile would persist as long as the vendors remained isolated.

To provide evidence for the claim that vendors’ brand profiles are relatively fixed, I am able to obtain additional prior FI redemption data from October 2009 to February 2012 and define vendor attrition over this period. First, the results in Table 8 are robust to using vendor attrition dating back to June 2011, nine months prior to the in-store survey. This finding suggests the brand profile responds slowly to competitive changes. Second, past attrition prior to June 2011 then should serve as a plausibly exogenous instrument for present vendor attrition rates. However, first-stage regressions indicate that past attrition is in fact a weak instrument. Nevertheless the empirical results indicate that vendors have an incentive to compete in brands, while their observed brand profile combined with the upcoming results of the second part of the empirical approach suggests they do in fact engage in this behavior. However, this incentive does not readily appear in explaining measured brand variables as a function of past vendor attrition.

7.2. Non-Price Competition and the Intensity of Spatial Competition

Table 10 presents the estimated coefficients of Equation 13. In general, estimation techniques that do not account for endogeneity in the intensity of spatial competition appear to yield inconsistent estimates. For example, compare the magnitudes of the ISC coefficient from models (a) to (c), ignoring the statistical insignificance of both estimates for the moment. Only the coefficient estimate of the 2SLS model is consistent with the theoretical prediction that non-price competition intensifies

\footnote{F-statistics from first-stage regressions are consistently below 10 for most permutations of monthly vendor attrition variables ranging from October 2009 to February 2012.}
with greater proximity of competitors. Hence, initial evidence suggests that A50 vendors tend to engage in maximum horizontal differentiation.

However, both estimates are clearly statistically insignificant. Consequently, Hausman-type tests fail to the reject null hypothesis of the consistency of OLS at commonly accepted significance levels. Estimating Equation 13 within a SEM framework, I find statistically significant positive estimated values for specifications (e) through (h). This finding indicates spatial autocorrelation in the unobserved factors influencing chosen wholesales costs. Hence the estimates in (a) through (d) are inefficient, requiring the GS2SLS-SEM approach for inference.

Additionally, “WIC Only” stores tend to carry less expensive brands, on average, although this result is not robust to specification. This finding may arise due to the fact that “WIC Only” vendors are the most likely to carry the “off” breakfast cereal brands which tends to lower the average wholesale costs. Even though few consumers would prefer these brands to nationally recognized ones, the opportunity cost of shelving space for WIC-approved cereals will be lower for these vendors compared to non-“WIC Only” vendors, all else equal. This explanation may also account for the insignificance of the coefficient for the number of registers. However, it is intuitive that chain A50 vendors have better brands, on average, as they are likely able to purchase better brands for a cheaper unit price.

8. Conclusion

Food retailers who do not compete in price have an incentive to invest in carrying more and better brands to maintain customers and increase their market share. However, carrying more and better brands is costly, and retailers tend to locate

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27I define the weighting matrix $W$ for only those variables for which market is defined to exclude the possibility of results biased by thin markets.
Table 10: Mean Chosen Breakfast Cereal Wholesale Costs per Ounce as a Function of the Intensity of Spatial Competition

