Amplification or mitigation? The role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases

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Amplification or mitigation? The role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases[1]

Abstract

This paper investigates the role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases. Using detailed consumer-level data from 2015 to 2019, we confirm the potential of online grocery services to mitigate the effect of limited healthy food access on the healthfulness of food purchases, especially for low-income households. We further investigate the potential underlying mechanisms for how online grocery shopping might mitigate the effect of food environment on the healthfulness of food purchases. We find that households living in areas with a higher density of food stores and a lower density of convenience and drug stores are more likely to adopt online grocery shopping. However, households who do online grocery shopping tend to purchase less healthful food overall in terms of the entire food basket, although online grocery shopping trips themselves are healthier than in-store trips. Therefore, the positive association between food environment and the healthfulness of food purchases is weaker among households who do online grocery shopping. Measures that can be taken to improve the healthfulness of food purchases for worse food environment areas and low-income households and to reduce nutrition inequality are also discussed.

Keywords: Healthfulness of food purchases; Diet quality; Online grocery shopping; Food environment; Nutrition inequality

JEL Classifications: I14; Q18; R20

[1] Statements:

a. Researcher(s) own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business.

b. The conclusions drawn from the NielsenIQ data are those of the researcher(s) and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

1. Introduction

Nutrition inequality caused by the differences in the healthy food supply has drawn increasing policy attention over the last decade (Caspi et al., 2012; Mercille et al., 2016; Morland et al., 2002). Limited access to healthy and fresh food and a poor food environment might cause obesity and other health-related issues, especially for low-income households (Alviola et al., 2013; Morland et al., 2006; Powell et al., 2007; Spence et al., 2009; Thomsen et al., 2016). A variety of programs and policies have been implemented or considered[2] to reduce the effects of limited access to affordable and nutritious food, such as the Healthy Food Financing Initiative[3] and the USDA food distribution program.[4] However, such efforts have not yielded a significant impact on improving the dietary behaviors of residents (Dubowitz et al., 2015; Elbel et al., 2017).

Online grocery shopping, the trend of purchasing groceries online as opposed to going to a brick-and-mortar store, may offer a new alternative. Although online grocery sales remain only a small percentage of US total grocery sales, they are growing rapidly and have more than doubled over the past five years (Mintel 2019). In addition, online grocery sales reached 9.5% of $1.097 trillion in total grocery sales in 2021 from 3.4% of $1.016 trillion in 2019, and it is predicted that the sales could increase to 20.5% of $1.285 trillion in 2026.[5] Moreover, grocery retailers and third-party services offering online grocery shopping options are developing rapidly. Traditional grocers such as Walmart have taken action to catch up with this new trend and provide fresh food delivery and pickup services in many markets.[6] New e-commerce aiming at online grocery shopping has also entered the market. For example, FreshDirect, essentially an online grocery store, delivers fresh food to consumers fast and conveniently. In addition, the third-party services partner with retailers, shop and deliver items to home for shoppers, such as Instacart which now offer services for more than 300 retailers and local stores.

[2] See https://obamawhitehouse.archives.gov/the-press-office/2011/07/20/first-lady-michelle-obama-announces-nationwide-commitments-provide-milli.

[3] See https://www.healthyfoodaccess.org/take-action-now-policy-efforts-impacts.

[4] See https://www.usda.gov/topics/food-and-nutrition/food-distribution.

[5] See https://info.mercatus.com/online-grocery-shopper-consumer-behavior.

[6] The number of stores offering delivery is 3,000 across the U.S., covering 70% of the population in 2021, according to a public post from Walmart's executive vice president and chief product officer. See https://www.linkedin.com/posts/mengchee_what-a-milestone-delivery-is-now-in-3000-activity-6760968489906823169-aCtp/.

As a result, online grocery shopping might act as an alternative to traditional grocery shopping for households living in urban neighborhoods and rural communities where access to healthy food choices can be limited. On one hand, with online grocery shopping, consumers, especially low-income food desert dwellers, can order groceries online and have them delivered. Therefore, online grocery shopping may have the potential to mitigate the impact of community access barriers of limited healthy food access and poor food environment, which is related to healthy food purchases and better diet quality. On the other hand, areas with better food environments are also more likely to have the availability of online grocery shopping services. Online grocery shopping thus may also have the potential to amplify the nutrition inequality associated with the differences in food environments.

To better inform public policies designed to improve the healthfulness of household food purchases, it is important to understand the role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases, and how federal and local policies can be reshaped to promote healthy purchases in the online grocery shopping environment. Specifically, this paper aims to answer the following questions. First, does online grocery shopping mitigate or amplify the relationship between food environment and the healthfulness of food purchases? Second, what are the potential underlying mechanisms for how online grocery shopping might amplify or mitigate the effect of food environment on the healthfulness of food purchases? This paper uses detailed consumer-level food purchases from Nielsen Consumer Panel Data from 2015 to 2019.

This paper contributes to the existing research that aims to better understand the food environment and public policies that are effective in improving the healthfulness of food purchases. Previous research has explored the role of the local food environment on diet quality, while the results are mixed and controversy exists. Early literature found that the food environment plays an important role in promoting diet quality (Caillavet et al., 2015; Larson et al., 2009; Morland et al., 2002; Story et al., 2008; R. L. J. Thornton et al., 2016). While Allcott et al. (2019) used multiple datasets and implemented both a reduced-form model and a structure model to separate the effect of food supply and consumers' preference for healthy food and found that neighborhood food environments did not show a meaningful impact on nutritional inequality. However, the role of online grocery shopping in the relationship between food environment and diet quality has not

been fully studied in previous studies. In contrast to these studies, we analyze the mediating role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases, and the potential that online grocery services have for addressing limited food access and poor food environment.

This paper also complements a growing empirical literature that investigates the economics of online grocery shopping. Previous literature has shown that online grocery shopping will promote diet health by reducing the purchase of vices (Huyghe et al., 2017), and increasing the consumption of healthy food categories such as dark green vegetables (Harris-Lagoudakis, 2021). In addition, Jilcott Pitts et al. (2018) claimed that online grocery shopping can act as a tool to mitigate the limited food access to a brick-and-mortar store. The differences in brand loyalty between instore shopping and online grocery shopping (Wang et al., 2019), default display option and navigation tools (Anesbury et al., 2016), shopping lists online (Davydenko & Peetz, 2020), delayed time between ordering and receiving the products and distraction associated with online grocery shopping could make differences on food choices and thus affect diet quality (Harris-Lagoudakis, 2021). This paper further investigates how online grocery shopping relates to the healthfulness of diet for both the entire food purchasing baskets and individual trips, with a special focus on low-income households.

