Does Automation Reduce Stigma? The Effect of Self-checkout Register Adoption on Purchasing Decisions*

Rebecca Cardinali[a]†, Lester Lusher[b], Rebecca L.C. Taylor[c], Sofia B. Villas-Boas[a]

[a]University of California, Berkeley

[b]University of Pittsburgh and IZA

[c]University of Illinois, Urbana-Champaign

March 18, 2024

Abstract

By removing human cashiers, self-checkout registers may alter feelings of embarrassment experienced by customers. Using high-frequency scanner data from supermarkets in the Washington D.C. area with staggered adoption of self-checkout, we conduct event study analyses on consumer purchases. We find large but noisy effects of self-checkout adoption on sales of some stigmatized items. Moreover, we show stigmatized items are much more likely to be purchased at self-checkout than at cashier registers, especially condoms and pregnancy tests. We estimate customers are willing to pay 8.6 cents in additional time cost for the privacy of purchasing condoms and pregnancy tests at self-checkout.

JEL: I12, D12

*We thank the retailer for granting us access to the data and the Giannini Foundation for support. We thank Itzik Fadlon, Scott Kaplan, Andrew Stevens, Andrea Velasquez and seminar participants at the University of Sydney, University of California, Berkeley, Monash University, and the University of Queensland for helpful comments.

†Rebecca Cardinali, Email: cardinali@berkeley.edu; Lester Lusher, Email: lesterlusher@pitt.edu; Rebecca L.C. Taylor, Email: rltaylor@illinois.edu; Sofia B. Villas-Boas, Email: sberto@berkeley.edu

1 Introduction

Self-checkout registers allow grocery store customers to scan their own items and complete transactions without the help of a cashier. With the increasing adoption of self-service technologies, including the rise of stores that have no checkouts or cashiers at all,[1] it is important to understand how self-service technologies impact both producers and consumers. While there is increasing concern about the potential effects of self-checkout and other forms of automation on employment (e.g. Acemoglu and Restrepo, 2018, 2020), less is known about potential effects on the consumer.

When self-checkout is available, consumer welfare could be enhanced due to reduced feelings of embarrassment and shame felt when purchasing stigmatized goods in front of others. Cashiers scan and thus see all items purchased by a customer. In the presence of a cashier, customers may be under-purchasing goods they are embarrassed to be seen purchasing, potentially swaying customers away from purchasing their optimal bundle of goods altogether. Alternatively, at self-checkout registers, customers privately scan most of their items on their own. According to a 2021 poll, the top 10 items Americans are most embarrassed to buy are all health products, including condoms, emergency contraceptives, pregnancy tests, period products, bed bug spray, head lice treatment, hemorrhoid cream, diarrhea relief, incontinence/bladder leakage products, and cold sore treatment.[2] This poll also found that more than half of the respondents had avoided purchasing products altogether out of fear of being judged, suggesting households likely underreact to health conditions in the absence of privacy.

Being able to privately purchase stigmatized items is particularly relevant for reproductive health products—such as condoms, pregnancy tests and emergency contraceptives—given the overturning of Roe v. Wade in June 2022. There is an open legal question about whether law

[1] *Source:*, Business Insider, "Understanding Amazon Go's tech and expansion into fast shopping." Online, accessed 11 Dec 2023.

[2] *Source:* SWNS Digital, "67% of Americans admit to judging fellow shoppers for what's in their carts." Online, accessed 12 May 2022.

enforcement can obtain an individual's "personal reproductive or sexual health information," such as financial records and purchase histories, in order to prosecute abortion cases in states where abortion is criminalized.[3] Privacy from being seen by others is additionally relevant in states where there are monetary incentives to sue those who assist another person in obtaining an abortion.[4] Furthermore, reducing or eliminating access to abortion likely has downstream effects onto family planning services and purchases of related goods such as condoms or emergency contraceptives (Fischer et al., 2018). Given the potential for stigmatization of these items, changes in the privacy of purchasing them, such as the adoption of automation technologies, could carry even more welfare effects in a world post Roe v. Wade.

This paper explores the effects of the self-checkout automation technology on consumer purchases of stigma goods. Does consumer behavior reflect the belief that the types of items purchased signal what type of person the purchaser is? Does the composition of purchased items tend to include more conventionally "embarrassing" or "taboo" items when the consumer is making a decision in a more private setting? To investigate these questions, we consider how decisions at grocery stores differ after the adoption of self-checkout registers. Using a regular checkout register will be considered more public because the cashier scans, and therefore directly observes, every item purchased by the customer. Self-checkout registers, in contrast, will be considered more private because customers scan most of their items on their own.

We first set up a simple conceptual model that incorporates the visibility of the purchase into the consumer's utility function. Then, using high-frequency scanner data across grocery stores in the Washington D.C.-Maryland-Virginia area, we run difference-in-differences (DiD) and event study models to compare purchases in stores that adopted self-checkout mid-sample vs control stores that do not adopt.[5] With the DiD model, we examine how self-

[3] *Source:* Congressional Research Service, "Abortion, Data Privacy, and Law Enforcement Access: A Legal Overview." Online, accessed 11 Dec 2023.

[4] *Source:* NPR, "As states ban abortion, the Texas bounty law offers a way to survive legal challenges." Online, accessed 26 Feb 2024.

[5] We employ the Callaway and Sant'Anna (2021) DiD and event study estimator to correct for the potential biases of traditional OLS event study models with two-way fixed effects.

checkout adoption affects the composition of goods purchased. Then, using linear probability and logit models, we examine how the number and types of items purchased influence the decision to use self-checkout registers. We select stigma items broadly based on existing literature[6] and public polls[2] on what items are most embarrassing to purchase. Our choice of items is shown in Table 1. These include pharmaceutical items (e.g., condoms, pregnancy tests, and bowel treatments), and unhealthy items (e.g., salty snacks and sugary drinks). We also examine items which may require more effort to scan at self-checkout to explore the costs of operating self-checkout machines,[7] as well as items that we use as placebos.

We first find statistically and economically significant effects on total sales of all goods at a store in response to self-checkout adoption. Interestingly, while total sales increase, most item categories' sale shares do not change post self-checkout adoption. After self-checkout adoption, the total number of transactions conducted at a store increases, while the average number of items sold per transaction and average price remain the same, therefore leading to an overall increase in total items sold and in total expenditures. Thus, it seems that self-checkout adoption is associated with greater productivity for the grocery store (i.e., stores process more transactions post-adoption). These findings are robust to focusing on samples of consumers that shop or do not shop at multiple stores in our sample.

Given the total number of items sold increases with self-checkout adoption, we then examine how the *share* of stigma items sold changes with self-checkout adoption. We find mixed evidence of stigma goods experiencing increases in sale share in response to self-checkout adoption. For instance, the sale share of bowel treatments increases by 11%, the sale share of condoms increases by 17%, and the sale share of yeast infection treatments increases by 22%; these treatment effects are all statistically significant at the 5% level.

[6]George and Murcott (1992) document potential embarrassment associated with purchasing pads and tampons while Dahl et al. (1998) document embarrassment associated with purchasing condoms, which motivated the inclusion of those items in our study. Olden (2018) also uses laundry-related items as a placebo category and examines sales of unhealthy stigma items such as soda and chips, motivating our choices of those items as well.

[7]For example, free weight apples require extra effort to scan at self-checkout because of the need to weigh them and enter product codes.

However, the sale shares of other stigma products are unaffected by self-checkout adoption, such as sanitary pads, incontinence products, and fungal treatments.

Lastly, we find strong evidence of substitution from regular to self-checkout registers for purchases of stigma items relative to other product types, especially pregnancy tests and condoms. For example, 18% of total items sold shift to a self-checkout register after self-checkout adoption, whereas 44% and 42% of pregnancy tests and of condoms are sold at self-checkout registers, respectively. Nearly all of the pharmaceutical stigma items considered in our sample are more likely to be purchased at a self-checkout register relative to all other items. Thus, although the sale share increases only for some stigma items, the evidence of substitution across register types suggests that self-checkout adoption is associated with improved consumer welfare via the reduced visibility associated with purchasing items "privately" at self-checkout registers. Our back-of-the-envelope calculations suggest people are willing to pay 38.6 seconds in additional time cost (equivalent to 8.6 cents) for the privacy of purchasing condoms and pregnancy tests at self-checkout.[8]

While not the focus of this study, it is worth noting other channels through which self-checkout and automation technologies may alter consumer welfare. First, self-checkout registers and other automation technologies may impact consumer welfare through overall increases in store efficiency and shorter wait times. In our retail setting, retailers replace one cashier-operated register with four self-checkout registers; however, cashiers process transactions with only one item 99 seconds faster than customers at self-checkout registers, and this time gap increases as the number of items in the transaction increases. Second, self-checkout register adoption could lead to a change in prices, if retailers pass potential labor savings and/or technology costs from self-checkout adoption onto customers. We do not find that self-checkout adoption altered prices, which is perhaps not surprising given DellaVigna and Gentzkow (2019) find most US retailers charge nearly uniform prices across their stores.