<table>
<thead>
<tr>
<th></th>
<th>(a)</th>
<th>(b)</th>
<th>(c)</th>
<th>(d)</th>
<th>(e)</th>
<th>(f)</th>
<th>(g)</th>
<th>(h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS</td>
<td>OLS</td>
<td>2SLS</td>
<td>2SLS</td>
<td>GS2SLS</td>
<td>GS2SLS</td>
<td>GS2SLS</td>
<td>GS2SLS</td>
</tr>
<tr>
<td>Nearest A50 Vendor (Miles)†</td>
<td>0.014</td>
<td>-0.778</td>
<td>0.387</td>
<td>-0.069</td>
<td>-0.013</td>
<td>0.178</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.47)</td>
<td>(1.08)</td>
<td>(1.10)</td>
<td>(1.91)</td>
<td>(1.82)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># A50 in 3-Mile</td>
<td>-0.4</td>
<td>-0.386</td>
<td>0.555</td>
<td>-0.31</td>
<td>-0.544</td>
<td>-0.585</td>
<td>-0.334</td>
<td>0.178</td>
</tr>
<tr>
<td></td>
<td>(1.30)</td>
<td>(0.61)</td>
<td>(0.78)</td>
<td>(1.81)</td>
<td>(1.95)</td>
<td>(0.96)</td>
<td>(1.70)</td>
<td></td>
</tr>
<tr>
<td>Radius†</td>
<td>-0.772</td>
<td>-0.791</td>
<td>-0.295</td>
<td>-0.042</td>
<td>0.434</td>
<td>0.441</td>
<td>0.402</td>
<td>0.415</td>
</tr>
<tr>
<td>“WIC-Only” dummy</td>
<td>(3.66)***</td>
<td>(3.69)***</td>
<td>(0.45)</td>
<td>(0.07)</td>
<td>(4.40)***</td>
<td>(4.46)***</td>
<td>(3.66)***</td>
<td>(3.87)***</td>
</tr>
<tr>
<td></td>
<td>(5.29)***</td>
<td>(5.27)***</td>
<td>(0.07)</td>
<td>(0.64)</td>
<td>(1.15)</td>
<td>(1.27)</td>
<td>(0.57)</td>
<td>(0.35)</td>
</tr>
<tr>
<td>Chain dummy</td>
<td>0.424</td>
<td>0.427</td>
<td>-0.031</td>
<td>0.135</td>
<td>-0.331</td>
<td>-0.372</td>
<td>-0.186</td>
<td>-0.118</td>
</tr>
<tr>
<td>Registers</td>
<td>(77.77)***</td>
<td>(73.87)***</td>
<td>(14.19)***</td>
<td>(21.59)***</td>
<td>(71.71)***</td>
<td>(61.31)***</td>
<td>(59.43)***</td>
<td>(32.73)***</td>
</tr>
<tr>
<td>Constant</td>
<td>22.158</td>
<td>22.244</td>
<td>23.862</td>
<td>20.73</td>
<td>22.172</td>
<td>22.19</td>
<td>22.469</td>
<td>21.121</td>
</tr>
<tr>
<td></td>
<td>(59.43)***</td>
<td>(59.43)***</td>
<td>(14.19)***</td>
<td>(21.59)***</td>
<td>(71.71)***</td>
<td>(61.31)***</td>
<td>(59.43)***</td>
<td>(32.73)***</td>
</tr>
<tr>
<td>ρ</td>
<td>0.308</td>
<td>0.335</td>
<td>0.287</td>
<td>0.349</td>
<td>(2.29)**</td>
<td>(2.52)**</td>
<td>(1.75)*</td>
<td>(1.75)*</td>
</tr>
<tr>
<td>N</td>
<td>284</td>
<td>284</td>
<td>284</td>
<td>284</td>
<td>199</td>
<td>199</td>
<td>199</td>
<td>199</td>
</tr>
</tbody>
</table>

Note: † denotes endogenous left-hand side variables where log(miles to nearest WIC Clinic) is the instrumental variable. Asterisks denote significance at the 10% (*), 5% (**) and 1% (***) levels. The GS2SLS-SEM-IV method is similar to GS2SLS-SEM except endogenous regressors are allowed.
themselves in a way that minimizes the necessity to engage in such measures. Using A50 vendors, an organic example of a non-price competing firm, I find that they compete in brands for least one product category. Carrying many brands of breakfast cereal reduces the rate of vendor attrition and increases their market share in conjunction with having more expensive brands. Having more and better brands in this category effectively reduces the intensity of spatial competition that an A50 vendor faces by attempting to increase its differentiation relative to rivals in a quality dimension. However, I do not find this result for fruit juice brands despite similar profit margins for respective FIs allowing for these goods. This finding is consistent with the conclusions of the demand literature (Nevo 2000; Huang, Perloff and Villas-Boas 2006; Chidmi and Lopez 2007) where consumers reveal a strong willingness-to-pay for particular breakfast cereal brands but not juice brands.

My findings are consistent with a theoretical model in the tradition of Hotelling (1929) that supports either the principle of minimum or maximum horizontal (i.e., geographic) differentiation as equilibria when faced with pure non-price competition. Overall, it appears that the array of approved food items under California WIC allows for intense non-price competition and, hence, I observe that vendors tend to maximally differentiate. Interestingly, this outcome is observationally equivalent to the case where the allowed wholesale costs for brand profiles is unlimited. This suggests that, given fixed payments for FIs, the competitive environment of FI redemption induces vendors to choose locations specifically to reduce their own costs and hence the costs of the Program.