Our results confirm the potential that online grocery services have for addressing limited food access and poor food environment, especially for low-income households who have been proven by previous research to be more likely to live in worse food environment areas and have unhealthier diets than non-low-income households(Alwitt & Donley, 1997; Gittelsohn et al., 2008; Gittelsohn & Trude, 2017; Sawyer et al., 2021; Yousefian et al., 2011). We further investigate the potential underlying mechanisms for how online grocery shopping might mitigate the effect of food environment on the healthfulness of food purchases. We find that households living in areas with a higher density of food stores and a lower density of convenience and drug stores are more likely to adopt online grocery shopping. However, households who do online grocery shopping tend to purchase less healthful food overall in terms of the entire food basket, although online grocery shopping trips themselves are healthier than in-store trips. Moreover, online grocery shopping adopters rely less on local food stores than non-adopters to get access to healthy foods because of the alternative option of purchasing groceries online. Therefore, the positive association

between food environment and the healthfulness of food purchases is weaker among households who do online grocery shopping. Further, the mitigating role of online grocery shopping is stronger for low-income households. Although low-income households purchase less healthful food than non-low-income households, the negative effect of limited access to healthy food can be mitigated by online grocery shopping options.

Understanding the role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases sheds light on the policies aiming to mitigate nutrition inequality. Policymakers can take advantage of online grocery shopping services in improving diet quality, especially for poor food environments areas and low-income households. First, actions can be taken to promote grocery retailers and third-party companies providing online grocery shopping to increase the availability of online grocery purchase options. Second, policies to reduce the costs and prices for online groceries can also be implemented to eliminate the higher price barriers for consumers to use online grocery services.

The rest of the paper is organized as follows. Section 2 describes the data used in this paper and presents summary statistics for the main variables. Section 3 describes the estimation method. Section 4 presents the estimation results. Section 5 concludes and discusses the implications for both related research and policymakers.

2. Data

We use Nielsen Consumer Panel Data from 2015 to 2019 to collect the household online grocery shopping purchases. The Nielsen Consumer Panel Data represents a longitudinal panel of approximately 60,000 US households who continually provides information about their households, what products they buy, as well as when and where they make purchases. This paper focuses on online grocery shopping behaviors and measures the local food environment at the county level. Following previous literature (Izumi et al., 2011; Powell & Han, 2011; L. E. Thornton et al., 2010)[7], the food environment in this paper is measured by the population density of food

[7] Previous literature has used different proxies to measure the food environment, such as the presence of food stores and supermarkets(Gustafson et al., 2010; Morland et al., 2002), the distance from or travel time to the nearest food stores/supermarkets/convenience stores(Michimi & Wimberly, 2010; Pearce et al., 2008), and the store density by land size and population(Izumi et al., 2011; Powell & Han, 2011; L. E. Thornton et al., 2010). This paper uses store density as the measurement due to data availability.

stores[8] and the population density of convenience and drug stores. The number of stores is from County Business Patterns Data, which provides subnational economic data by industry such as the number of business establishments.[9]

In general, there is an increasing trend of online grocery shopping during our sample period. The percentage of online grocery shopping adopters, which is defined as households who purchase grocery products online at least once in a panel year, increased from 8.91% in 2015 to 10.98% in 2019. There are 297,173 observations in the data covering five years.[10] The summary statistics of the main variables are shown in Table 1. The first two columns show the mean values and standard deviations for each variable for all households, the third and fourth columns report the mean values for online grocery shopping non-adopters and adopters respectively, and the last column gives the results of a two-sample t-test with unequal variances between the two groups.

As can be seen in part A, the average percentage of consumers who bought groceries online in a year is 9% (27,087 observations). A typical household spent 3078.58 dollars per year on grocery products and 0.49% ($15.19) was spent via online grocery shopping. A typical household purchases groceries 108.86 times per year, which is slightly more than the results from Statista (2022) that the weekly grocery shopping trips per household in the United States are 1.5-1.6 from 2015 to 2019.[11] Overall, the number of online grocery trips among all households is 0.31 per year, while the number is 3.44 among online grocery shopping adopters. This means that a typical adopter shopped groceries online quarterly. Compared to the non-adopters, the adopters spent more on grocery purchases and shop more frequently.

The local food environment is measured by the number of stores per 10,000 population. Specifically, we use two proxies for local food environments: a) food stores and b) convenience and drug stores. Previous literature has shown that the presence of and distance to food stores as well as convenience and drug stores are correlated with the healthfulness of food consumption (Dhakal & Khadka, 2021; Lind et al., 2016; Rummo et al., 2015). On average, the number of food stores per 10,000 population is 2.07. And the non-adopters of online grocery shopping (2.05) live

[8] Food stores include grocery stores, supermarkets and warehouse clubs.
[9] https://www.census.gov/programs-surveys/cbp.html.
[10] After dropping the outliers whose number of grocery trips in a year is less than 1% quantile or more than 99% quantile, there are 58,321, 60,580, 60,272, 59,030 and 58,970 households from 2015 to 2019 respectively.
[11] See https://www.statista.com/statistics/251728/weekly-number-of-us-grocery-shopping-trips-per-household/.

in areas with a lower density of food stores than the adopters (2.22) and the difference is statistically significant at a 1% confidential level.

The healthfulness of food purchases of households' total basket, in-store basket, and the online basket is presented in part C of Table 1, which is measured by the expenditure share of healthy food categories based on the Thrifty Food Plan (TFP)(U.S. Department of Agriculture, 2021). It divides the food into six groups (vegetables, fruits, grains, dairy, protein foods, miscellaneous) and 24 categories (e.g. dark-green vegetables, red and orange vegetables, whole/non-whole fruit) which are recommended for either increased or reduced consumption (Volpe et al., 2017). As seen in the table, without controlling for other factors, the adopters have a higher yearly healthy food expenditure share than the non-adopters and the difference between the two groups is significant at only a 10% confidential level. However, there is no significant difference in the healthy food expenditure share in the in-store basket between adopters and non-adopters.

