An analysis of shopping behavior at warehouse-club stores and its store-network-density implications

Stanley Frederick W.T. Lim[1] (wtsfl2@cam.ac.uk)
Institute for Manufacturing, University of Cambridge

Elliot Rabinovich
[1] Department of Supply Chain Management
W.P. Carey School of Business, Arizona State University

Sungho Park
Department of Marketing
W.P. Carey School of Business, Arizona State University

Minha Hwang
McKinsey & Company, San Francisco

Abstract

Contrary to other retailers' pursuit of increasingly dense store networks and easier consumer access, warehouse club (WC) retailers have relied on sparse store networks to compete across numerous markets. Little research, however, has examined the shopping behaviors that have enabled WC retailers to succeed using this strategy. Based on a quasi-natural experiment with consumers' subscriptions to Costco Wholesale as a treatment mechanism, we measure tradeoffs among members' shopping behaviors at Costco and contrast them against those at non-WC stores. This analysis shows that, relative to non-WC retailers, Costco's sales are significantly more inelastic relative to consumers' travel distances to stores.

Keywords: Retail operations, quasi-natural experiment, econometrics

Introduction

Since its inception as a business model over four decades ago, warehouse club (WC) retailing has grown to become one of the most successful retail formats in the U.S., accounting for almost $250 billion of annual sales. It has also grown at a faster rate over the past twenty years than any other retail format, including online retailing (Hortaçsu and Syverson, 2015)[1]. WC retailers' success is rooted in operational strategies adapted from low-cost models found in the wholesale industry. A key attribute of these strategies involves WC retailers' reliance on low-density store networks to serve the markets where

[1] Amazon, the largest online retailer in the U.S., reported an increase in annual sales of about $43 billion between 2000 and 2015. The largest WC retailers, Costco and Sam's Club, increased their annual sales by $58 billion and $33 billion over the same period, respectively (Hortaçsu and Syverson, 2015).

they operate, enabling these retailers to achieve high labor productivity and efficiencies in store replenishments and inventory management.

Consider the case of Costco Wholesale, arguably the largest, most successful WC retailer in the U.S.[2] On average, Costco operates approximately two stores in each of the markets it competes. This strategy of market expansion based on low-density store networks is contrary to what Costco's competitors outside WC retailing have done in the past with their store networks. Retailers like Kroger and Walmart, for instance, have typically chosen to enter new markets by opening multiple stores almost simultaneously and have expanded at a faster pace than Costco the number of stores they operate in each of their markets (Kroger, 2016; Walmart, 2016). Of course, underlying Costco's decision in deciding which markets to enter is the awareness that consumers who choose to pay the annual membership fees required to shop at Costco's stores may exhibit a lower sensitivity to accessing these stores relative to accessing non-WC stores (i.e. grocery, drugstore, general merchandise and super-center). In turn, this disparity in sensitivity to store access may influence the number of miles consumers are willing to travel to Costco's stores, as well as the frequency of visits, and expenditures over time at these stores versus non-WC stores.

Past analytical modeling has advanced theoretical arguments and assumptions contrasting shopping behavior by consumers at WC stores and their purchasing behavior at non-WC stores (as a function of expenditures, visits, and traveled miles). This is despite the fact that no empirical evidence has been offered about these behaviors and how they vary as distance between consumers and WC stores increases. Kim and Choi (2007) speculate that consumers who join WC retailers will increase their amounts of visits, expenditures, and traveled miles to stores under other formats in order to supplement the limited assortments typically available at WC stores; contrasting about 4,000 stock-keeping units (SKUs) at a typical WC store with 45,000 SKUs at an average super-center store (Hosken et al., 2012). In putting forth this conjecture, however, Kim and Choi (2007) assume that the distance separating WC members from WC stores is immaterial to the relationship between their shopping behavior at WC stores and at non-WC stores. Without a comparison between consumers' shopping behaviors at a retailer's store and their behaviors at other stores, estimations of the contributing elements to supporting WC retailers' business model remain incomplete.