The ability to choose location while competing using a vertical quality component differentiates my work from other applications in non-price competition.
Namely, my findings differ from those of studies of the airline industry where firms compete in quality until exhaustion of profits. The ability to differentiate in horizontal space allows the A50 vendors to earn positive profits, in theory, and thus mimics location behavior under price competition. Additionally, I show that non-price dimensions are important as competitive “ends” in and of themselves, as opposed to a means to increase prices charged to consumers.

The observation that participants highly value the opportunity to purchase more and better brands should be of interest to policymakers and Program administrators. Recent federal budget cuts reduced funding to the Program nationwide and cost-containment is a high priority among program administrators. To the extent that any policy changes affect the brands that WIC vendors carry, reductions in the welfare of participants may occur. For example, if California WIC administrators decide to cut costs by limiting the availability of costly breakfast cereal brands for purchase then consumer welfare would dramatically decrease. Existing WIC participants may fail to fully redeem their FIs if no offered brands are preferred nothing at all. Additionally, prospective participants may be dissuaded from participation in the Program if they are unable to purchase the specific goods they value the most. On the other hand, restricting the costs of allowable juice brands would have minimal consequences for welfare or participation and hence may be better targets for cost reduction measures, although only a minority of vendors are seen to carry expensive juice brands. Further, restricting brand choice of relevant product categories available for non-price competition may induce vendors to relocate to minimally differentiate in space. The realization of such an outcome may exacerbate issues of food access for WIC consumers, where fewer unique A50 vendor locations are available. Policymakers would do well to appreciate the im-

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portance of brand and non-price attributes broadly to and food retailers’ market outcomes, the welfare of WIC participants and Program access.

9. References


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10. Appendix

Before I provide the proof of the Theorem, a few auxiliary results need to be established. The difficulty of the proof arises from the properties of $x_i^c(\cdot)$. To elaborate, for a given $\bar{x}$, if there exists an $a'_1 \in [0, \frac{1}{2}]$ such $x_1^c(a'_1) = \bar{x}$ then $x_i^c$ is piecewise continuous and non-differentiable at $a'_1$. Further, the same must be true of $x_2^c(a, b; \bar{x})$ and hence profit is piecewise continuous and non-differentiable at no more than two points. The following Propositions consider the properties of the profit functions under different cases of $\bar{x}$.

**Proposition 1.** Suppose there exists $A_1 \subseteq [0, \frac{1}{2}]$ such that $x_1^c(a, b) < \bar{x}$ for all $a \in A_1$ for both vendors. Then, $\pi_1$ is strictly monotonically decreasing for all such $a$.

**Proof.** In this case, $x_i^c(a, b) = x_1^c(a, b)$ for all $a \in A_1$ so the profit for vendor 1 is given as

$$
\pi_1 = (p - x_i^*) \left( \frac{x_1^* - x_2^*}{2c_1(b - a)} \right) + \frac{a + b}{2} = \frac{c_2}{3} (b - a)(2 + a + b) \left( \frac{1}{3}(1 - a - b) + \frac{a + b}{2} \right)
$$
Differentiating with respect to $a$

$$\frac{\partial \pi_1}{\partial a} = -\frac{2c_t}{3}(1 + a) \frac{1}{3}(1 - a - b) + \frac{a + b}{2} + \frac{c_t}{18}(b - a)(2 + a + b) < 0 \iff \frac{c_t}{18}(b - a)(2 + a + b) < \frac{2c_t}{3}(1 + a) \frac{1}{3}(1 - a - b) + \frac{a + b}{2} \iff (b - a) < 2(1 + a)$$

which is true for all $a \in A_1$ for any $b \in [0.5, 1]$. \(\Box\)

If $A_1 = [0, 0.5]$ then Proposition 1 is essentially the case where no upper-bound effectively exists. In this case, vendors would maximally differentiate in the horizontal attribute. Intuitively, vendors seek to maximize the profit margin of the FI while splitting the share.