[8] This calculation is based on our estimate that transactions with one item take 99 seconds longer on average at self-checkout vs. regular checkout, and uses a median US hourly wage in 2009 of $15.95 to translate time costs into monetary costs.

Third, self-checkout may influence consumer welfare by altering the physical and mental effort required at checkout. We find that fresh produce, which requires extra effort to scan, is less likely to be purchased at self-checkout registers. Products most likely purchased by older adults, such as incontinence products, are also less likely to be purchased at self-checkout registers. Thus, while our main results suggest that adding self-checkout as an option is welfare enhancing for the purchases of stigmatized items, completely shifting all registers to self-checkout may not enhance consumer welfare.

Our findings contribute to work on "social frictions," a term used by Goldfarb et al. (2015) to describe implicit costs linked to transactions in certain social settings. There is also a large behavioral economics literature on social signaling and self-image (see Bursztyn and Jensen (2017) for a review), especially with regard to prosocial behavior (e.g. Bénabou and Tirole, 2006). Our work relates to social signaling, and our context introduces an additional trade-off associated with self-checkout registers. When deciding between self-checkout and cashier-operated registers, the consumer faces two trade-offs: first, higher visibility at regular checkout vs the decreased visibility that comes with using self-checkout, and second, the increased costs associated with scanning one's own items at self-checkout vs being assisted by a cashier at regular checkout. In a closely related paper, Dahl et al. (2001) use field experiments to study embarrassment through the use of condom vending machines on a university campus. Our study uses a natural experiment through the staggered adoption of self-checkout registers in grocery stores that are part of a large chain.[9] An additional contribution of our study is that we utilize data on the exact register where transactions in our stores occurred, which is unique to our dataset compared to other supermarket scanner data sets (e.g., the Nielsen Retail Scanner data).

[9] A related working paper from Olden (2018) looks at the purchases of unhealthy food items in Scandinavian stores that switched to entirely or almost entirely self-service registers. The stores in our data have a mixture of self-checkout and regular registers, which allows us to look at substitution between the two types of registers. We also focus on pharmaceutical stigma items, whereas Olden (2018) focuses more on unhealthy food items. In comparison, we do not find evidence of increases in sale shares of unhealthy items, namely salty snacks and sugary drinks. In another related working paper, Streletskaya (2016) uses video footage of customers in a wine shop and finds that customers are less likely to purchase any item when other customers are present.

Finally, our results are especially timely given recent policy changes. The overturning of Roe v. Wade in June 2022 has highlighted privacy concerns around reproductive health decisions. Since Roe's overturning in 2022, 14 states have banned abortions. In response, drug stores such as Walgreens and CVS said they would apply for FDA approval to dispense abortion pills in states where abortion is legal, improving (private) access for women in need.[10] Our results for condoms and pregnancy tests highlight the value of privacy among items related to reproductive health, in a landscape where getting an abortion is becoming increasingly challenging.

2 Conceptual Model & Hypotheses

We consider a simple model to generate testable hypotheses about stigma and social image concerns at checkout. Our model is loosely based off of ideas of social signaling and self-image presented in Bénabou and Tirole (2006), but the framework presented in their paper relates to altruism and prosocial behavior, and thus is not directly applicable to the purchase of stigma items. Modeling the visibility of purchases through the use of self-checkout is unique because choosing to use self-checkout involves a trade-off between privacy and higher effort costs associated with scanning one's own items. The effort costs add another layer to the consumer's social signaling concerns. There may be several additional sources of disutility that factor into the consumer's decision about which register to choose, but for simplicity we assume that effort costs are the most prominent.

[10] *Source:* New York Times, "Walgreens Says It Won't Offer the Abortion Pill Mifepristone in 21 States," Online, accessed 13 March 2023.

Consider an individual i in a grocery store choosing between 3 alternatives:

$$a \in \begin{cases} SC & = \text{ buy stigma good } x \text{ at self-checkout} \\ R & = \text{ buy stigma good } x \text{ at a regular register (with a cashier)} \\ NB & = \text{ do not buy stigma good } x \end{cases}$$

Assume each individual i has the following utility function:

$$U_i^a(x) = u_i^a(x) - (1 + \lambda_i^a(x))c_i^a(x) \text{ for } a \in \{SC, R, NB\} \tag{1}$$

or equivalently

$$U_i^a(x) = u_i^a(x) - c_i^a(x) - \lambda_i^a(x)c_i^a(x) \text{ for } a \in \{SC, R, NB\} \tag{2}$$

where $u_i^a(x)$ is the utility gained and $c_i^a(x)$ is the utility lost from purchasing stigma good x through alternative a. The social signaling aspect is captured by $\lambda_i^a(x) \geq 0$, which we can think of as an interaction between how much individual i cares about social signals she may be sending through her purchase (which depends on what stigma good x is) and the visibility of her purchase (which depends her choice of alternative a). For example, if individual i is very embarrassed about purchasing condoms, but her purchase is not visible to anyone else, the associated $\lambda_i^a(x)$ would be 0. The associated $\lambda_i^a(x)$ would also be 0 if individual i's purchase is visible to others, but she does not get embarrassed at all about purchasing condoms. In the case where individual i does feel embarrassed about purchasing stigma good x *and* her purchase is visible to others, we would have $\lambda_i^a(x) > 0$. Therefore, the third term in equation (2) scales the costs of purchasing x by both the visibility of the purchase and the potential embarrassment an individual may feel from buying the stigma item.

We first consider the individual's choice between alternatives SC and R. We assume

$\lambda_i^{SC} = 0$ because the purchase is not visible to a cashier when the individual chooses to use self-checkout. We also assume that $c_i^{SC}(x) \geq c_i^R(x)$ because the individual must exert some effort to scan her own item at self-checkout while a cashier would have done the work to scan the item at a regular register. Then

$$U_i^{SC}(x) = u_i^{SC}(x) - c_i^{SC}(x)$$
$$U_i^R(x) = u_i^R(x) - (1 + \lambda_i^R(x))c_i^R(x)$$

Individual i chooses to use self-checkout over a regular register if $U_i^{SC}(x) \geq U_i^R(x)$. For now, we assume that $u_i^{SC}(x) = u_i^R(x)$, that is, individual i gains the same amount of utility from acquiring the good whether she acquired it at self-checkout or a regular register (this rules out someone who might gain extra utility from speaking with the cashier at a regular register or from operating the self-checkout equipment). Then the individual chooses self-checkout over a regular register if

$$c_i^{SC}(x) \leq (1 + \lambda_i^R(x))c_i^R(x)) \tag{3}$$

Solving for $\lambda_i^R(x)$ when equation (3) holds with equality yields a condition under which individual i would be indifferent between SC and R:

$$\lambda_i^R(x) = \frac{c_i^{SC}(x)}{c_i^R(x)} - 1 \tag{4}$$

Equation (4) makes intuitive sense under our previous assumption that $c_i^{SC}(x) \geq c_i^R(x)$. In the case where $c_i^{SC}(x) > c_i^R(x)$ strictly, equation (4) implies that $\lambda_i^R(x) > 0$ meaning the individual would feel some level of embarrassment from purchasing x in a visible environment. Then in order for individual i to be indifferent between SC and R when she feels some level of embarrassment, she would need the effort cost associated with self-checkout to be large enough to equal the costs associated with going to a regular register scaled by the embarrassment she would feel at the regular register. In the case where the assumption holds with equality, that is, $c_i^{SC}(x) = c_i^R(x)$, equation (4) implies $\lambda_i^R(x) = 0$ meaning the individual would not get embarrassed from purchasing x in a visible environment. In this case, the costs $c_i^{SC}(x)$ and $c_i^R(x)$ would have to be the same in order for individual i to be indifferent between SC and R because her costs would not be scaled by the social signaling parameter.

In our empirical analysis, we will test the hypothesis that $\lambda_i^R(x) > 0$ for some individuals and stigma items by examining substitution from regular registers to self-checkout registers for purchases of stigma items after stores adopt self-checkout. If $\lambda_i^R(x) > 0$ for enough people, we would expect to see some substitution from regular registers to self-checkout registers for stigma items. However, if $c_i^{SC}(x)$ is much greater than $c_i^R(x)$ for many individuals, we might see individuals still choosing to use regular registers.