Using a unique dataset combining data from multiple sources, our study seeks to quantify differences in consumers' shopping activities underlying Costco's decisions to enter new markets across the US. This will allow us to identify key shopping attributes enabling Costco to compete in markets using low-density store networks against non-WC retailers serving those same markets but using store networks with higher density levels. To that end, we focus on consumers' subscriptions to newly opened stores operated by Costco as single, stand-alone facilities across different U.S. markets as a treatment mechanism within a difference-in-differences (DID) analysis framework that contrasts consumers' shopping behavior at Costco against their behavior at non-WC format stores.

Our results show that in choosing to become Costco members, consumers increase their own costs of traveling to the stores. Once they become members, consumers as a whole increase their weekly visits and vehicle miles traveled not only to stores operated by Costco but also to the non-WC stores. This result is consistent with assumptions

[2] Costco currently serves an estimated 31 million active members in the U.S. (Costco, 2016). In 2016, Costco reported sales of $116 billion and a market share of almost 55% in the WC segment of the retail industry (CSIMarket, 2017). Over the past five years, Costco has reported an average of 3% growth in same-store sales, which exceeds significantly the 0.66% average reported by its competitors in the WC retailing segment and the 2.5% average reported by competitors in the broader retailing industry (eMarketer, 2017).

supporting analytical demand models in the literature regarding the supplementary relationship between the number of visits and mileage amounts consumers incur when shopping at WC retailers and those incurred when shopping at retail stores under other formats (e.g. Kim and Choi, 2007). Our result constitutes the first empirical evidence demonstrating such spillover phenomenon involving WC retailers. However, we also observe that these weekly vehicle-miles decrease with the distance that separates Costco members' homes from Costco's stores. According to our results, for every additional mile separating Costco members and Costco's stores, members will increase by 0.40% their weekly amount of miles traveled to visit these stores relative to those traveled by the average member. However, they will more than offset this increase by *cutting* their weekly amount of miles traveled to visit non-WC stores by 0.79% relative to those traveled by the average member.

Literature review

Despite their prominence in the retail industry, Costco and other WC retailers have received minimal attention in the operations management literature. Hitherto, operations management research has only considered WC retailers as part of broader samples of publically traded retailers in order to analyze metrics such as inventory performance and gross margins through company filings (e.g. Gaur et al., 2005).

Warehouse club retailing

The extant literature has examined how incumbent retailers' sales change (Martens et al., 2010) and how they alter their prices (Courtemanche and Carden, 2014) after WC retailers enter their markets. More recently, Ellickson et al. (2017, 2014) observed that consumers' shopping activities across WC stores depend on consumers' income and stores' neighborhood locations. Moreover, Chen (2016) found that consumers' purchasing activities cutting across WC and other retail formats have increased significantly over the past decade. This work is part of a broader body of literature that has examined agglomeration (and spillover) effects on store profitability and intensity of competition (Datta et al., 2007), product pricing (Zhu et al., 2011) and retail employment (Basker, 2005) of store entries. This literature, however, has yet to examine consumers' cross-format shopping behaviors between WC retail stores and non-WC stores. Moreover, there is scarce empirical evidence in this literature demonstrating the existence of positive spillovers between WC store patronage and purchases at non-WC stores.

Retail store networks

Research in operations management has addressed decisions regarding the design of retail store networks mainly through the use of analytical formulations that prescribe optimal solutions to trade-offs between transportation and facility location costs (Daskin, 2013). Only recently have studies in this body of literature incorporated empirical evaluations of consumers' purchasing behaviors to inform those decisions (Fisher et al., 2016). Our comparison of the value of accessibility and utility per visit and miles traveled by consumers shopping at Costco's WC stores versus non-WC stores contributes to this research stream about the levels of density that should be considered when designing store networks across these formats.