Part D of Table 1 gives the summary statistics for the main control variables. Compared to the non-adopters, the household head ages are higher, and the ratios of being married are lower for the adopters. And the adopters have a higher education, smaller household size, and a higher probability to have internet access than the non-adopters.

3. Model

3.1 Online Grocery Shopping and the Healthfulness of Food Purchases: Whole Basket and Yearly Level

To better understand the role of online grocery shopping, we first evaluate the relationship between the local food environment, online grocery shopping, and its interactive effect on the combined purchases (in-store and online across all stores) in a year. Specifically, we focus on the role of online grocery shopping in the relationship between food environment and the healthfulness of their food purchases. The equation of interest is written as:

$$HealthShare_{ht} = \alpha_1 Env_{ht} + \alpha_2 Online_{ht} + \alpha_3 Env_{ht} * Online_{ht} + \beta X_{ht} + Time + County + \varepsilon_{ht} \quad (1)$$

where $HealthShare_{ht}$ is the healthy food expenditure share of total grocery basket for household h at year t. Env_{ht} is a measure of the household food environment, which is measured by the number of food stores and the number of convenience and drug stores per 10,000 population in a county. $Online_{ht}$ is a dummy variable that equals 1 if household h does online grocery shopping in year t, which will capture the direct effect of online grocery shopping on a household's healthfulness of food purchases. X_{ht} is a vector of demographic variables of the households, including age, education which is measured by the years of schooling, marital status, the race of the household head[12], household income, and household size. $Time$ and $county$ are time fixed effect at the year level and county fixed effect respectively. ε_{ht} is the error term. Further, an interaction term of the food environment and online grocery shopping is also included in the estimation, which will explore the role of online grocery shopping in mitigating or amplifying the effect of the food environment on the healthfulness of consumers' food purchases.

3.2 Mechanism

This section further explores the potential mechanisms of how online grocery shopping may mitigate or amplify nutrition inequality associated with the difference in food environments, by sequentially investigating the relationship between a) food environment and online grocery shopping adoption and b) online grocery shopping adoption and the healthfulness of food purchases.

First, in general, the local food environment may have two opposite effects on online grocery shopping at this early stage. On one hand, a higher density of food stores can be positively associated with online grocery shopping due to the availability of online grocery shopping services. In an area with a higher density of food stores, it is more likely to have more local grocery retailers that offer online grocery shopping services, including both curbside pickup and delivery services. While in an area with a lower food store density, the number of retailers with online grocery shopping and third-party services might both be limited even though consumers may prefer to do grocery shopping online. On the other hand, a higher density of food stores may also be negatively related to online grocery shopping. When there are no sufficient food stores in an area, households

[12] When there are two household heads, we use the average of characteristics the female head and male head.

may have more incentive to switch to the alternative, online grocery shopping, to get access to fresh and healthy foods.

Second, the relationship between online grocery shopping adoption and the healthfulness of food purchases can also be either positive or negative. On one hand, previous literature has shown that online grocery shopping is usually healthier than in-store grocery trips (Harris-Lagoudakis, 2021; Huyghe et al., 2017; Zatz et al., 2021) due to reasons such as differences in brand loyalty between in-store shopping and online grocery shopping (Wang et al., 2019), delayed consumption and distraction (Harris-Lagoudakis, 2021). On the other hand, online grocery shopping may squeeze out in-store purchases for healthy foods. Consumers may switch their healthy food purchases online, and spend larger shares of their expenditure on unhealthy food when shopping in-store. In addition, there are usually extra processing and delivery fee, as well as membership fees when shopping grocery online, which generates extra costs than in-store shopping and may restrict the food choices for in-store shopping. Therefore, the in-store trips after adopting online options may be less healthy than before the adoption.

3.2.1 Food Environment and Online Grocery Shopping Behavior

We investigate the relationship between food environment and online grocery shopping behavior from two perspectives: a) online grocery shopping decision and b) online grocery shopping frequency. We first evaluate the relationship between food environment and households' online grocery shopping decisions by estimating the logit model (2), and we then use a Zero-inflated Poisson (ZIP) model to investigate the association between the food environment and online grocery shopping frequency in model (3):

$$Online_{ht} = \gamma_1 Env_{ht} + \theta_1 Y_{ht} + Time + County + \varepsilon_{ht} \quad (2)$$

$$Freq_{ht} = \gamma_2 Env_{ht} + \theta_2 Y_{ht} + Time + County + \varepsilon_{ht} \quad (3)$$

where $Online_{ht}$ is a dummy variable that equals 1 if household *h* uses online grocery shopping in year *t*, $Freq_{ht}$ is the number of online grocery shopping trips in a panel year, Env_{ht} is a measurement of the household food environment. Y_{ht} is a vector of demographic variables of the households and is the same as X_{ht} in model (1), additionally including a dummy variable indicating the availability of internet access. $Time$ and $county$ are time fixed effect at the year level and county fixed effect respectively. ε_{ht} is the error term.

Given the existence of the excess zero in the frequency of online grocery shopping, we implement the ZIP model when investigating the association between the food environment and online grocery shopping frequency. The ZIP regression is used to model count data that has an excess of zero counts. In our data, there are two types of households: households who do not purchase groceries online in a year (frequency =0) and households who purchase groceries online at least once in a year (frequency >0). When the frequency of online grocery shopping is zero, it can either be because a household has no access to online grocery shopping services or because they have access but choose not to buy groceries online. ZIP model can capture both cases appropriately.

3.2.2 Online Grocery Shopping and the Healthfulness of Food Purchases: Trip Level

We now use detailed trip-level data to estimate the relationship between online grocery shopping and the healthfulness of food purchases. There are three types of trips: a) the online trips of online grocery shopping adopters who purchased groceries online at least once in a panel year, b) the in-store trips of online grocery shopping adopters, and c) the in-store trips of non-adopters who did not use online grocery shopping in a year. The equation of interest can be written as:

$$HealthShare_m = \lambda\, OnlineTrip_m + \delta X_{ht} + Time + county + \varepsilon_m \quad (4)$$

$HealthShare_m$ is expenditure share of healthy food categories for a specific trip m, which is used as an indicator for the healthfulness of purchases. $OnlineTrip_m$ is a dummy variable that equals 1 if the trip is an online grocery shopping trip and 0 if an in-store trip.