When individual i chooses alternative NB, she neither gains utility from acquiring the good nor incurs the costs, so $u_i^{NB}(x) = 0$ and $c_i^{NB}(x) = 0$, implying $U_i^{NB}(x) = 0$. If individual i chooses NB, it must be true that $U_i^{NB}(x) = 0 \geq U_i^k(x)$ for $k \in \{SC, R\}$, the remaining alternatives. In choosing NB, it could have been the case that $U_i^{NB}(x) = U_i^{SC}(x) = U_i^R(x) = 0$ (so she never gets utility from purchasing good x) or that $U_i^k(x) < 0$ for $k = SC$, $k = R$, or both (so she prefers not buying anything to buying it at self-checkout and/or prefers not buying anything to buying it at a regular register). If $U_i^R(x) < 0$ because of a large $\lambda_i^R(x)$, then it could be the case that introducing self-checkout would increase purchases of stigma item x (as long as $c_i^{SC}(x)$ is not too large). In our empirical analysis, we test the hypothesis that purchases of stigma items increase due to the adoption of self-checkout.

It is worth noting that this simple model does not fully capture all the complexities of our real-world setting. In particular, our model considers purchasing stigma good x in isolation, that is, there are no other items in the individual's shopping cart that could also contribute to her decision of whether to use self-checkout or a regular register. For example, the costs of self-checkout may increase when there are more items in a shopping cart. Additionally, an individual may be more embarrassed to have a one-item transaction that only consists of condoms vs having a twenty-item transaction in which one of the many items is condoms. These different levels of effort and embarrassment associated with bundle composition are not captured in this model because the model does not consider bundles that could include both stigma and non-stigma goods. Still, the model provides some basic intuition to motivate our empirical analysis.

3 Data

Our data come from stores in Washington D.C., Maryland, and Virginia that are part of a large grocery store chain. We use two different data sets with overlapping stores for our empirical analysis. Both data sets contain transaction-level data spanning December 2008 through February 2011. We restrict our analysis to transactions from stores that were open during the entire sample period. For each transaction, we have information on the universal product code identifiers (UPC ID) as well as the quantities and prices paid for each unique item in the transaction. We also have data on the time, date, and store in which each transaction was completed.

The first data set contains a random sample of 10% of all the transactions that occurred in 30 stores between December 1, 2008 and February 28, 2011.[11] These data contain transactions for every day of the week and hour of the day. These data do *not* contain information on the type of register that was used for each transaction, so we cannot distinguish whether a transaction was completed at self-checkout or a regular register. Still, using these data, we can test whether self-checkout adoption affects purchases of goods on the "extensive margin" (i.e. total purchases) for a representative sample of all transactions that occurred during the stores' hours of operation.

The second data set contains information on every transaction completed on Saturdays between 5:00PM and 6:00PM. Importantly, this sample includes information on whether each

[11] The 10% sample was selected as follows. At every store, a transaction is given a unique transaction ID based on the order in which the transaction is completed. The retailer gave us every tenth transaction that occurred at each store during the sample period.

transaction was completed at self-checkout or a regular register for all transactions in this window. In total, this data set includes 51 stores between December 1, 2008 and February 28, 2011.

We will refer to the first data set as *Random10%* and the second data set as *Evenings* from now on. The 30 stores in *Random10%* are a subset of the 51 stores included in *Evenings*. Thinking of self-checkout adoption as the treatment in the potential outcomes framework, Table 2 shows the breakdown of "always treated," "never treated," and "treated mid-sample" stores in our sample.

The left panel of Figure 1 uses the *Evenings* data set to document the fraction of transactions that were completed at self-checkout among the stores that adopted mid-sample, while the right panel of Figure 1 shows the fraction of transactions completed at self-checkout among stores which had self-checkout during the entire sample. Keep in mind that the *Random10%* data set contains a subset of these stores. In the left panel of Figure 1, in addition to visualizing the staggered adoption of self-checkout, we also see that many stores adopted self-checkout toward the end of our sample, which will influence our choice of estimator for event studies later on. Comparing the left and right panels of Figure 1 shows that after adoption, self-checkout registers were put to use to a similar extent in stores that adopted mid-sample and stores that always had self-checkout.

Table 3 compares characteristics of treatment and control stores in both data sets. The always-treated stores are not included. The total building size and total selling area variables come from a store census from April 2013 conducted by the retailer. The number of full-service registers is calculated using the scanner data from December 2008, which is the first month of the sample and the pre-period for all stores. Total selling area corresponds to the square footage of the part of the store where customers shop (so space for inventory is not included) whereas total building size is the square footage of the entire building. We see that stores which were treated mid-sample, that is, those which adopted self-checkout during the sample period, were larger on average. The treated stores have a larger average building size, a larger average selling area, and a greater number of full-service registers than control stores. Conversations with store managers suggest larger stores adopted first because of the floor space needed to implement self-checkout. The retailer in our setting adopted self-checkout by replacing one (and in some cases two) full-service registers with four self-checkout registers. Having differences in fixed attributes between treated and control stores does not invalidate the identifying assumptions of our empirical strategy, which we discuss in the next section. However, these differences are worth noting when we consider external validity and how our results might replicate in other settings. Our results may be most relevant for medium to large grocery stores, similar to the treated stores in our sample.[12]

4 Empirical Strategy

4.1 Model to Test for Changes on the Extensive Margin

First, we use difference-in-differences (DiD) and event study models to investigate whether self-checkout adoption leads to increased purchases of stigma items on the extensive margin (i.e., the quantity of stigma items purchased). We sum the transaction-level data in *Random10%* to the store-month level to avoid too many zero observations (since stigma items are purchased relatively infrequently). To follow best practices for DiD and event study estimation, we remove the stores that adopted self-checkout before our sample period (Baker et al., 2022), which leaves us with 27 stores in total. Moreover, instead of using traditional Ordinary Least Squares (OLS) with two-way fixed effects—which has been shown to be potentially biased in DiD models with variation in treatment timing, especially when treatments occur either early or late in the sample period (de Chaisemartin and D'Haultfœuille, 2020; Borusyak et al., 2021; Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021; Sun and Abraham, 2021)—we use the estimator developed by Callaway and Sant'Anna (2021)

[12]According to industry reports, supermarkets in the US range from 10,000 to 90,000 square feet, with an average of 44,000 square feet (*Source*: Institute for Self Reliance, Online, accessed 6 Feb 2024). The stores in our sample range from 14,500 to 62,000 square feet.

that corrects for this potential bias.[13] We will refer to the Callaway and Sant'Anna (2021) estimator as *CS*. The *CS* method is implemented using the Stata package `csdid`.

Using the notation provided in Roth et al. (2022), the building block of the *CS* estimator is the group-time average treatment effect on the treated,

$$ATT(g,t) = \mathbb{E}[Y_{st}(g) - Y_{st}(\infty) \mid G_{st} = g] \tag{5}$$

which gives the average treatment effect at time t for the cohort first treated in time g. The ∞ symbol is used to represent the never-treated control units. Our treatment variable Y_{st} is the total number of stigma items purchased at store s in time t divided by the total number of items purchased at store s in time t. For example, in the *condoms* model, Y_{st} corresponds to the share of condoms and sexual lubricants purchased as a fraction of total items purchased in store s in time t. Under the assumptions of parallel trends and no anticipation[14] and using only the never treated stores as the control group, we can identify $ATT(g,t)$ by comparing the expected change in outcome for cohort g between periods $g-1$ and t to that for a never treated control group as follows,

$$ATT(g,t) = \mathbb{E}[Y_{st} - Y_{s,g-1} \mid G_s = g] - \mathbb{E}[Y_{st} - Y_{s,g-1} \mid G_s \in \{\infty\}] \tag{6}$$

$ATT(g,t)$ is then estimated by replacing expectations with their sample analogs,

$$\widehat{ATT(g,t)} = \frac{1}{N_g} \sum_{s:G_s=g} [Y_{st} - Y_{s,g-1}] - \frac{1}{N_{\{\infty\}}} \sum_{s:G_s \in \{\infty\}} [Y_{st} - Y_{s,g-1}] \tag{7}$$

Finally, the event study parameters are given by,

$$ATT_\ell = \sum_g w_g ATT(g, g+\ell) \tag{8}$$

[13] We explore the robustness of our results to the use of other estimators in online appendix Figure A1.

[14] With the "parallel trends assumption" we assume that, in the absence of treatment, the average outcomes for treated and control groups would have followed parallel paths over time. With the "no anticipation assumption" we assume that the treatment has no causal effect before its implementation.

which is the weighted average of the treatment effect ℓ periods after adoption across different adoption cohorts.[15] In our data set, we have 6 adoption cohorts (i.e., $g = \{9, 13, 15, 22, 23, 24\}$) and ℓ spans -23 (i.e., 23 months before self-checkout register adoption) to 18 (i.e., 18 months after adoption). Note, $\ell = 0$ represents the month in which self-checkout was adopted. Given some stores did not have self-checkout for the entire adoption month, interpretation of these $\ell = 0$ coefficients should be made with this in mind. Also, the *CS* event study estimator uses the first event time period ($\ell = -23$) as the reference period.