Data description

Our analysis uses four main sources of data: (1) a panel dataset of household shopping activity collected through AC Nielsen's Homescan, (2) Costco store locations and openings scraped from Costco's online store directory, (3) U.S. Energy Information Administration (EIA) retail gasoline prices, and (4) Environmental Systems Research Institute (ESRI) business locations. We focus on five U.S. markets where Costco entered

by opening an individual store between October 2003 and March 2006. The five markets we have chosen offered a variety of economic and demographic attributes relevant to the generalizability of our findings that matched closely those in the broader U.S. population. The panel data cover all major retail format stores, including grocery stores, mass merchandise stores, drugstores, and supercenters. Moreover, the data include information on panelist households' purchasing activity at Costco. From this panel, we convert the trip-level data into weekly data and compute each household's weekly count of visits (*weekly visit*) and weekly expenditures excluding sales taxes (*weekly spent*) at Costco stores and at non-WC stores. From the Homescan data set, we also obtained household-level demographic information such as household size, income, age, and household locations based on five-digit zip codes from home addresses.

We then used data from the ESRI directory, along with information on households' addresses in the Homescan panel and the addresses for the Costco stores to estimate the mileage for each trip by each household to stores operated by Costco and to the non-WC format stores. To estimate the mileage for each trip, we used a great circle distance approach. We then aggregated this trip-level mileage on a weekly basis to compute the vehicle miles traveled (*weekly mileage*) for each household's visits to Costco stores and to non-WC stores. We would also like to note that the results we obtained using the great circle distance approach to estimate the trips' mileage are consistent with those we obtained using actual road network conditions via Google Maps' API (available upon request). Moreover, the results are consistent regardless of whether we estimate mileage using discrete point-to-point trips to each store or a policy in which households have the opportunity to bundle their visits to multiple stores as part of the same trip (Gijsbrechts et al., 2008, Wygonik and Goodchild, 2012). ***Appendix A*** expands on the details regarding the implementation of different variations of this "trip chaining" policy. By choosing to use in this paper discrete point-to-point trips to each store as the basis for our mileage calculations in our analyses, we obtain results in which it is more challenging to observe any potential offsets by Costco members between the travel miles they incur when visiting Costco stores versus non-WC stores. This is because for every store visit, the distance is calculated twice (i.e. to and fro). Therefore, to observe any offsets, the reduction in mileage from stores under other formats needs to be substantially higher than the additional mileage incurred at Costco stores.

Although AC Nielsen meticulously samples the households in its Homescan panel to safeguard the panel's level of generalizability relative to the broader population (Muth et al., 2007), our own evaluation confirmed that the households sampled across the five markets offered a variety of economic and demographic attributes relevant to the generalizability of our findings that matched closely those in the broader population.

Our selection of the treatment households follows six conditions:

(1) The household's distance from a treatment Costco store is less than or equal to 35 miles. This is the maximum radius from each of the five stores in our analysis before their coverage overlaps with a neighboring store in another market[3];

(2) The household remains in the Homescan panel for at least 100 days before and after the opening of the treatment Costco store;

(3) The household records in the Homescan panel at least one shopping trip to any retail store in any five-week period during the focal period;

[3] We also ran the analyses at 30, 25 and 20 miles, and found qualitatively similar results. The results are available from the authors, upon request.

(4) The household records more than one shopping trip to a Costco treatment store in the Homescan panel after the opening of the store; and

(5) No records of trips to Costco exist for the household prior to the opening date of the focal Costco stores.

We also identify the control households in a similar manner, using conditions (1) - (3), but we modify condition (2) to "household stays in the panel for at least 200 days". The household selection criteria result in 540 households for our analysis: 70 treatment households and 470 control households with five identified stores opening in five different markets. Because the study is performed at the weekly level, we obtained 9,256 household-week observations from the treatment households.

Econometric approach

We use a DID approach with propensity score adjustment to account for potential endogeneity in Costco's decisions to open new stores in the different markets we considered. We report in this paper the propensity score weighting approach and use the propensity score matching approach as a robustness check (Rosenbaum and Rubin, 1983). First, we identify those households that were unaffected by the treatment (the opening of Costco stores in the five markets we considered). This population corresponds to those households who did not become Costco members after the opening of the stores. Then, from these households, we select a *control group* that shares certain observed characteristics with those households exposed to the treatment. The latter group of households corresponds to the *treatment group* and includes those households who became Costco members after the opening of the stores. We then evaluate the effect of the treatment by comparing the differences in the values for different dependent variables (Y), i.e., *weekly visit, weekly spent,* and *weekly mileage*, between the treatment group and the control group, before and after the treatment application. Figure 1 illustrates the design of this quasi-natural experiment.