**Proposition 2.** Suppose there exists $A_2 \subseteq [0, \frac{1}{2}]$ such that $x^*_t(a,b) \geq \bar{x}$ for all $a \in A_1$ for both vendors. Then, $\pi_1$ is strictly monotonically increasing for all such $a$.

**Proof.** Here, $x^*_t(a,b) = \bar{x}$ for both vendors for $a \in A_2$. The profit function is

$$\pi_1 = (p - \bar{x}) \frac{a + b}{2}$$

which is strictly increasing in $a$. \(\Box\)

If $A_2 = [0, 0.5]$ then the constraint always binds and Proposition 2 implies that vendors locate centrally to maximize market share with a fixed profit margin. This result is the Hotelling (1929) result although arrived at in a much different manner.
However, when \( p - c < \bar{x} < p A_1 \) or \( A_2 \) can be at most a proper subset of [0, 0.5]. For such \( \bar{x} \) the properties of \( \pi_i \) are unclear as it may be non-differentiable up to two points.

**Proposition 3.** Suppose that for some \( b \) either (a) \( x_1^c = \bar{x} \) and \( x_2^c = x_2^* \leq \bar{x} \) for all \( a \in A_3 \subseteq [0, \frac{1}{2}] \) or (b) \( x_2^c = \bar{x} \) and \( x_1^c \leq \bar{x} \) for all \( a \in A_4 \subseteq [0, \frac{1}{2}] \). If either \( A_3 \neq \emptyset \) or \( A_4 \neq \emptyset \) then \( \pi_1 \) is strictly monotonically increasing in each respective region. Further, both \( A_3 \) and \( A_4 \) cannot simultaneously be non-empty.

**Proof.** Define \( A_j = \{a \mid a \in A_j \text{ or } a > \sup A_j\} \) and \( A_j = \{a \mid a \in A_j \text{ or } a < \inf A_j\} \) for \( j = 3, 4 \). Suppose there exists \( A_3 \neq \emptyset \). Because \( \partial x_2^c / \partial a = \frac{2}{3} c_1 (2 - a) \geq \partial x_1^c / \partial a = \frac{2}{3} c_1 (1 + a) > 0 \), for any \( a \in A_3 \) it must be that \( x_1^c(a, b) = \bar{x} \) and \( x_2^c(a, b) \leq \bar{x} \). Further, for any \( a \in A_3 \) it must be that \( x_1^c(a, b) \leq \bar{x} \) and \( x_2^c(a, b) \leq \bar{x} \). Because \( A_3 \cup A_3 = [0, 0.5] \), it must be that \( A_4 = \emptyset \) if \( A_3 \) exists.

Profit is defined over \( A_3 \) as

\[
\pi_1 = (p - \bar{x}) \left( \frac{\bar{x} - x_2^c}{2c_1(b - a)} + \frac{a + b}{2} \right) = (p - \bar{x}) \left( -\frac{p - \bar{x}}{2c_1(b - a)} + \frac{2 + a + b}{3} \right).
\]

. Taking the first derivative with respect to \( a \) gives

\[
\frac{\partial \pi_1}{\partial a} = (p - \bar{x}) \left( \frac{p - \bar{x}}{2c_1(b - a)^2} + \frac{1}{3} \right) > 0
\]

and hence \( \pi_1 \) is strictly monotonically increasing for \( a \in A_3 \).

Now, suppose \( A_4 \neq \emptyset \). It must be that \( x_1^c(a, b) \leq \bar{x} \) and \( x_2^c(a, b) = \bar{x} \) for all \( a \in A_4 \) and \( x_1^c(a, b) \leq \bar{x} \) and \( x_2^c(a, b) \leq \bar{x} \) for all \( a \in A_4 \). Hence, \( A_3 = \emptyset \).