We run the *CS* event study estimator separately for each item category mentioned in Table 1. For example, there is one event study for *condoms* that includes all different brands and package sizes of condoms and sexual lubricants that were purchased in store s and month t. Standard errors are estimated using a multiplicative wild bootstrap procedure clustered at the store level.[16] We have 729 store-month observations. If $\lambda_i^R(x)$ from our model was high enough to lead individuals to choose not to buy stigma items before the introduction of self-checkout, we would expect the estimates for ATT_ℓ for $\ell \in \{0, ..., 18\}$ to be positive.

An important threat to the identification of DiD and event study models is whether the parallel trends assumption holds. While this assumption can never be tested directly, if sales of stigma items are trending differently at treated and control stores prior to the adoption of self-checkout, control stores may not be a proper counterfactual for treated stores (i.e., it would be hard to assume that the treated and control groups would trend in parallel absent the treatment) and the event study model may not identify the effect of self-checkout adoption. Thus, we will provide evidence in favor of this assumption by examining the coefficients on ATT_ℓ for the pre-adoption period, which we would expect to be close to and/or indistinguishable from 0 if there are no differential pre-trends.

[15] We use the *CS* default weights for w_g.

[16] We estimate standard errors using a wild bootstrap procedure instead of a cluster–robust variance estimator because we have fewer than 30 stores in the 10% sample (Cameron et al., 2008).

4.2 Model to Test for Changes in Register Choice

Second, after analyzing how self-checkout adoption affects purchases along the extensive margin, we estimate both linear probability and Logit models to see how the choice of where to make a purchase changed *within* a store: at a regular register vs a self-checkout register. We refer to this as an intensive margin effect (i.e., where to purchase stigma items). To do this, we consider data at the transaction level (n=244,441) to estimate differences in observable characteristics associated with transactions at self-checkout vs regular registers. That is, we estimate

$$Pr(SelfCheckout_{tsym} = 1) = \Phi(\alpha + X_t'\delta + \gamma_s + \gamma_{ym}) \quad (9)$$

where the outcome variable is an indicator equal to one if the transaction t was conducted at a self-checkout register. X_t' includes a full vector of indicators for whether the transaction included various types of goods (e.g. condoms), as well as a control for the size of the transaction (i.e., the number of items purchased). This latter control is important since the purchase of certain items may be associated with transaction size, which itself may influence a consumer's choice of which register type to pick. Through δ, we can observe whether customers are more likely to pick a self-checkout register when their purchase includes specific items, holding transaction size constant. We hypothesize that stigma items will have larger δ's than non-stigma items, reflecting a higher likelihood for stigma items to be purchased at self-checkout than non-stigma items due to more privacy, holding transaction size constant. Finally, γ_s and γ_{ym} reflect store and year-month fixed effects, respectively. We consider both a linear probability model and a Logit model for estimation.

5 Results

5.1 Extensive Margin Results

5.1.1 Effect on total sales

While the focus of this paper is on purchases of stigma items, it is important to first broadly understand the effects of self-checkout adoption on total store sales to motivate our preferred model specification. Using the *Random10%* data, the panels in Figure 2 show the event study results of self-checkout adoption on total store-month sales, measured as the total number of items sold (panel a), the total expenditures paid (panel b),[17] and the total number of transactions processed (panel c).[18] In panel (a) we find stores that adopt self-checkout registers experience a persistent 3000 item increase in items sold per month, which translates to 6.8% increase in store sales ($\widehat{ATT_1} = 3194$). Since we have a random 10% sample of transactions, this translates to approximately 30,000 more items sold per store-month for the full sample of transactions.[19] Stores that adopt self-checkout registers also see similar increases in total expenditures and total transactions per month (panels b and c), which further suggests self-checkout adoption is a revenue enhancing decision for these stores. It is interesting to note that store sales fall the month before adoption, which reflects the need to shut down parts of the store temporarily in order to add self-checkout registers. Panel (d) shows that the average number of items sold per transaction does not change with self-checkout adoption. This means self-checkout adoption is not altering the average size of transactions nor is it only attracting new transactions of a certain size. Finally, panel (e) shows that the average price per item does not change with self-checkout adoption, thus

[17] Total expenditures sums across the price paid for all transactions at store s in month t. So if 5 transactions costing $10 each were made at store s in month t, total expenditures would equal $50.

[18] All DiD estimates presented in this section use the estimator developed by Callaway and Sant'Anna (2021). In Online Appendix Figure A1, we show the robustness of our results to the use of four alternative DiD estimators (i.e., traditional OLS with two-way fixed effects as well as estimators developed by Borusyak et al. (2021), de Chaisemartin and D'Haultfœuille (2020), and Sun and Abraham (2021)).

[19] In Online Appendix Figure A2 we examine the robustness of the results across adoption cohorts. We find positive effects of self-checkout adoption on total items sold in 5 of the 6 adoption cohorts.

the increase in transaction volume is not due to lower prices after self-checkout adoption. With respect to the parallel trends assumption, these figures show that treated and control coefficients were not trending differentially before self-checkout adoption.[20]

A potential concern is that customers from control stores in our sample are switching to treated stores. This would be a violation of the stable unit treatment value assumption (SUTVA) and would lead to an overestimated treatment effect as switchers would be counted twice. While a 10% sample of transactions is not ideal for tracking individual customers, we do see customers multiple times in the data through the use of customer loyalty cards. Thus, to test this concern, we re-estimate the event study models dropping the customer loyalty cards that are used at multiple stores in our sample. Roughly 26% of customer loyalty cards are used at multiple stores. As shown in Online Appendix Figure A3, dropping multi-store customers does not change our results.

5.1.2 Effect on department groups

Given the large increase in total items sold per store-month, for the remainder of this section we will examine how the shares of items sold—i.e., the number of a particular item sold divided by the number of total items sold—is influenced by self-checkout adoption. For baseline comparisons, Appendix Table A1 presents the percent shares of total items sold for each product group considered in this section, in the pre-adoption period for all stores (Dec 2008–July 2009). First, in Figure 3, we collapse the event study estimates into their difference-in-differences (DiD) counterparts, using the CS estimator, and plot the DiD estimates for each department group side-by-side. Department groups can be thought of as aisles or sections of the store (e.g., bakery, fresh produce, floral, and frozen aisles). This exercise allows us to examine if the increase in items sold from self-checkout adoption impacted certain areas of the store more so than others. Overall, the DiD estimates shown in Figure 3 are not statistically distinguishable from zero at the 5% level, suggesting broad department

[20] Moreover, using Wald tests of equality for panels (a), (b), and (c), we cannot reject that the coefficients for the five months prior to adoption are all statistically equal to each other.

groups were not differently impacted by the adoption of self-checkout registers. The one exception is the baby item department (which mainly sells diapers and infant formula), which experiences a 0.15 percentage point decline in its share sold off a baseline share of 0.84%.[21]

5.1.3 Effect on stigma items

Next, we examine specific stigma items, as listed in Table 1. From our model, we hypothesized that if $\lambda_i^R(x)$ was very large, some individuals may have opted not to buy stigma items at grocery stores at all prior to self-checkout adoption. We find modest evidence of this for some stigma goods in our event studies. As seen in Figure 4, the event studies for condoms (panel a), yeast infections (panel b), and bowel treatments (panel c), show slightly higher shares being bought at treated stores after self-checkout adoption. However, although most coefficients in these panels are positive after the adoption of self-checkout, they are noisy and mostly statistically insignificant. The stigma items in the remaining panels—sanitary pads (panel d), pregnancy tests (panel e), and incontinence products (panel f)—do not experience visible changes in their share of purchases post-self-checkout adoption. These event studies are corroborated by their DiD counterpart estimates, presented in Figure 5. Bowel treatments, yeast infection treatments, and condoms all experience increases after self-checkout adoption in their shares sold that are statistically significant at the 5% level, whereas the other stigma items do not. While the changes in sale shares for bowel treatments, yeast infection treatments, and condoms may seem small, these are 11%, 22%, and 17% increases in sale shares compared to their baseline shares.

One may be concerned that the introduction of self-checkout would not have as much of an effect on stigma items if they are locked up at the grocery store, and therefore customers have to interact with a store employee to obtain the item anyway. While we do not have

[21] Given baby items are bulky to purchase and using self-checkout registers can be challenging with children in tow, it is perhaps not surprising that self-checkout adoption did not increase the share of baby items purchased. This could also reflect that while Supplemental Nutrition Assistance Program (SNAP) purchases could be made at self-checkout during our sample period, purchases through the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) could not be made at self-checkout registers during our sample period (Ambrozek et al., 2023).

data on which items were locked during our sample period (2008–2011), the authors' informal perusal of supermarkets in 2022 suggests that condoms and pregnancy tests are sometimes locked or behind a counter, whereas incontinence and sanitary pads/tampons are not locked. Thus we find effects even for items that may be locked up while we do not find effects for items that are not locked up, which suggests how the items are kept does not drive our results.