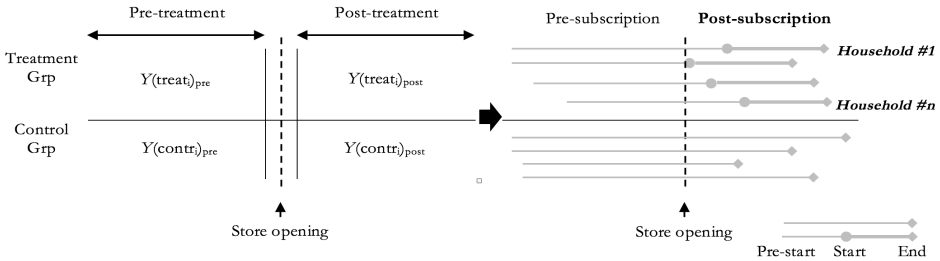

Figure 1 – Quasi-natural experimental design

Notwithstanding, it is critical that we dismiss the possibility of an unobserved external shock leading to the observed effects on the dependent variables among the treatment households, instead of attributing them to Costco membership subscription. As such, we perform a series of tests based on placebo treatments at weeks 12, 20, 30 and 40 during our focal period. We did not find any significant effects from these treatments (see ***Appendix B***). Moreover, a key identification assumption in DID is that the outcomes in the treatment and control groups follow the same longitudinal trend in the absence of the treatment. We did not find evidence to reject the parallel trends assumption. We further verify that our weights properly balance the treatment and control groups by following Guo and Fraser (2009) to carry out this validation procedure (please refer ***Appendix C***). Therefore, these tests increase our confidence of the observed impact of Costco membership subscription on treatment households' shopping activity.

Results and discussion

We first present results from the main treatment effects using a DID specification ($TREAT_i \times AFTER_{it}$) with the binary variable $TREAT_i$= 1 if household *i* belongs to the treatment group and 0 otherwise. Similarly, $AFTER_{it}$ = 1 if week *t* corresponds to the post-treatment period (i.e. after household *i* subscribed to Costco's membership) and 0 otherwise. Second, we present the results from our analysis of the moderation effects by distance between Costco stores and treatment households using a difference-in-difference-in-differences specification ($TREAT_i \times AFTER_{it} \times FAR_i$). Given that one of the dependent variables (i.e. visit) is a count variable, we use a Poisson regression[4].

Main treatment effects

As expected, the coefficients in Table 1 show a positive and significant increase across all dependent variables among treatment households, relative to control households for purchases at Costco. Whereas results in Table 2 provide evidence that after becoming Costco members, households increase their number of visits to these stores by about 4% per week and raise their weekly spending and number of miles traveled to these stores by about 9% and 7%, respectively. Underlying this spillover phenomenon may be limitations in assortment variety at Costco stores that may induce consumers to increase their shopping activities at other retail store formats where they can find broader assortments.

Using the estimates in Table 1 and 2, we find that members' weekly mileage accumulated per visit, amount of dollars spent per visit, and the amount of dollars spent per mile to Costco' stores, exceed by 7.4%, 29%, and 20%, respectively, relative to non-WC stores. This implies that Costco members' shopping behaviors reflect a significantly lower sensitivity to accessing this WC retailer's stores than to accessing non-WC stores.