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Over $A_4$, profit is

$$
\pi_1 = (p - x_1^*) \frac{x_1^* - \bar{x}}{2c_t(b - a)} + \frac{a + b}{2}
$$

$$
= \frac{c_t}{3} (b - a)(2 + a + b) \frac{p - \bar{x}}{2c_t(b - a)} + \frac{a + b - 1}{3}
$$

$$
= \frac{c_t}{3} \left( \frac{1}{2c_t}(p - \bar{x}) \right) + \frac{b^2 - a^2}{3} + \frac{a - b}{3}
$$

. The first derivative with respect to $a$ is

$$
\frac{\partial \pi_1}{\partial a} = \frac{1}{3} \frac{p - \bar{x}}{2c_t} + \frac{b^2 - a^2}{3} + \frac{a + b}{3} + (2 + a + b) \frac{-2a}{3} + \frac{1}{3}
$$

$$
= \frac{1}{9} \left( \frac{3(p - \bar{x})}{2c_t} + \frac{b^2 - a^2}{3} + \frac{a + b}{3} + (2 + a + b) \frac{-2a}{3} + \frac{1}{3} \right)
$$

$$
= \frac{1}{9} \left( \frac{3(p - \bar{x})}{2c_t} + b^2 - 3a^2 - 2a - 2ab + 2 \right)
$$

which is strictly positive if and only if

$$
\frac{p - \bar{x}}{6c_t} > 3a^2 - b^2 + 2a + 2ab - 2
$$

Note the RHS of the above expression is, *ceteris paribus*, strictly increasing in $a$ and strictly decreasing in $b$ for $b > a$, which must be the case.\(^{28}\) The feasible maximum of the RHS occurs then for $a, b \to \frac{1}{2}$ and so $-1$ is an upper bound. Hence, the above inequality holds true and $\pi_1$ is strictly monotonically increasing for $a \in A_4$. \(\square\)

The following Lemma rules out any interior solutions. Essentially, for any

\(^{28}\)Note that $x_1^* - x_2^* = \frac{2c_t}{2c} (b - a)(1 - a - b)$. That $A_4 = \emptyset$ implies that $x_1^* < x_2^*$ in this region which occurs if and only if $a + b > 1$
Lemma. Suppose vendors strategically and simultaneously choose both location and \( x_i \), and \( p - c < \bar{x} < p \). Any Nash Equilibrium, if one exists, will be a combination of one strategy from each of the following sets: 

\[
S_1 = \{(a = 0, x_1 = x_1^c(0, b)), (a = \frac{1}{2}, x_1 = x_1^c(\frac{1}{2}, b))\} \text{ and } S_2 = \{(b = \frac{1}{2}, x_2 = x_2^c(a, \frac{1}{2})), (b = 1, x_2 = x_2^c(a, 1))\}.
\]

Proof. First, note that when \( \bar{x} \leq p - c \) then \( A_1 = [0, 0.5] \) as \( x_1^c(a, b) = x_1^* \leq \bar{x} \); and when \( \bar{x} \geq p \), \( A_2 = [0, 0.5] \) as \( x_1^c(a, b) = \bar{x} \leq x_1^* \). In both cases, \( \pi_1 \) is strictly monotone over \([0, 0.5]\) and exactly one strategy dominates all others according to Propositions 1 and 2. On the other hand, for \( p - c < \bar{x} < p \), there exists pairs \( (a, b) \) such that the upper bound may or not bind for either vendor for different subsets of the region. In other words, there exists \( (a, b) \) such that \( A_3 = \emptyset \) or \( A_4 = \emptyset \).29 In this case, \( \pi_1 \) is not strictly monotone over the whole region and hence it is not clear that a dominant strategy exists.

Now, suppose \( b = 1 \). Because \( \bar{x} > p - c \) it must be that \( A_1 = \emptyset \) as \( x_1^c(0, 1) = p - c \). For \( a \in (0, 0.5) \), because \( a + b > 1 \Rightarrow x_1^c(a, 1) \leq x_2^c(a, 1) \) and \( \partial x_2^c / \partial a > 0 \) either \( A_4 = \emptyset \), \( A_2 = \emptyset \) or both, depending on \( \bar{x} \). Thus, \( A_1 \cup A_4 \cup A_2 = [0, 0.5] \) and \( \pi_1 \) has the following properties: (a) piecewise continuous for all \( a \) (b) strictly monotone decreasing in \( a \) for \( a \in A_1 \) by Proposition 1 and (c) strictly monotonically increasing \( a \) for \( a \in A_4 \cup A_2 = \emptyset \) by (a) and Propositions 2 and 3. Therefore, 

\( (a = 0, x_1 = x^c(0, 1)) \) strictly dominates all other \( (a, x_1 = x^c(a, 1)) \) for \( a \in A_1 \); and, 