5.1.4 Effect on hard-to-scan and unhealthy items

Similarly for the share of items which require effort to scan on one's own, we do not find effects before and after the adoption of self-checkout. The panels (a)-(b) in Online Appendix Figure A4 do not show an effect for free weight apples or onions, nor is there an effect for dog food (panel c). In panel (d), we examine alcohol and tobacco products. We do not find self-checkout adoption affects their share of sales. Even though alcohol and tobacco could be considered stigma items, they require a cashier to check the identification (i.e. age) of the customer purchasing them, even at self-checkout registers. Having to wait for a cashier to come to your self-checkout register to check your ID could make purchasing alcohol/tobacco less convenient at self-checkout. Thus, it is perhaps not surprising we find no effect of self-checkout adoption on their sale shares. For the share of unhealthy items, Online Appendix Figure A4 shows no effect of self-checkout adoption for sugary drinks (this categorization excludes fruit juices) in panel (e) and salty snacks in panel (f). The DiD results, presented in Online Appendix Figure A5, again corroborate the event study results—i.e., most difficult to scan and unhealthy items experience no statistically significant change in sale share with self-checkout adoption.

5.1.5 Effect on placebo items

Online Appendix Figure A6 shows the results of the event study for laundry-related products. Before and after self-checkout adoption, the ATT_ℓ estimates from equation 8 are not significantly different from 0. This is what we would expect from our laundry-related products, which we included as a placebo, because we do not think that customers would be embarrassed to buy laundry products or have to exert a great deal of extra effort to scan them on their own, i.e. we would not expect self-checkout introduction to affect shares of purchases of these products on the extensive margin.

5.1.6 Summary of Extensive Margin Results

In summary, we find large and statistically significant effects of the introduction of self-checkout registers on total sales but little to no significant effect of self-checkout registers on the share of most stigma item sales. The important exceptions to this are bowel treatments (diarrhea/constipation/hemorrhoid), yeast infection treatments, and condoms, which experience modest increases in their sale shares. These results are consistent with stigma leading to less than optimal purchases of these items before self-checkout adoption. We also find no statistically significant effects on the share of sales of other purchased items.

5.2 Register Substitution Results

Since we cannot distinguish between which type of register is used in the *Random10%* data, we explore the relationship between purchases at self-checkout vs regular full-service registers using the *Evenings* data. While we did not use the pre-sample adopters in our previous event study analysis using *Random10%*, we do include them in this register substitution analysis using the *Evenings* data. We drop stores and time periods without self-checkout, then sum up the number of each stigma item purchased at full-service vs self-checkout. We then calculate the share of item x sold at self-checkout by dividing the quantity of item x sold at self-checkout by the quantity of item x sold at any register. Figure 6 plots the shares for total items, pharmaceutical stigma items, grocery store departments, and the remaining item groups.

After self-checkout is adopted, 18% of total items sold shift to self-checkout. In comparison, 44% of pregnancy tests and 42% of condoms switch to self-checkout. Thus, people are nearly 25 percentage points more likely to buy these stigma items at self-checkout than at full-service registers. Figure 6 shows that the other pharmacy stigma items are also more likely to be purchased at self-checkout registers than the average item sold. The only item that shifts to a lesser degree is incontinence products, which are generally purchased by older individuals who may be less inclined to use self-checkout registers than younger individuals.[22]

Next, Figure 6 plots the shares of items sold at self-checkout vs regular full-service registers by grocery store department. These more aggregated item groups show that most types of items do not greatly shift from full-service to self-checkout, at least not beyond the average. Thus once again, the substitutions for pregnancy tests and condoms particularly stand out across register location after self-checkout adoption.

Finally, Figure 6 plots the shares sold at self-checkout vs regular full-service registers for other item groups considered. Fresh fruits and vegetables (i.e., apples and onions) which are harder to scan are less likely to be bought at self-checkout registers, yet dog food, which we also hypothesized is harder to scan, is more likely to be bought at self-checkout registers. The remaining unhealthy items are more likely to be purchased at self-checkout registers. It is worth noting that the share of pregnancy tests and of condoms bought at self-checkout are also much larger than those of unhealthy items, suggesting items related to sexual reproduction are particularly stigmatizing to purchase in front of others.

While these simple bar plots provide convincing evidence that certain stigma items—namely pregnancy tests and condoms—are more likely to shift to self-checkout registers than other items, we conduct a second more rigorous regression analysis of these probabilities. Using the *Evenings* data and the sample of stores with self-checkout registers, we run a linear probability model (LPM) and a Logit model on the probability of choosing self-checkout registers given transaction characteristics. Our data for this analysis is at the transaction

[22] Studies consistently find that older adults adopt new technologies at lower rates than those in younger age groups for various reasons, including differences in perceived value and confidence in the ability to learn the technology (Charness and Boot, 2009; Berkowsky et al., 2017).

level, with a total of 244,441 transactions. In both regression models, our outcome variable is an indicator for whether a transaction was processed at a self-checkout register. Our first explanatory variable is the number of items per transaction. We hypothesize the more items in a transaction, the less likely the transaction will occur at self-checkout. It is also important to include the number of items per transaction as certain items may be more likely to be purchased in smaller (or larger) transactions and we want to disentangle the effects of transaction size from types of items purchased. Our remaining explanatory variables are indicators for whether the transaction contains items from particular item groups. The item groups we consider are the same as those presented in Figure 6.[23] Finally, we include store and year-month fixed effects and standard errors are estimated using bootstrap procedures.

Table 4 presents the results of the LPM model in column 1 and the marginal effects of the logit model in column 2. Starting in column 1, we find an additional item per transaction is associated with a 0.5 percentage points lower probability of choosing a self-checkout register, which aligns with our hypothesis. The remaining product group indicators are arranged from most positive coefficients to most negative coefficients. Confirming the results in Figure 6, we find that purchasing condoms, pregnancy tests, and yeast infection treatments is associated with a 16.4, 13.3, and 7.1 percentage point increase in the probability of using self-checkout registers, respectively. The coefficients for these items are double and triple the size of most other item groups considered. With the exception of incontinence products, most stigma items (highlighted in bold) are associated with higher self-checkout use.

Additionally, purchasing sanitary pads, pet department, bowel treatments, and frozen department items are also associated with an increase in using self-checkout, ranging from 2 to 2.7 percentage points. Conversely, purchasing general merchandise items and fresh produce items are negatively associated with self-checkout use, with coefficients ranging from -9.6 to -4.7 percentage points. The magnitude of the Logit results in column 2 align closely with the LPM results, though statistical significance does vary slightly, especially for

[23]We adjust the department indicators to only include items not already in one of the other item categories. Thus stigma goods are not included in the Health/Beauty items group in this analysis.

item groups that were only marginally significant or insignificant in column 1. Overall, the register substitution results show that most stigma items, and condoms and pregnancy tests in particular, are more likely to be purchased at self-checkout than other items considered, suggesting that self-checkout registers reduce the stigma felt by consumers in purchasing these items.

5.3 Considering Mechanisms

One may be concerned that the substitution results for condoms and pregnancy tests are coming from the fact that people may be more likely to purchase these items when their transactions are smaller, and people may be more likely to choose self-checkout when they have small transactions of say, 10 items or fewer. This is not captured in our simple theoretical model, which would predict that the substitution effects for condoms and pregnancy tests are due to stigma.

To address this concern, our LPM and Logit regressions in the previous section provide evidence that, even after controlling for transaction size, we find certain stigma items are more likely to be purchased at self-checkout. Additionally, we can provide some evidence that customers do also buy these items in larger sized transactions. The following analysis considers *condoms and pregnancy tests*. The x-axis in Online Appendix Figures A7a, A7b, and A7c shows the total number of items purchased in transactions that include at least one condom/lubricant item or at least one pregnancy/ovulation test in the *Evenings* data. The y-axis shows how many transactions of that size are in the data. For reference, out of the 1,097 transactions including at least one condom or pregnancy test item, 1,000 contain only one of these items and the rest contain at most 5 of these items.

Figures A7a and A7b plot transaction size at stores where self-checkout is available (both stores that were always treated and stores that were treated mid-sample), showing transactions that occurred at self-checkout vs regular registers. Figure A7a shows that most of the purchases that include condoms and pregnancy tests at self-checkout registers are 10 items or fewer, but there are some transactions with greater than 10 and even greater than 20 items in a transaction. Figure A7b shows purchases at regular registers in stores where self-checkout is also available (both stores that were always treated and stores that were treated mid-sample). We see that some people with fewer than 10 items in their purchased bundle that includes condoms or pregnancy tests still choose regular registers even when self-checkout is available.