Table 1 – Shopping activity at Costco

	Spent	Mileage	Visit
TREAT×AFTER	0.4282*** (0.0173) [a]	0.2229*** (0.0088)	0.1199* (0.055)
Household fixed effect	Yes	Yes	Yes
Seasonality	Weekly	Weekly	Weekly
Propensity score weight	Yes	Yes	Yes
# Observations	73,700	73,700	73,700
# Households	540	540	540
R^2 ($Wald\ \chi^2$)	0.265	0.274	(1,380***)

[a] Robust standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 2 – Shopping activity at other retail stores

	Spent	Mileage	Visit
TREAT×AFTER	0.0882* (0.0438) [a]	0.0665* (0.0323)	0.0353* (0.0168)
Household fixed effect	Yes	Yes	Yes
Seasonality	Weekly	Weekly	Weekly
Propensity score weight	Yes	Yes	Yes
Observations	73,700	73,700	73,700
# Households	540	540	540
R^2 ($Wald\ \chi^2$)	0.258	0.374	(52,633***)

[a] Robust standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Moderation effects by distance between Costco stores and treatment households

The coefficient of interest for this analysis is $TREAT_i \times AFTER_{it} \times FAR_i$ where FAR_i is a measure of distance in miles separating household *i* from the nearest Costco store. Table 3 shows that members' weekly expenditures at Costco stores decrease with the distance separating these households from the stores. Although our results in the previous section suggests that WC retailers like Costco are less vulnerable to spatial competition than non-

[4] We noted the higher occurrences of zeros among Costco trips. Therefore, we also apply the zero-inflated Poisson as an alternate specification for estimating these regressions as robustness checks, in which we obtain qualitatively similar results. These results are available upon request.

WC retailers, Costco's market pull appears to be dependent of the distance separating its stores from its members. We observe that, on average, members cut their weekly expenditures at Costco by 0.34% for every mile increase in the distance separating their homes from Costco's stores. This reduction in weekly sales is an important part of the cost that Costco incurs from its reliance on low-density store networks and should be considered when designing trading radii that maximize per-store revenues. If we combine this decrease in weekly expenditures caused by the effect of distance with the percentage increase in driving costs caused by the 0.40% increase in weekly mileage that members put in when visiting Costco stores for every mile separating them from the stores, we can calculate members' cost elasticity of accessing these stores. The ratio between -0.34% and 0.40% (-0.85) indicates that members are driving-cost inelastic.

The results in Table 4 show that Costco members' number of weekly visits to non-WC stores and the amount of miles traveled per week to these stores decrease as the distance separating members and Costco stores increases. The marginal effects of distance (i.e. a one mile increase from the sample average distance from Costco store) on weekly mileage and number of weekly visits to these retail stores is -0.79% and -0.48%, respectively. There is no evidence to suggest that distances between members and Costco stores have a statistically significant impact on weekly expenditures by these households at non-WC stores. This suggests "rationality" in play: members that are farther removed from Costco stores are increasingly more intentional in patronizing other stores. These households offset the additional visits and travel miles they incur when visiting increasingly distant Costco stores with reductions in visits and travel miles to non-WC stores.

Table 3 – Moderating impact of distance on shopping activity at Costco

	Spent	Mileage	Visit
TREAT×AFTER×FAR	-0.0034* (0.0016) [a]	0.0040*** (0.0009)	-0.0018 (0.0040)
TREAT×AFTER	0.4724*** (0.0304)	0.1719*** (0.0139)	0.0431** (0.0205)
Household fixed effect	Yes	Yes	Yes
Seasonality	Weekly	Weekly	Weekly
Propensity score weight	Yes	Yes	Yes
Observations	73,700	73,700	73,700
# Households	540	540	540
R^2 ($Wald\ \chi^2$)	0.265	0.274	(1380***)

[a] Robust standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Table 4 – Moderating impact of distance on shopping activity at other retail stores

	Spent	Mileage	Visit
TREAT×AFTER×FAR	-0.0043 (0.0048) [a]	-0.0079* (0.0039)	-0.0048* (0.0022)
TREAT×AFTER	0.1434 (0.0832)	0.1679** (0.0606)	0.0932* (0.0364)
Household fixed effect	Yes	Yes	Yes
Seasonality	Weekly	Weekly	Weekly
Propensity score weight	Yes	Yes	Yes
Observations	73,700	73,700	73,700
# Households	540	540	540
R^2 ($Wald\ \chi^2$)	0.258	0.374	(52633***)