We first use all trips done by all households to evaluate if there are any differences in the expenditure shares between online trips and in-store trips (including both adopters and non-adopters). We then perform a subsample analysis focusing on adopters' all shopping trips (both online and in-store), to evaluate the effect of online grocery shopping on adopters' healthfulness of purchases, compared to their own in-store trips. Further, we only include the subsample of in-store grocery trips of all households to measure if there are differences in expenditure shares of healthy food categories for in-store trips between online grocery adopters and non-adopters.

4. Results

4.1 Food Environment, Online Grocery Shopping and the Healthfulness of Food Purchases

The main results from Equation (1) are presented in Table 2. We can see from column (1) that households living in an area with a higher food store density and thus a better food environment tend to purchase healthier food, which is consistent with the literature in the sense that households living in an area with more food stores are more likely to have access to fresh and healthy food. Households living in an area with a higher convenience and drug store density are more likely to purchase less healthful food.

The healthfulness of the entire food basket for households who do online grocery shopping online is lower, compared to households not using online grocery shopping. One possible explanation is that households may shop for fresh produce such as fresh fruits and vegetables online, which are typically healthier, and buy unhealthier food categories when shopping in brick-and-mortar stores. Given that online grocery shopping only accounts for a small proportion of total grocery spending, the healthfulness of their online grocery shopping is outweighed by that of their in-store shopping. We will explain it in more detail at a trip level in section 4.2.2.

We focus on the role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases, which is captured by the interaction terms of online grocery shopping and food environment. The interaction term of convenience and drug store density and online grocery shopping has a positive and significant effect on the healthfulness of food purchases, suggesting that the negative effect of local convenience and drug stores on the healthfulness of food purchases is smaller for households who use online grocery shopping. Thus, online grocery shopping adopters tend to depend less on the local food environment to get access to healthy foods due to the alternative option of purchasing groceries online. Specifically, for the online grocery shopping adopters, an additional increase in the number of convenience and drug stores per 10,000 population decreases healthy food expenditure share by 0.17%, compared to a 0.27% decrease for households not using online grocery shopping.

Figure 1 shows the relationship between predicted margins of healthy food expenditure shares and food environment for both online grocery shopping adopters and non-adopters. Figures 1A and 1B show the results for food store density, and convenience and drug store density

respectively. Overall, with the increase in food store density and the decrease in convenience and drug store density, the healthfulness of food purchases improves for both adopters and non-adopters. Moreover, our results suggest that online grocery shopping is particularly important for households living in an area with fewer food stores and more convenience and drug stores.

As can be seen in Figure 1A, when the number of food stores is less than 3.07 per 10,000 population, the households that use online grocery shopping tend to purchase healthier food than the households not using the online option. Given that the average number of food stores per 10,000 population is 2.07, the predicted healthy food expenditure shares for online grocery shopping adopters are larger than non-adopters at the average level of food store density. About 90% of households in our sample live in areas where food store density is less than 3.07, which means that over 90% of households living in areas with fewer food stores can benefit from online grocery shopping.

We can know from Figure 1B that when the number of convenience and drug stores is greater than 4.00 per 10,000 population, the households that use online grocery shopping tend to purchase healthier food than the non-adopter. Given that the average number of convenience and drug stores per 10,000 population is 5.39, the predicted healthy food expenditure shares for online grocery shopping adopters are larger than non-adopters at the average level of convenience store density. Over 75% of households in our sample live in areas where the convenience and drug store density are greater than 4.00, which means that over three-fourths of households living in more convenience and drug stores can benefit from online grocery shopping.

4.2 Mechanism

4.2.1 Food Environment and Online Grocery Shopping Behavior

We first present the relationship between the food environment and online grocery shopping behavior, from Equations (2) and (3), in Table 3. Results from the binary logit model are presented in Column (1), which evaluates the association of the food environment and households' online grocery shopping decisions. We find that a household is more likely to adopt online grocery shopping if living in an area with a higher density of food stores. Translating to the marginal effects, the coefficient of 0.1273 implies that an additional increase in the number of food stores per 10,000 population will increase the probability of using online grocery shopping in a year by 1.05% on

average. The result is significant at a 1% confidential level. In addition, a household is less likely to adopt online grocery shopping if living in an area with a higher density of convenience and drug stores. Translating to the marginal effects, the coefficient of -0.0105 implies that an additional increase in the number of convenience and drug stores per 10,000 population will decrease the probability of using online grocery shopping in a year by 0.09% on average.

There might be many households who do not do online grocery shopping either because the service was not available in their areas or they choose not to, even with the availability. So, we further use a ZIP model to evaluate the effect of the food environment on their online grocery shopping frequencies and the results are presented in Column (2). The result is in line with the previous online grocery shopping decisions: the adopters buy groceries online more frequently when living in an area with a higher density of food stores and a lower density of convenience and drug stores. Specifically, an additional increase in the number of food stores per 10,000 population increases the number of online grocery trips for a household in a year by 0.07 times, while an additional increase in the density of convenience and drug stores will reduce the frequency of online grocery shopping trips by 0.01 times. Given that the average number of online grocery trips is 0.31 per year, it indicates a 22.58% increase and a 3.23% decrease respectively. In addition, households with lower income, older ages, and higher education are more likely to use online grocery shopping. Compared to Asian and other races, White households are less likely to use online grocery shopping, while Black households have a larger probability to purchase groceries online. In addition, households with internet access are more likely to use online grocery shopping.

Overall, the results imply the combined net effect of the two forces: households are more likely to purchase groceries online when living in a better food environment with more food stores. The positive effects of food stores on online grocery shopping decisions due to availability dominate the negative effects on the food stores due to consumers seeking substitutions.

4.2.2 Online Grocery Shopping and the Healthfulness of Food Purchases: Trip Level

Table 4 shows the relationship between online grocery shopping and the healthfulness of food purchases at the trip level. Column (1) presents the results using all shopping trips (online and in-store) done by all types of shoppers (both online shopping adopters and non-adopters). The healthy food expenditure shares of online grocery strips are 1.5242% higher, compared to the in-store

grocery shopping trips. In addition, older, married households with higher incomes and smaller household sizes tend to have healthier food purchases.