Finally, Figure A7c shows that many of the purchases that include condoms or pregnancy tests at regular registers at stores where self-checkout is not available are smaller than 10 items, but there are also larger sized transactions that include condoms or pregnancy tests. Overall, these descriptive statistics additionally suggest that small transaction sizes for transactions that include condoms and pregnancy tests is not the only factor driving customers to substitute from regular to self-checkout registers for purchases that include these items.

6 Discussion

The first set of results on the extensive margin indicate that $\lambda_i^R(x)$ is not large enough for customers to be under-purchasing most stigma items before the introduction of self-checkout, with the exceptions being bowel treatments, yeast infection treatments, and condoms. The substitution results for condoms and pregnancy tests indicate that $\lambda_i^R(x) > 0$ for some people who switch from regular to self-checkout registers, but this $\lambda_i^R(x)$ must not have been large enough for those who purchase pregnancy tests to have been under-purchasing pregnancy tests before self-checkout was available. Still, these customers may benefit from welfare increases due to the availability of self-checkout and the privacy it provides relative to regular checkout.

In order to estimate the "cost" associated with stigma, we can consider a simple trade-off the consumer faces when switching between self-checkout (SC) vs. a cashier register (CR). While SC comes with privacy and reduced stigma, it also requires extra time and effort to be exerted by the customer. While we cannot directly measure "effort" in this context, we can estimate time costs. For instance, a transaction with one item takes 99 seconds longer at SC vs. CR on average (see intercepts in Figure 7). From our main regression results, we found that relative to all other goods, transactions with condoms and pregnancy tests are nearly 15 percentage points more likely to be purchased at SC than CR. This represents a 39% increase in the likelihood of using SC. This suggests that on average those who purchase these products are willing to spend an extra 38.6 seconds (39% times 99 seconds) for increased privacy. Furthermore, most transactions are greater than one item, and the "marginal time cost" of transaction size is higher for SC vs. CR (the slope for SC is steeper vs. CR in Figure 7); so, the larger the bundle (of stigma goods with other goods), the greater the time cost at SC vs. CR.

We could then take this analysis one step further by assuming a value of time. A common approach is to use half the median hourly wage (Small and Verhoef, 2007; Zamparini and Reggiani, 2007). The U.S. median hourly wage in 2009 was $15.95 per hour.[24] Thus in this case, the privacy cost of 38.6 seconds would be worth 8.6 cents. Prior literature has also estimated costs associated with privacy in experimental settings. For example, in an online setting, Tsai et al. (2011) find that participants were willing to spend 60 cents to protect their purchase data. In a survey intervention with female shoppers across two women's clothing stores in Pittsburgh, Acquisti et al. (2013) estimate a willingness to pay of 19 cents to protect customer purchase data. To our knowledge, our study is the first to estimate a monetary cost associated with privacy in a natural setting.

7 Conclusion

We investigate how the introduction of self-checkout registers impacts the purchases of stigma items. We first build a conceptual model that illustrates how stigma and social image

[24] *Source:* U.S. Bureau of Labor Statistics, "Occupational Employment Statistics (OES) Highlights." Online, accessed 26 Feb 2024.

concerns can drive changes in purchasing decisions. We then utilize plausibly exogenous variation in the timing of self-checkout adoption across grocery stores from a single chain in the Washington D.C. area to isolate to the causal effect of self-checkout on purchase decisions.

We first find an increase in the total volume of sales across stores in response to self-checkout adoption, with no change in price. To evaluate whether stigma items specifically responded to self-checkout, we then consider whether the share of total purchases shifted toward stigma items. On this "extensive" margin, the evidence is mixed: shares of purchases of bowel treatments, yeast infection treatments, and condoms all significantly increased, whereas the remaining stigma items considered do not display a statistically significant increase. On the intensive margin, we find evidence of substantial substitution from regular to self-checkout registers for most stigma items. In particular, we find a large share of condoms and pregnancy tests shift to self-checkout registers relative to the average item sold, suggesting these items have higher stigma costs. Additionally, we provide evidence that transaction size is not the only factor driving the choice to use a self-checkout register.

These results shed light on how automation may enhance consumer welfare. The evidence along both the extensive and intensive margins suggest that consumers indeed infer some type of "cost" when purchasing stigma items. Given more purchases are made in total with no change in price, and with a shift in the purchases of stigma goods toward the more private setting, our results suggest that consumers are indeed better off with the option to use self-checkout registers. However, fully shifting to only self-checkout registers may not be welfare enhancing as we also find products that customers disprefer to purchase at self-checkout (e.g., fresh produce and baby items). Our results are particularly informative on the discussion around cashier automation, as some retailers have started to roll back their self-checkout machines, citing in part customer demand for personal interaction with cashiers.[25]

It's also important to note that a significant share of the stigma goods that responded

[25] *Source:* CNN Business, "Target is testing a new self-checkout policy." Online, accessed 8 Feb 2024.

to automation in our study relate to reproductive health (in particular, condoms and pregnancy tests). States across the US are increasingly restricting access to abortions, especially with the overturning of Roe v. Wade, which likely carries downstream ramifications on the purchases of condoms and other reproductive health products. In a context where there will be perhaps more customer dependence on stigmatized goods such as condoms, our results suggest that the welfare benefits of automation are further increasing in the US.

An important contribution of this paper is obtaining data on the specific type of register where transactions occur in addition to transaction level characteristics. However, due to the random sub-sample of transactions and limited time windows of our datasets, we cannot effectively track consumers over time. Future work could collect data on all purchases made by individuals over time in order to include individual-level fixed effects. Another limitation is that our data comes from a primarily urban setting. Future work should consider how our results replicate in rural settings, where social interactions and stigma costs could be different than in more densely populated areas. Furthermore, this paper provides important initial insights into the potential effects of automation on consumer purchasing decisions. Carefully linking these decisions to health outcomes, such as fertility and reproductive health outcomes, is an area for future research.

References

Acemoglu, Daron and Pascual Restrepo (2018) "The Race between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment," *American Economic Review*, 108(6), 1488–1542.

——— (2020) "Robots and Jobs: Evidence from US Labor Markets," *Journal of Political Economy*, 128(6), 2188–2244.

Acquisti, Alessandro, Leslie K John, and George Loewenstein (2013) "What is privacy worth?" *The Journal of Legal Studies*, 42 (2), 249–274.

Ambrozek, Charlotte, Timothy KM Beatty, Marianne P Bitler, Xinzhe H Cheng, and Matthew P Rabbitt (2023) "Effects of WIC EBT on food retail," *Working paper*.

Baker, Andrew C, David F Larcker, and Charles CY Wang (2022) "How much should we trust staggered difference-in-differences estimates?" *Journal of Financial Economics*, 144 (2), 370–395.

Bénabou, Roland and Jean Tirole (2006) "Incentives and Prosocial Behavior," *American Economic Review*, 96(5), 1652–1678.

Berkowsky, Ronald W, Joseph Sharit, and Sara J Czaja (2017) "Factors predicting decisions about technology adoption among older adults," *Innovation in Aging*, 1 (3), igy002.

Borusyak, Kirill, Xavier Jaravel, and Jann Spiess (2021) "Revisiting Event Study Designs: Robust and Efficient Estimation," *Working Paper*, 1–67.

Bursztyn, Leonardo and Robert Jensen (2017) "Social Image and Economic Behavior in the Field: Identifying, Understanding, and Shaping Social Pressure," *Annual Review of Economics*, 9, 131–153.

Callaway, Brantly and Pedro H.C. Sant'Anna (2021) "Difference-in-Differences with multiple time periods," *Journal of Econometrics*, 225(2), 200–230.

Cameron, A Colin, Jonah B Gelbach, and Douglas L Miller (2008) "Bootstrap-based improvements for inference with clustered errors," *The Review of Economics and Statistics*, 90 (3), 414–427.

de Chaisemartin, Clément and Xavier D'Haultfœuille (2020) "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects," *American Economic Review*, 9 (110), 2964–2996.

Charness, Neil and Walter R Boot (2009) "Aging and information technology use: Potential and barriers," *Current directions in psychological science*, 18 (5), 253–258.

Dahl, Darren, Gerald Gorn, and Charles B. Weinberg (1998) "The Impact of Embarrassment on Condom Purchase Behaviour," *Canadian Journal of Public Health*, 89(6), 368–370.

Dahl, Darren W., Rajesh V. Manchanda, and Jennifer J. Argo (2001) "Embarrassment in Consumer Purchase: The Roles of Social Presence and Purchase Familiarity," *Journal of Consumer Research*, 28(3), 473–481.