[a] Robust standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Overall, although the results in Tables 1 and 2 indicate, across the board, households that become Costco members increase their weekly mileage by 29%, resulting from an increase of about 22% in weekly vehicle-miles traveled by these households to Costco stores and an increase of about 7% to non-WC stores, the results in Tables 3 and 4 show that the total vehicle-miles per week traveled by these households to shop at Costco and at non-WC stores depend on the distance separating these households from the Costco stores. For every mile above the sample average value observed for this distance (15.54 miles), these households *reduce* their *total weekly mileage* by 0.39% (-0.0079 + 0.0040) on average. Because this reduction in weekly vehicle miles is at the expense of households' patronage at non-WC stores, households located farther away from Costco

stores are trading off their choice to travel more miles in order to purchase at Costco against the miles they travel to patronize the other retail stores.

Implications and future research

Implications for practice and theory

Our analysis regarding the effect of distances separating Costco's stores from their members on members' weekly expenditures at these stores is valuable for WC retailers like Costco because they inform how much revenue these retailers can obtain as a function of consumers' proximity to their stores. As such, our study provides managers guidance regarding trading radii for WC stores and the level of density for store networks in individual markets in order to maximize revenues per store. Moreover, decisions about store network density in individual markets are also relevant to all retailers concerned about the environmental impact of having distant stores that encourage consumers to drive farther than they otherwise would if outlets were closer to them (Cachon, 2014; Shoup, 2011; Glaeser, 2011; Duany and Speck, 2010; Owen, 2009). Our empirical findings contribute to the analytical modeling literature by shedding light on the distance effect on consumer shopping behavior.

Limitations of study and future research

Future research may examine the vulnerability of WC retailers to spatial competition from retailers operating online and offering consumers the opportunity to have their purchases delivered directly to their homes. Given the lower transaction costs incurred by households online, we believe these findings could enrich our results that have focused mainly on spatial competition from brick-and-mortar retailers. To extend the external validity of our findings, there is also an opportunity to replicate our study to contrast purchasing behaviors at Sam's Club, the second largest WC retailer in the U.S.

Conclusions

Our evaluation of shopping behaviors at Costco by households who choose to become members of this WC retailer upon its entry to their markets and our comparison of these households' shopping behaviors against their purchasing activities at non-WC store formats yield several insights.

(1) There is a supplementary relationship between the weekly expenditures, number of visits, and mileage amounts consumers incur when shopping at WC retailers and those they incur when shopping at non-WC stores. Our paper provides the first empirical evidence demonstrating this positive spillover phenomenon in a WC retailing context.

(2) In choosing to supplement their shopping at WC stores with shopping at non-WC stores, households exhibit a shopping behavior that is substantially less sensitive to the level of access available at WC stores versus that available at non-WC stores. We provide quantification on a set of consumer metrics: spent per mile, spent per visit, and miles per visit.

(3) Household members who are located closer to Costco's stores are the ones responsible for most of the added miles we observed. Although members who live farther away from Costco's stores do put in more miles (by 0.40%) per week visiting these stores relative to members who live closer to the stores, they more than make up for these additional miles by decreasing their weekly mileage traveled to other format stores by 0.79% in relation to the weekly mileage put in by the other members.

(4) There is a limit to how low Costco's store network density should be. Despite its greater market pull relative to non-WC retailers, Costco's revenues per member decrease at a rate of 0.34% for every incremental mile separating members' homes from Costco's stores. From our results, this radius extends as far as 141.5 miles.

We believe our findings are highly valuable contributions to further our understanding of WC retail operations which has, hitherto, been accorded limited attention.

References

Basker E. (2005), Job creation or destruction? Labor market effects of Wal-Mart expansion. *The Review of Economics and Statistics,* Vol. 87 No. 1, pp. 174-183.

Cachon GP. (2014), Retail Store Density and the Cost of Greenhouse Gas Emissions. *Management Science*, Vol. 60 No. 8, pp. 1907-1925.

Chen C. (2016), Competition among retail formats. *Working paper, Northwestern University*.

Courtemanche C and Carden A. (2014), Competing with Costco and Sam's Club: Warehouse club entry and grocery prices. *Southern Economic Journal*, Vol. 80 No. 3, pp. 565-585.