\( (a = 0.5, x_1 = x^c(0.5, 1)) \) strictly dominates all other \( (a, x_1 = x^c(a, 1)) \) for \( a \in A_4 \cup A_2 \).

\[ ^{29} \text{However, even with } \bar{x} \leq p - c \text{ there still exist } (a, b) \in \{(0, 0.5) \times [0.5, 1]\} \text{ where } A_4 = A_4 = \emptyset. \]
Next, suppose $b \in [0.5, 1)$. First, note there exists $a' \in (0, 0.5]$ such that $a + b = 1 \Rightarrow x^c_1(a, b) \geq x^c_2(a, b)$ for $a \in [0, a']$ and $a + b \geq 1$ for $a \in [a', 0.5] \Rightarrow x^c_1(a, b) \geq x^c_2(a, b)$. This implies that either $[0, 0.5] = A_1 \cup A_3 \cup A_2$ or $[0, 0.5] = A_1 \cup A_4 \cup A_2$. By reasons similar to the case of $b = 1$, $(a = 0, x_1 = x^c(0, 1))$ strictly dominates all other $(a, x_1 = x^c(a, 1))$ for $a \in A_4$; and, $(a = 0.5, x_1 = x^c(0.5, 1))$ strictly dominates all other $(a, x_1 = x^c(a, 1))$ for $a \in A_3 \cup A_4 \cup A_2$. 

I reproduce the statement of the Theorem and conclude with the proof.

**Theorem.** A unique Nash equilibrium in location and $x_i$ exist for two ranges of $\bar{x}$: minimum horizontal differentiation when $\bar{x} \leq p - c_t$ and maximum horizontal differentiation when $\bar{x} \geq p - \frac{25}{17} c_t$. When $p - c_t < \bar{x} < p - \frac{25}{17} c_t$ both minimum and maximum horizontal differentiation are Nash equilibria.

**Proof.** Case 1: $\bar{x} \leq p - c$. By Proposition 2, $A_1 = [0, \frac{1}{2}]$ and profit is strictly increasing in $a$ for vendor 1. By symmetry, $\pi_2$ will be strictly decreasing in $b$. Hence, $\{(a = \frac{1}{2}, x_1 = \bar{x}), (b = \frac{1}{2}, x_1 = \bar{x})\}$ is the unique Nash Equilibrium.

Case 2: $p - c < \bar{x} < p$. From Lemma 10, the only relevant strategy sets for each vendor are $A = \{(a = 0, x_1 = x^c_1(0, b)), (a = \frac{1}{2}, x_1 = x^c_1(\frac{1}{2}, b))\}$ for vendor 1 and $B = \{(b = 1, x_2 = x^c_2(a, 1)), (b = \frac{1}{2}, x_2 = x^c_2(a, \frac{1}{2}))\}$. I verify in the Appendix that for $p - c < \bar{x} < p - \frac{25}{17}$ the following conditions hold

$$\pi_1(a = 0, b = 1, x^c_1(0, b), x^c_2(0, b)) \geq \pi_1(a = 0.5, b = 1, x^c_1(0.5, 1), x^c_2(0.5, 1))$$

$$\pi_1(a = 0.5, b = 0.5, x^c_1(0.5, 0.5), x^c_2(0.5, 0.5)) \geq \pi_1(a = 0, b = 0.5, x^c_1(0, 0.5), x^c_2(0, 0.5))$$
and likewise for vendor 2. Further, I verify that for \( p - \frac{26}{12} \leq \bar{x} < p \) that

\[
\pi_1(a = 0, b = 1, x_1^*(0, b), x_2^*(0, b)) \geq \pi_1(a = 0.5, b = 1, x_1^*(0.5, 1), x_2^*(0.5, 1))
\]

\[
\pi_1(a = 0.5, b = 0.5, x_1^*(0.5, 0.5), x_2^*(0.5, 0.5)) < \pi_1(a = 0, b = 0.5, x_1^*(0, 0.5), x_2^*(0, 0.5))
\]

and likewise for vendor 2.