We further restrict our sample to the online grocery shopping adopters only and compare their online and in-store grocery shopping trips. We find that the coefficient of online trips is still positive and significant, suggesting that online grocery shopping adopters' online trips are healthier than their own in-store trips. This may be explained by the substitution across retail channels when consumers are shopping for different categories of products. Consumers may order fresh and healthier groceries from online grocery shopping and buy less healthy items from other channels. Knowing that in-store trips are generally less healthy, we then restricted our sample to just in-store trips done by all shoppers to evaluate whether there are any differences in the healthfulness of in-store baskets between online grocery shopping adopters and non-adopters. As can be seen in column (3), the healthy food expenditure shares of in-store trips for adopters are lower than the non-adopters. In other words, consumers who shop healthier online may overcompensate by shopping less healthy on their in-store trips. In general, we find that online grocery trips are healthier than in-store grocery trips. But for online grocery shopping adopters, although their online grocery baskets are healthier than the non-adopters, the in-store baskets are less healthy than that of the non-adopters.

The combined results from the two steps help us to discover the potential underlying mechanisms for how online grocery shopping might mitigate the effect of food environment on the healthfulness of food purchases. Households living in areas with a higher density of food stores and a lower density of convenience and drug stores are more likely to adopt online grocery shopping. However, households who do online grocery shopping tend to purchase less healthful food overall in terms of the entire food basket, although online grocery shopping trips themselves are healthier than in-store trips. Therefore, the positive association between food environment and the healthfulness of food purchases is weaker among households who do online grocery shopping.

4.3 Low-Income Households

Low-income households typically have limited access to healthy food, live in a poor food environment, and have lower diet quality. In this section, we focus on low-income households and assess whether online grocery shopping has a differentiated effect on the healthfulness of food

purchases for low-income households. Specifically, we introduce a three-way interaction term of the food environment, online grocery shopping dummy, and low-income household dummy.

$$HealthShare_{ht} = \alpha_1 Env_{ht} + \alpha_2 Online_{ht} + \alpha_3 Env_{ht} * Online_{ht} + \alpha_4 LowInc_{ht} + \alpha_5 Env_{ht} * LowInc_{ht} + \alpha_6 Online_{ht} * LowInc_{ht} + \alpha_7 Env_{ht} * Online_{ht} * LowInc_{ht} + \beta Z_{ht} + Time + County + \varepsilon_{ht} \quad (5)$$

where $LowInc_{ht}$ is a dummy variable that equals 1 if a household is a low-income household. We define low-income households as those with an annual income below 130% of the poverty line, which is the reference for many food-related policies, such as SNAP eligibility. Z_{ht} is a vector of demographic variables of the households and is the same as X_{ht} in previous models, excluding the log of income.

Estimation results in Table 5 show that low-income households purchase less healthy food than non-low-income households. Specifically, the expenditure share on healthy food categories for low-income households is 1.06% lower than for non-low-income households. The interaction terms of low income, online grocery shopping, and food store density allow us to explore the differentiated effects on the healthfulness of food purchases by groups.

We further calculate the net average marginal effects of online grocery shopping and store density on the healthfulness of food purchases for four groups: 1) low-income households using online grocery shopping, 2) low-income households not using online grocery shopping, 3) non-low-income households using online grocery shopping, and 4) non-low-income households not using online grocery shopping. The results are presented in Table 6. Column A shows the average marginal effect of food store density by the four groups. For low-income households who use online grocery shopping, the food store density does not have a significant effect on their healthfulness of food purchases. However, the effect is positive and significant (0.6698) for those low-income households who do not shop grocery online. In addition, the difference in the average marginal effect of the food store density between low-income households who do not use online grocery shopping and low-income households who use online grocery shopping is negative and significant. In other words, online grocery shopping mitigates nutrition inequality caused by different food store densities for low-income households. Column B shows the average marginal effect of convenience and drug store density by the four groups. For low-income households who

use online grocery shopping, the negative effect of convenience store density on their healthfulness of food purchases is not significant. However, the negative effect is significant (-0.2814) for those low-income households who do not shop grocery online. The difference in the average marginal effect is not significant for low-income households, while it is significant for non-low-income households. In addition, the negative marginal effect of the convenience and drug store density is larger for those non-low-income households who do not use online grocery shopping. In other words, online grocery shopping mitigates the negative effects of convenience and drug store density on the healthfulness of food purchases for non-low-income households.

Finally, Figure 2 shows the predicted margins for healthy food expenditure shares for the four groups. We can see that in general, non-low-income households purchase healthier food than low-income households. What is worth noting in Figure 2A is that when the number of food stores is less than 3.70 per 10,000 population, the low-income households that use online grocery shopping tend to buy healthier food than the low-income households not using the online option. Given that the average food store density is 2.15 for low-income households in our dataset, we can say that online grocery shopping can improve the healthfulness of food purchases for low-income households and help reduce the inequality in nutrition between low-income households and non-low-income households at the average food store density. In addition, the 90% quantile of food store density for low-income households is 2.93, which means that over 90% of low-income households can benefit from the online grocery shopping option and improve the healthfulness of food purchases. As can be seen in Figure 2B, when the number of convenience and drug stores is larger than 1.28 per 10,000 population, the adopters of online grocery shopping purchase healthier food than non-adopters for low-income households; and when the density of convenience stores and drug stores is larger than 4.18 per 10,000 population, the adopters of online grocery shopping purchase healthier food than non-adopters for both non-low-income households and low-income households.

5. Conclusion and Discussion

This paper investigates the role of online grocery shopping in the relationship between food environment and household healthfulness of food purchases with a focus on low-income households. To reduce nutrition inequality, increasing healthy food supply by investing in poor

food environment areas is one of the most common measures and has been discussed a lot in previous literature. Although Allcott et al. (2019) argued that policies to increase healthy food supply could not play a significant role in reducing nutritional inequality, the online grocery shopping option was not discussed in the paper. Our results confirm the potential of online grocery services to address the limited healthy food access and poor food environment, especially for low-income households. The conclusion of the main results in this paper and discussion on measures that can be taken to improve diet qualities for worse food environment areas and low-income households and to reduce nutrition inequality are presented below.

We further investigate the potential underlying mechanisms for how online grocery shopping might mitigate the effect of food environment on the healthfulness of food purchases. We find that households living in areas with a higher density of food stores and a lower density of convenience and drug stores are more likely to adopt online grocery shopping. However, households who do online grocery shopping tend to purchase less healthful food overall in terms of the entire food basket, although online grocery shopping trips themselves are healthier than in-store trips. Therefore, the positive association between food environment and the healthfulness of food purchases is weaker among households who do online grocery shopping.