Daskin MS. (2013), *Network and discrete location: Models, algorithms, and applications,* New York: John Wiley.

Datta S, Sudhir K and Talukdar D. (2007), A structural model of entry and location choice: The differentiation-agglomeration tradeoff. *Working paper, Yale University, USA*.

Duany, A. and Speck, J. (2010), *Plan to reduce sprawl will boost health, environment [online]*. Washington Post. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2010/10/15/AR2010101505197.html [Accessed 14 Feb 2017].

Ellickson, P.B., Grieco, P.L.E. and Khvastunovb, O. (2014), Taste versus space: Demand heterogeneity in the grocery industry. *Working Paper, Simon Business School*.

Ellickson, P.B., Grieco, P.L.E and Khvastunovb, O. (2017), Measuring competition in spatial retail. *Working Paper, Simon Business School*.

Fisher, M., Kim, Glaeser, C. and Su, X. (2016), Optimal retail location: Empirical methodology and application to practice. *Working Paper, Wharton School of Business*.

Gallino, S. and Moreno, A. (2014), Integration of online and offline channels in retail: The impact of sharing reliable inventory availability information. *Management Science*, Vol. 6, No. 6, pp. 1434-1451.

Gaur, V., Fisher, M.L. and Raman, A. (2005), An econometric analysis of inventory turnover performance in retail services. *Management Science,* Vol. 51 No. 2, pp. 181-194.

Gijsbrechts, E., Campo, K. and Nisol, P. (2008), Beyond promotion-based store switching: Antecedents and patterns of systematic multiple-store shopping. *International Journal of Research in Marketing,* Vol. 25 No. 1, pp. 5-21.

Glaeser E. (2011), *Triumph of the city: How our greatest invention makes us richer, smarter, greener, healthier, and happier,* New York: Penguin Group.

Guo, S. and Fraser, M.W. (2009), *Propensity score analysis: Statistical methods and applications*. 2nd ed. Thousands Oak, CA: SAGE Publications, Inc.

Hortaçsu A and Syverson C. (2015), The Ongoing Evolution of US Retail: A Format Tug-of-War. *Journal of Economic Perspectives* Vol. 29 No. 4, pp. 89-112.

Hosken, D., Olson, L.M. and Smith, L.K. 2012. Do retail mergers affect competition? Evidence from grocery retailing. *Working Paper 313, Federal Trade Commission*.

Kim S-H and Choi S.C. (2007), The role of warehouse club membership fee in retail competition. *Journal of Retailing,* Vol. 83 No. 2, pp. 171-181.

Martens B.J., Dooley F.J. and Florax R. (2010), A spatial analysis of the effect of entry by supercenter and warehouse club retailers on grocery sales. *Journal of Food Distribution Research,* Vol. 41 No. 2, pp. 46-57.

Owen D. (2009), *Green metropolis: Why living smaller, living closer, and driving less are the keys to sustainability,* New York: Penguin Group.

Rosenbaum P.R. and Rubin D.B. (1983), The central role of the propensity score in observational studies for causal effects. *Biometrika,* Vol. 70 No. 1, pp. 41-55.

Shoup D. (2011), *The high cost of free parking,* Chicago: American Planning Association.

Zhu T, Singh V and Dukes A. (2011), Local competition, entry, and agglomeration. *Quantitative Marketing and Economics,* Vol. 9 No. 2, pp. 129-154.

Appendix

A. Trip chaining procedure to estimate trips' mileage

Our mileage estimations could be biased since the great circle distance approach uses a point-to-point distance calculation which may overestimate the weekly mileage amounts for households located farther from Costco store. This is because this policy does not account for the possibility of households' bundling visits to different stores as part of the same trip (Gijsbrechts et al., 2008). To test for this possibility, we reran the analyses by considering the effects of this form of trip chaining. Since we do not have visibility as to which trips were bundled by the households, we use the trip chaining policy for all store visits that each household reported within the same day and calculate the shortest route and the corresponding distance across these visits. We used two different traveling salesman solution approaches to estimate the trip-

chained distance on each day. The first one relies on the great circle distance with solutions generated via a Branch and Bound approach. The second one generates a set of distance matrices based on actual road networks using the *Google Maps Distance Matrix API* (the pseudocode reported below). We found qualitatively similar results supporting our main findings using both of these approaches.