Case 3: \( \bar{x} \geq p \). The strategy set \{\((a = 0, x_1 = x_1^*(0, 1)), (b = 1, x_2 = x_2^*(0, 1))\}\) is the unique Nash Equilibrium by Proposition 1 as \( A_2 = [0, \frac{1}{2}] \).

The following provides the details for justification of \{\((a = \frac{1}{2}, x_1 = x_1^*(\frac{1}{2}, \frac{1}{2})), (b = \frac{1}{2}, x_2 = x_2^*(\frac{1}{2}, \frac{1}{2}))\)\} and \{\((a = 0, x_1 = x_1^*(0, 1)), (b = 1, x_2 = x_2^*(0, 1))\)\} as Nash Equilibria in location and \( x_i \) under case 2 of Theorem 10. I present each sub-case in normal form using \( p = 2 \) and \( c_t = 1 \) as a numerical example, for now. The solutions are invariant to values of \( p \) and \( c_t \).

The first two sub-cases occur for \( p - c < \bar{x} \leq p - \frac{7}{12}c_t \) where the upper bound binds only for \( a = b = 0.5 \). Whether or not maximum horizontal differentiation is a Nash Equilibrium depends on whether \( \bar{x} \in (p - c, p - \frac{2}{3}c_t) \) or \( \bar{x} \in (p - \frac{2}{3}c_t, p - \frac{7}{12}) \).

Table 11: Profit \( \pi_i, p - c < \bar{x} = 1.2 \leq p - \frac{2}{3}c_t \)

<table>
<thead>
<tr>
<th>( a = 0 )</th>
<th>( a = 0.5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b = 0.5 )</td>
<td>((0.2, 0.6))</td>
</tr>
<tr>
<td>( b = 1 )</td>
<td>((0.5, 0.5))</td>
</tr>
</tbody>
</table>

The next sub-case occurs where the upper bound binds only for the vendor who locates at the end point when the other vendor locates in the center.

The last two sub-cases occur when the constraint always binds for all vendors when at least vendor locates centrally. Whether or not minimum differentiation is
Table 12: Profit $\pi_i$, $p - \frac{2}{3}c_t < \bar{x} = 1.4 \leq p - \frac{7}{12}c_t$

<table>
<thead>
<tr>
<th></th>
<th>$a=0$</th>
<th>$a=0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b=0.5$</td>
<td>(0.15, 0.45)</td>
<td>(0.3, 0.3)</td>
</tr>
<tr>
<td>$b=1$</td>
<td>(0.5, 0.5)</td>
<td>(0.45, 0.15)</td>
</tr>
</tbody>
</table>

Table 13: Profit $\pi_i$, $p - \frac{7}{12}c_t < \bar{x} = 1.5 \leq p - \frac{5}{12}c_t$

<table>
<thead>
<tr>
<th></th>
<th>$a=0$</th>
<th>$a=0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b=0.5$</td>
<td>(0.167, 0.389)</td>
<td>(0.25, 0.25)</td>
</tr>
<tr>
<td>$b=1$</td>
<td>(0.5, 0.5)</td>
<td>(0.389, 0.167)</td>
</tr>
</tbody>
</table>

A Nash Equilibrium depends on whether $\bar{x} \in (p - \frac{5}{12}c_t, p - \frac{25}{72}c_t]$ or $\bar{x} \in (p - \frac{25}{72}c_t, p)$.

Table 14: Profit $\pi_i$, $p - \frac{5}{12}c_t < \bar{x} = 1.65 \leq p - \frac{25}{72}c_t$

<table>
<thead>
<tr>
<th></th>
<th>$a=0$</th>
<th>$a=0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b=0.5$</td>
<td>(0.174, 0.340)</td>
<td>(0.175, 0.175)</td>
</tr>
<tr>
<td>$b=1$</td>
<td>(0.5, 0.5)</td>
<td>(0.340, 0.175)</td>
</tr>
</tbody>
</table>
Table 15: Profit $\pi_i$, $p - \frac{25}{x_t}c_t < \bar{x} = 1.75 \leq p$

<table>
<thead>
<tr>
<th>$a=0$</th>
<th>$a=0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b=0.5$</td>
<td>(0.174, 0.340)</td>
</tr>
<tr>
<td>$b=1$</td>
<td>(0.5, 0.5)</td>
</tr>
</tbody>
</table>