In addition, low-income households purchase less healthful food than non-low-income households, but the negative effect of limited access to healthy food can be mitigated by online grocery shopping options. Among low-income households, results show that the association between food store density and the healthfulness of food purchases is not significant for adopters. In addition, low-income households are proven by previous literature to be more likely to live in areas with worse food environments and our results show that over 90% of low-income households can benefit from the online grocery shopping option to get a better diet. Therefore, online grocery shopping has the potential to improve the healthfulness of food purchases for low-income households living in a poor food environment and then reduce nutrition inequality. Actions can thus be taken to facilitate online grocery shopping for better diet quality.

Policymakers can take measures to promote grocery retailers and third-party companies providing online grocery shopping to increase the availability of online grocery purchase options, especially for low-income households living in a poor food environment. For example, to facilitate the process for low-income households, the US Department of Agriculture launched a pilot

program in April 2019 that allowed food stamp recipients to use their electronic benefits transfer (EBT) cards to purchase food online for delivery from retailers including Walmart, Amazon, and ShopRite. Instacart joined them in October 2021 through a partnership with Aldi and is increasing their participation through partnerships with three more retailers: Publix Super Markets, The Save Mart Companies, and Golub Corp's Price Chopper/Market 32. Moreover, higher prices online than in local in-store grocery purchases are an important factor that prevents households from using online grocery shopping. Policies to reduce the costs and prices of online groceries shopping can also be implemented. For example, policymakers can subsidy to grocery retailers and third-party companies that provide online grocery shopping services or open a "Green Channel" for faster and lower-cost shipping and delivery for online grocery shopping.

As far as we know, this paper is the first to explore the role of online grocery shopping in the relationship between food environment and the healthfulness of food purchases. Although a limitation exists in that it is not a causal analysis, it provides evidence of their association, especially for low-income households. More importantly, it provides a new perspective for the research addressing the food environment, food desert, and nutrition inequality and interest in the new trend of online grocery shopping.

Tables and Figures

Table 1 Summary Statistics of the Main Variables

Variable	Mean	Std. Dev.	Non-Adopters	Adopters	Mean Difference
A. Online grocery shopping behaviors					
Online grocery shopping adopter	0.09	0.29	N/A	N/A	N/A
Online grocery shopping frequency	0.31	2.39	N/A	3.44	N/A
In-store grocery shopping frequency	108.55	66.13	107.50	119.05	-11.55***
Grocery shopping frequency	108.86	66.14	107.50	122.49	-14.99***
Online grocery expenditure ($)	15.19	143.56	N/A	166.65	N/A
In-store grocery expenditure ($)	3063.39	1768.32	3042.48	3271.90	-229.42***
Total grocery expenditure ($)	3078.58	1771.21	3042.48	3438.55	-396.07***
B. Food environment (measured by the number of stores per 10,000 population)					
Food Store Density	2.07	0.97	2.05	2.22	-0.17***
Convenience and Drug Store Density	5.39	1.75	5.39	5.38	0.01

Variable	Mean	Std. Dev.	Non-Adopters	Adopters	Mean Difference
C. Healthy food expenditure share (%)					
Total basket	25.47	9.73	25.46	25.57	-0.11*
Online basket	2.30	10.86	N/A	25.24	N/A
In-store basket	25.46	9.75	25.46	25.51	-0.05
D. Demographic variables					
Age	56.04	13.23	55.97	56.70	-0.73***
Annual income ($)	60907.34	36815.84	60896.31	61017.35	-121.04
Education: years of schooling	14.58	1.94	14.57	14.63	-0.07***
Married	0.65	0.48	0.65	0.64	0.01***
Household size	2.43	1.32	2.43	2.39	0.04***
Race: White	0.81	0.40	0.81	0.76	0.05***
Race: Black	0.11	0.31	0.10	0.14	-0.04***
Race: Asian and Others	0.09	0.28	0.09	0.09	-0.01***
Internet access	0.95	0.21	0.95	0.96	-0.01***

Note: a. The number of observations is 297,173, with 27,087 online grocery shopping adopters and 270,086 non-adopters; b. “N/A” means non-applicable.

Table 2 Effects of Online Grocery Shopping on the healthfulness of food purchases: Whole Basket and Yearly Level

VARIABLES	(1) Dependent Var.: Healthfulness of Purchases	(2) Dependent Var.: Healthfulness of Purchases
Food Store Density	0.6392***	0.6477***
	(0.0387)	(0.0407)
Online Grocery Shopping Adopter		-0.6434**
		(0.2726)
Adopter # Food Store Density		-0.0354
		(0.0752)
Convenience/Drug Store Density	-0.2638***	-0.2729***
	(0.0184)	(0.0188)
Adopter # Convenience/Drug Store Density		0.0984**
		(0.0408)
Age	0.0999***	0.0999***
	(0.0025)	(0.0025)
Log(income)	1.1450***	1.1447***
	(0.0459)	(0.0459)
Education	0.7047***	0.7047***
	(0.0174)	(0.0174)
Married	1.7759***	1.7763***
	(0.0770)	(0.0770)
Household size	-0.8540***	-0.8543***
	(0.0245)	(0.0245)
Race: White	-2.4057***	-2.4075***
	(0.1193)	(0.1193)
Race: Black	-0.5337***	-0.5295***
	(0.1493)	(0.1493)
Constant	0.2691	0.3206
	(0.5282)	(0.5289)
Observations	297,167	297,167
R-squared	0.0889	0.0889
Year FE	YES	YES
County FE	YES	YES

Note: a. Standard errors clustered by households are presented in parentheses; b. *** p<0.01, ** p<0.05, * p<0.1; c. county fixed effects and time fixed effects at year level are included.