Pseudocode. Trip chaining procedure.
Input: trip-level consumer panel data
for each *household i* = 1,…, *n* **do**
  for each *day* $d \in D$ **do**
    if $j_d > 1$,
      Construct a travelling salesman problem for *trip stop* t_{kd} for *k=1,…,* j_d;
      if ∃ any t_{kd} = NaN, assign t_{kd} with *city-specific average* given by *distance mile*$_{one\text{-}way}$;
        Solve the travelling salesman problem for $\forall t_{kd}$ and let the minimized distance given by Φ_{min};
        Replace each t_{kd} with the average distance obtained from $\frac{\Phi_{min}}{j_d}$;
    if $j_d = 1$ and t_{1d} != NaN,
      Assign t_{1d} with computed point-to-point distance *p2p*$_{one\text{-}way}$; **else if** t_{1d} = NaN,
      Assign t_{1d} with *city-specific average* given by *distance mile*$_{one\text{-}way}$;
  end
end

B. Placebo tests for spurious correlations

We apply placebo treatment indicators in weeks 12, 20, 30, and 40 during our focal period. Table B1 reports the results for the placebo treatment in week 12. These results show that the estimate for the interaction term is not statistically significant. Since we found similar results for the other placebo dates, we have no evidence of unobserved events leading to changes in the dependent variables among the treatment households.

Table B1 – Placebo test with fictitious treatment on week 12

	log(Spent+1)	log(miles+1)	Visit
TREAT×AFTER	0.0315 (0.0819)	0.0294 (0.0639)	0.0383 (0.0354)
Household fixed effect	Yes	Yes	Yes
Seasonality	Weekly	Weekly	Weekly
Propensity score weight	Yes	Yes	Yes
Observations	17,917##	17,917##	17,917#
# Households	540	540	540
R^2 (*Wald* χ^2)	0.3151	0.4171	(34326***)

Robust standard errors in parentheses; * p<0.05, ** p<0.01, *** p<0.001
Week 87 omitted because of collinearity, ## Week 70 omitted because of collinearity

C. Validation of the propensity score weighting approach

To validate the propensity score weighting approach, we compare estimates from a series of unweighted and weighted regressions. In these regressions, we choose a specific covariate, e.g. household size, as the dependent variable and select the treatment indicator, i.e. whether a household is a Costco member, as the independent variable. The model is specified as:

$$X = \beta_1 Treatment + \beta_0 \quad \text{(C1)}$$

where X is equal to each covariate (logit(X) if the covariate is binary and X if the covariate is continuous). A significant coefficient estimation (β_1) means that there is a significant difference between the treatment and control groups. Thus, for a covariate to be balanced across both groups, $\beta_1$should be insignificant. The weighted regression approach eliminates these differences and provide evidence that our propensity score adjustments adequately balance the data. Table C1 summarizes these results.

Table C1 – Propensity score covariate balance test

	Unweighted		Logit Link Function		Probit Link Function	
	Estimate	t-value	Estimate	t-value	Estimate	t-value
Household size	-0.0023 (0.0145)	-0.16	0.0579 (0.1167)	0.50	0.0081 (0.0212)	0.38
Combined income	6222.50 (292.961)	21.24	675.24 (475.28)	1.42	735.20 (469.61)	1.57
Combined age	2.4222 (0.1146)	21.14	-0.3671 (0.2417)	-1.52	-0.00246 (0.1599)	-1.54
Distance to Costco	-0.7534 (0.0153)	-49.30	-0.0109 (0.0162)	-0.67	0.0066 (0.0163)	0.40
Distance^2 to Costco	-5.3891 (0.1169)	-46.09	0.0679 (0.1051)	0.65	0.1539 (0.1038)	1.48
State gas price	-0.0314 (0.0049)	-6.43	-0.0153 (0.0092)	-1.66	-0.022 (0.0155)	-1.43