DellaVigna, Stefano and Matthew Gentzkow (2019) "Uniform pricing in US retail chains," *Quarterly Journal of Economics*, 134 (4), 2011–2084.

Fischer, Stefanie, Heather Royer, and Corey White (2018) "The impacts of reduced access to abortion and family planning services on abortions, births, and contraceptive purchases," *Journal of Public Economics*, 167, 43–68.

George, Alison and Anne Murcott (1992) "Research Note: Monthly Strategies for Discretion: Shopping for Sanitary Towels and Tampons," *The Sociological Review*, 40(1), 146–162.

Goldfarb, Avi, Ryan C. McDevitt, Sampsa Samila, and Brian S. Silverman (2015) "The Effect of Social Interaction on Economic Transactions: Evidence from Changes in Two Retail Formats," *Management Science*, 61(2), 2825–3096.

Goodman-Bacon, Andrew (2021) "Difference-in-differences with variation in treatment timing," *Journal of Econometrics*, 2 (225), 254–277.

Olden, Andreas (2018) "What Do You Buy When No One's Watching? The Effect of Self-Service Checkouts on the Composition of Sales in Retail," hdl.handle.net/11250/2490886, Working Paper.

Roth, Jonathan, Pedro HC Sant'Anna, Alyssa Bilinski, and John Poe (2022) "What's Trending in Difference-in-Differences? A Synthesis of the Recent Econometrics Literature," *arXiv preprint arXiv:2201.01194*, 1–58.

Small, Kenneth and Erik T Verhoef (2007) *The economics of urban transportation*: Routledge.

Streletskaya, Nadia A (2016) "Social Presence and Shopping Behavior: Evidence from Video Data," *Working Paper*.

Sun, Liyang and Sarah Abraham (2021) "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects," *Journal of Econometrics*, 2 (225), 175–199.

Tsai, Janice Y, Serge Egelman, Lorrie Cranor, and Alessandro Acquisti (2011) "The effect of online privacy information on purchasing behavior: An experimental study," *Information systems research*, 22 (2), 254–268.

Zamparini, Luca and Aura Reggiani (2007) "Freight transport and the value of travel time savings: a meta-analysis of empirical studies," *Transport Reviews*, 27 (5), 621–636.

Table 1: Items Under Consideration

	Items
Stigma items	
Pharmacy	Condoms (condoms & sexual lubricants);
	Pregnancy tests (pregnancy & ovulation tests);
	Fungal treatments (wart removers & antifungal treatments);
	Incontinence products (adult incontinence/bladder leakage products);
	Sanitary pads (sanitary napkins & tampons);
	Bowel treatments (antidiarrheal, constipation & hemorrhoid);
	Yeast infection treatments (feminine odor & yeast infection);
Unhealthy	Salty snacks;
	Sugary drinks;
Requires effort to scan	Heavy dog food;
	Free weight apples;
	Free weight onions & garlic;
Placebo	Laundry-related items

Notes: Motivation for selecting pads and tampons as potential stigma item comes from George and Murcott (1992), while Dahl et al. (1998) identifies condoms as a potential stigma item. Olden (2018) examines sales of unhealthy stigma items such as soda and chips, while using laundry-related items as a placebo category. Further selection of potential stigma products drawn from poll from SWNS Digital, "67% of Americans admit to judging fellow shoppers for what's in their carts." Online, accessed 12 May 2022.

Table 2: Description of the Two Data Sets Used

	Random10%	*Evenings*
Adopted SC	9	12
Always had SC	3	7
Never had SC	18	32
Total Stores	30	51
Years	Dec2008-Feb2011	Dec2008-Feb2011
Days of the week	All	Saturday
Times	All	5-6 PM
Transactions	Random 10%	All
Register Type	No	Yes

Notes: The 30 stores in *Random10%* are a subset of the 51 stores included in *Evenings*. The *Random10%* data set does *not* contain information on the type of register that was used for each transaction. The *Evenings* data set includes information on whether each transaction was completed at self-checkout or a regular register.

Table 3: Comparison of treated and control stores

	Random10%			*Evenings*		
	Treated Mid-sample	Never Treated	p-value of diff	Treated Mid-sample	Never Treated	p-value of diff
Total Building Size	45018.67	36984.33	0.1321	46300.17	37793.22	0.0238
Total Selling Area	30157.89	23950.22	0.1202	31415.08	25062.75	0.0253
Full-service Registers	9.22	7.28	0.0329	9.42	7.13	0.0015
D.C.	2	6		2	6	
Maryland	7	8		9	15	
Virginia	0	4		1	11	
Total Count	9	18		12	32	

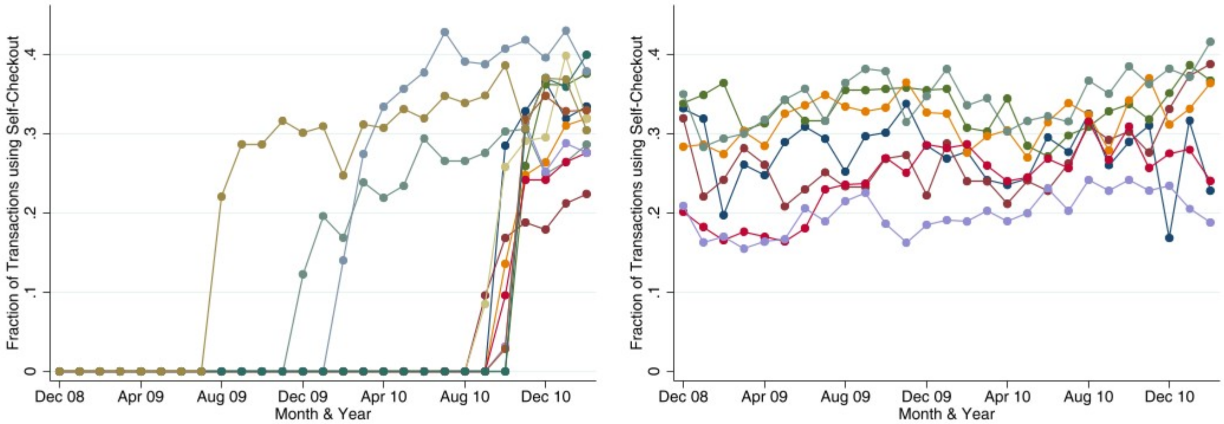
Notes: Total Building Size and Total Selling Area are measured in square feet and come from a store census conducted by the retailer in 2013. Full-service Registers is the average number of cashier-operated registers per store in December 2008 (the first month of the sample period), calculated using the scanner data.

Table 4: Probability of Choosing Self-checkout Registers by Transaction Characteristics

				(cont.)	
	LPM	Logit		LPM	Logit
No. Items Purchased	-0.005***	-0.010***	Bakery Dept.	-0.001	0.008***
	(0.000)	(0.000)		(0.013)	(0.002)
Condom/Lube	0.164***	0.164***	Laundry	-0.002	-0.005
	(0.033)	(0.031)		(0.013)	(0.005)
Pregnancy/Ovulation Test	0.133***	0.128**	Baby Dept.	-0.006	-0.001
	(0.036)	(0.060)		(0.010)	(0.007)
Feminine Odor/Yeast Infection	0.071**	0.086***	Apples, bagged	-0.009	-0.011
	(0.032)	(0.032)		(0.007)	(0.009)
Wart/Fungal Infection	0.030	0.045	Health/Beauty Dept.	-0.012	-0.008**
	(0.024)	(0.028)		(0.008)	(0.003)
Diarrhea/Constipation/Hemorrhoid	0.027*	0.036*	Meat/Seafood Dept.	-0.016**	-0.003
	(0.014)	(0.019)		(0.007)	(0.003)
Sanitary Pads/Tampons	0.025***	0.032***	Sugary Drink	-0.020**	-0.012***
	(0.005)	(0.009)		(0.007)	(0.002)
Pet Dept.	0.023**	0.037***	Onions, bagged	-0.020*	-0.033***
	(0.008)	(0.005)		(0.010)	(0.010)
Frozen Dept.	0.020**	0.033***	Apples, free weight	-0.026***	-0.030***
	(0.008)	(0.002)		(0.005)	(0.006)
Ready-to-eat/Deli Dept.	0.011	0.018***	**Incontinence**	-0.032	-0.052*
	(0.008)	(0.003)		(0.023)	(0.028)
Shelf-stable Grocery Dept.	0.010	0.027***	Floral Dept.	-0.037**	-0.037***
	(0.020)	(0.002)		(0.014)	(0.005)
Dog Food	0.010	0.015	Fresh Produce Dept.	-0.047***	-0.026***
	(0.017)	(0.016)		(0.012)	(0.002)
Dairy/Refrig. Dept.	0.010	0.025***	Alcohol/Tobacco Dept.	-0.076	-0.071***
	(0.008)	(0.002)		(0.068)	(0.003)
Salty Snack	0.009	0.018***	General Merch. Dept.	-0.096**	-0.090***
	(0.006)	(0.003)		(0.039)	(0.002)
Onions, free weight	0.000	0.005	Observations	244,441	244,441
	(0.004)	(0.005)	R squared/Psuedo R	0.064	0.065

Notes: Table presents results from a linear probability model (LPM) and Logit model where both specifications include year-month fixed effects and store fixed effects. Stigma items are presented in **bold**. Unit of observation is the transaction level. Standard errors are estimated using bootstrap procedures (Stata command `wildbootstrap` clustered at the store level in column 1 and `bootstrap` in column 2).