Table 3 Effects of Food Environment on Online Grocery Shopping Behavior

	(1)	(2)
VARIABLES	Decision (All Hhds-Logit)	Frequency (All Hhds- ZIP)
Food Store Density	0.1273***	0.1321***
	(0.0090)	(0.0093)
Convenience/Drug Store Density	-0.0105**	-0.0312***
	(0.0053)	(0.0086)
Age	0.0049***	0.0061***
	(0.0007)	(0.0012)
Log(income)	-0.0276**	-0.0729***
	(0.0121)	(0.0200)
Education	0.0136***	0.0121
	(0.0045)	(0.0079)
Married	0.0260	-0.0285
	(0.0209)	(0.0355)
Household size	-0.0019	-0.0228*
	(0.0074)	(0.0134)
Race_White	-0.1374***	0.0440
	(0.0282)	(0.0485)
Race_Black	0.1683***	-0.0105
	(0.0348)	(0.0592)
Internet access	0.2020***	-0.0799
	(0.0380)	(0.0773)
Constant	-2.8163***	1.4231***
	(0.1530)	(0.2336)
Observations	296,876	297,173
R-squared		

Note: a. Robust standard errors clustered by households are presented in parentheses; b. *** p<0.01, ** p<0.05, * p<0.1; c. County fixed effects and time fixed effects at year level are included; d. In the Logit model regressions, some observations are dropped and not used due to predicting success or failure perfectly.

Table 4 Effects of Online Grocery Shopping on the Healthfulness of Food Purchases : Trip Level

	Dependent Var.: Healthfulness of Purchases		
	(1)	(2)	(3)
VARIABLES	All Trips of All Hhds	All Trips of Adopters	In-store Trips of All Hhds
Online Trip	1.5242***	1.9319***	
	(0.2996)	(0.2949)	
Adopter			-0.5027***
			(0.1023)
Age	0.1322***	0.1304***	0.1323***
	(0.0035)	(0.0085)	(0.0035)
Log (Income)	1.2578***	1.1655***	1.2592***
	(0.0621)	(0.1464)	(0.0622)
Education	0.8096***	0.8029***	0.8101***
	(0.0239)	(0.0551)	(0.0239)
Married	1.6286***	1.7667***	1.6250***
	(0.1058)	(0.2519)	(0.1059)
Household Size	-0.8597***	-0.6688***	-0.8605***
	(0.0333)	(0.0859)	(0.0334)
Race_White	-2.9661***	-3.1940***	-2.9711***
	(0.1555)	(0.3777)	(0.1557)
Race_Black	-1.8286***	-1.6466***	-1.8251***
	(0.1889)	(0.4345)	(0.1891)
Constant	-4.8954***	-4.5679***	-4.8683***
	(0.6833)	(1.6196)	(0.6844)
Observations	32,351,273	3,317,876	32,258,130
R-squared	0.0115	0.0120	0.0115

Note: a. Robust standard errors clustered by households are presented in parentheses; b. *** p<0.01, ** p<0.05, * p<0.1; c. County fixed effects and time fixed effects at year level are included.

Table 5 Effects of Online Grocery Shopping on the Healthfulness of Food Purchases: Low-income Households

VARIABLES	(1) Healthfulness of Purchases
Food Store Density	0.6793***
	(0.0408)
Online Grocery Shopping Adopters	-0.6933**
	(0.2781)
Adopters # Food Store Density	-0.0135
	(0.0768)
Convenience Store Density	-0.3163***
	(0.0190)
Adopters # Convenience Store Density	0.0932**
	(0.0416)
Low Income	-1.2824***
	(0.4545)
Low Income # Food Store Density	-0.0095
	(0.1485)
Adopters # Low Income	1.1584
	(1.1552)
Adopters # Low Income # Food Store Density	-0.4510*
	(0.2598)
Low Income # Convenience Store Density	0.0350
	(0.0603)
Adopters # Low Income # Convenience Store Density	0.0751
	(0.1730)
Constant	10.4058***
	(0.3561)
Observations	297,167
R-squared	0.0835

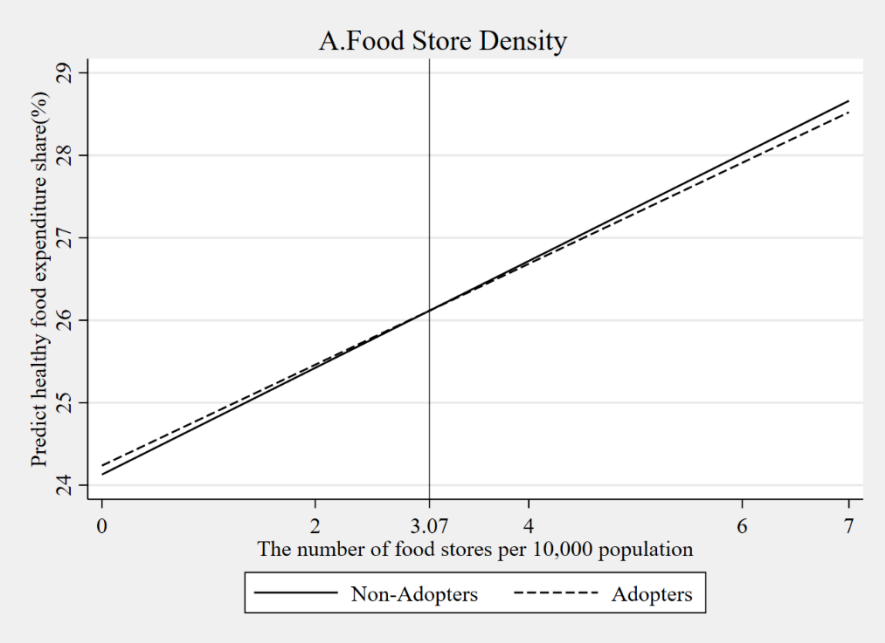
Note: a. Robust standard errors clustered across households are presented in parentheses; b. *** p<0.01, ** p<0.05, * p<0.1; c. County fixed effects and time fixed effects at year level are included; d. The same controlled variables except for the log of income are included.

Table 6 Average Marginal Effects of Food Environment on the Healthfulness of Food Purchases: Low-income Households

Average Marginal Effects (AME) by Groups	**A. AME of Food Store Density**	**B. AME of Convenience Store Density**
Low-Income Households Using Online Grocery Shopping	0.2053	-0.1131
	(0.2202)	(0.1650)
Low-Income Households Not Using Online Grocery Shopping	0.6698***	-0.2814***
	(0.1496)	(0.0603)
Difference	-0.4645*	0.1682
	(0.2546)	(0.1707)
Non-Low-Income Households Using Online Grocery Shopping	0.6658***	-0.2231***
	(0.0755)	(0.0421)
Non-Low-Income Households Not Using Online Grocery Shopping	0.6793***	-0.3163***
	(0.0408)	(0.0190)
Difference	-0.0135	0.0932**
	(0.0768)	(0.0416)

Note: a. Robust standard errors clustered across households are presented in parentheses; b. *** p<0.01, ** p<0.05, * p<0.1; c. County fixed effects and time fixed effects at year level are included; d. The same controlled variables except for the log of income are included.

Figure 1 The Predict Margins of Healthy Food Expenditure Shares (%): Online Grocery Shopping Adopters and Non-adopters



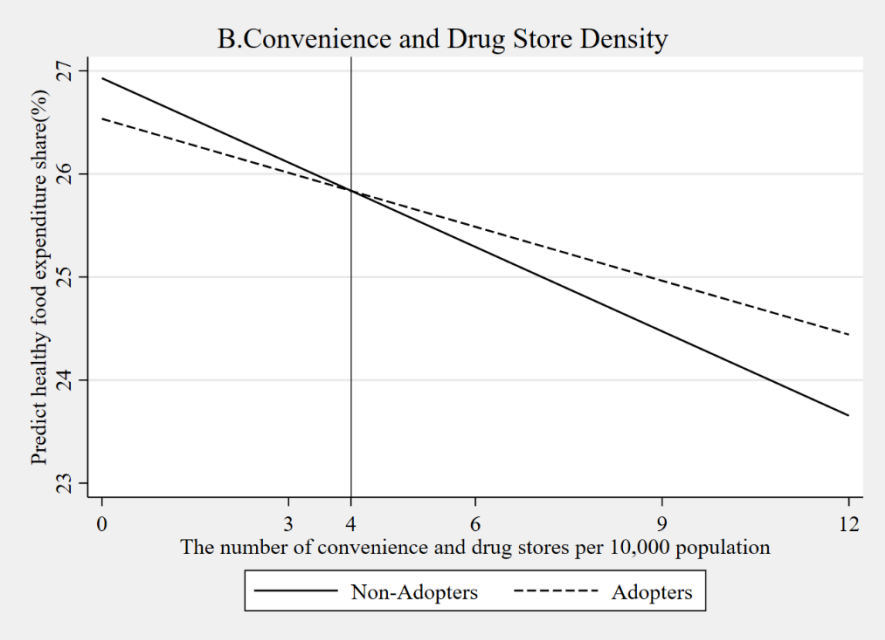
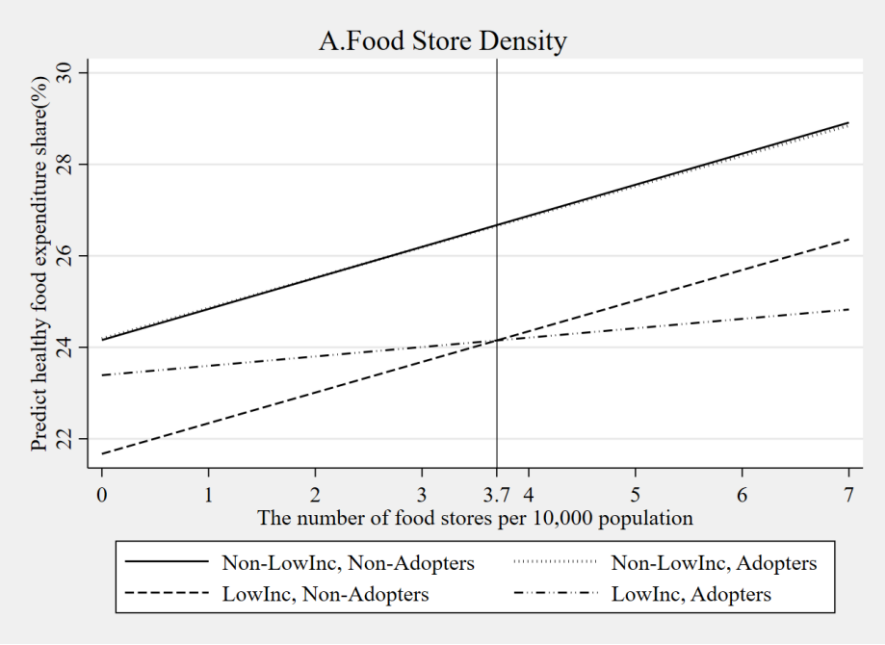
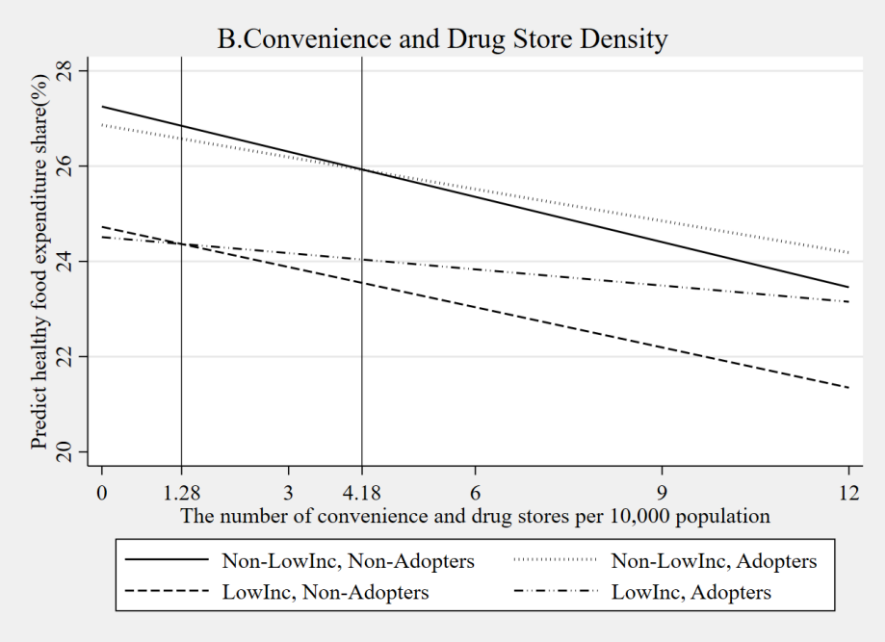


Figure 2 The Predict Margins of Healthy Food Expenditure Shares (%): Online Grocery Shopping and Low-income Households





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