Figure 1: Staggered Adoption of Self-Checkout



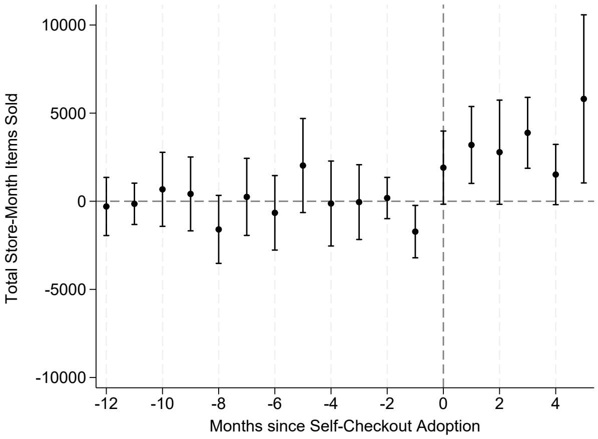
(a) Adoption Mid-sample

(b) Adoption Pre-sample

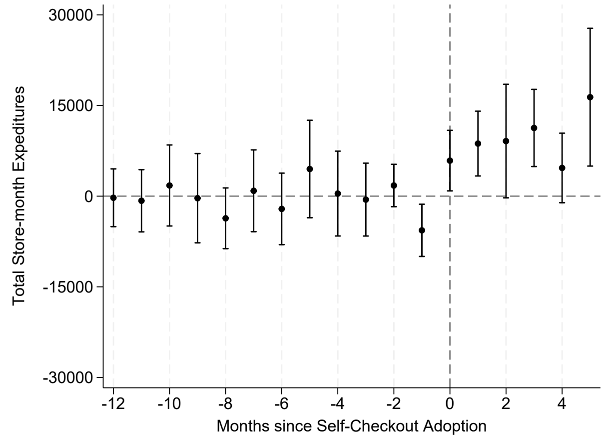
Notes: This figure shows the fraction of transactions that were completed at self-checkout among stores that adopted mid-sample and among stores which had self-checkout during the entire sample. This figure uses data from the *Evenings* data set (the *Random10%* data set contains a subset of these stores).

Figure 2: Effect of Self-checkout Register Adoption on Total Store-month Sales

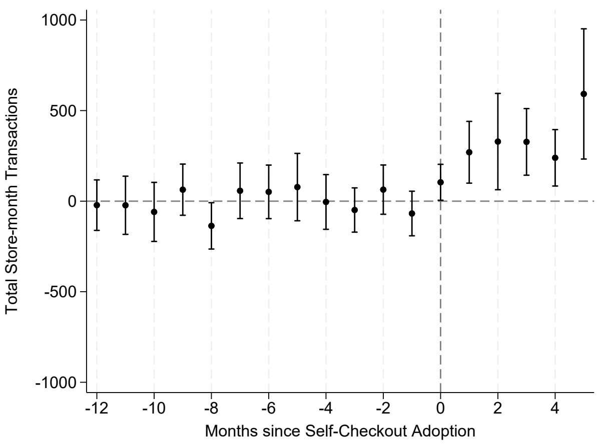
(a) Total Items Sold



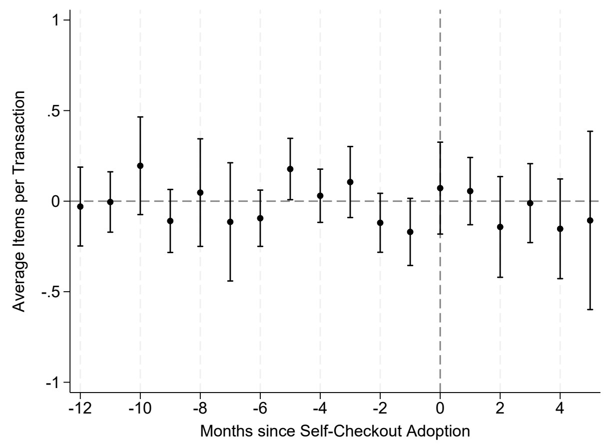
(b) Total Expenditures



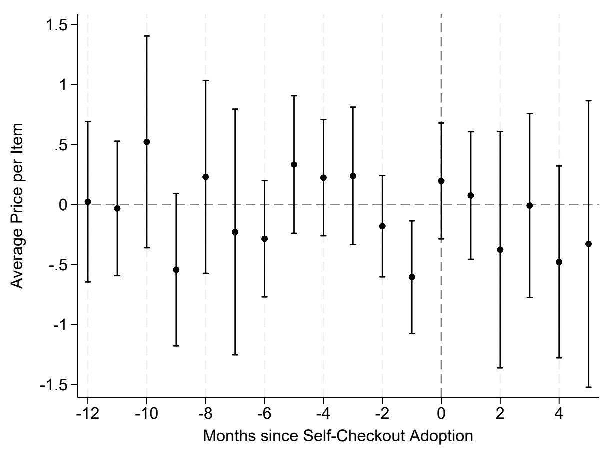
(c) Total Transactions



(d) Avg. Items per Transaction

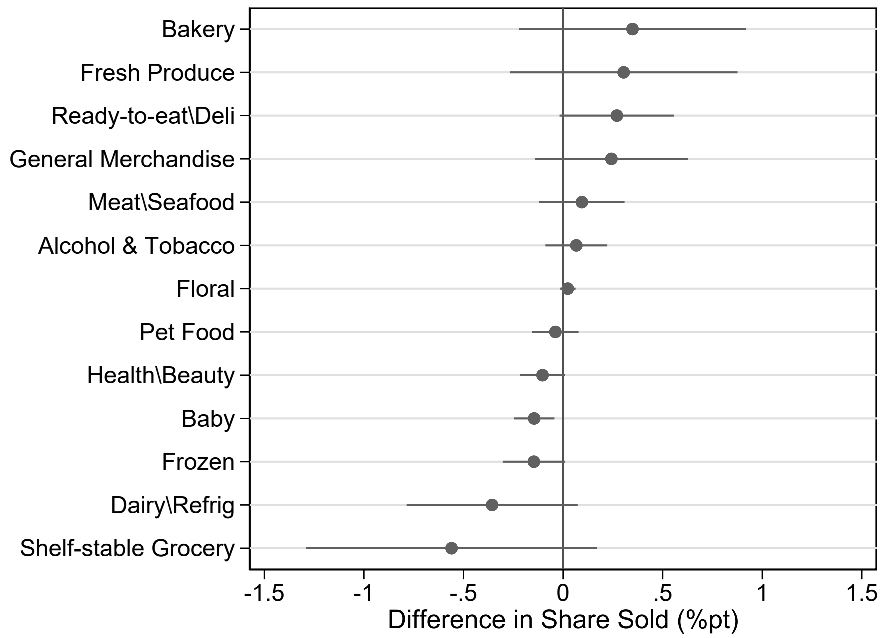


(e) Avg. Price per Item



Note: This figure has five panels and shows the event study results of self-checkout adoption on total store-month sales, measured as the total number of items sold (panel a), the total expenditures paid (panel b), and the total number of transactions processed (panel c). Panel (d) shows event study results of self-checkout adoption on the average items per transaction and panel (e) shows effects on the average price per item.

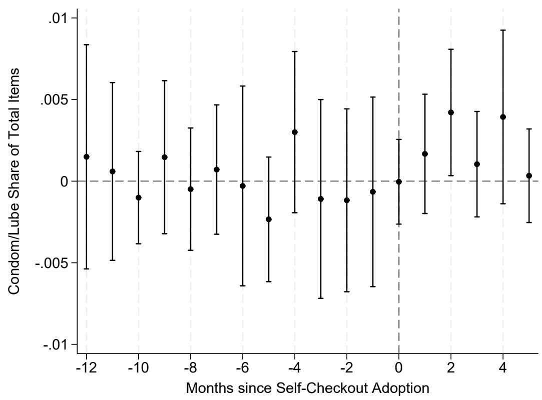
Figure 3: Effect of Self-checkout Register Adoption on Share of Items Sold by Store Department (DiD)



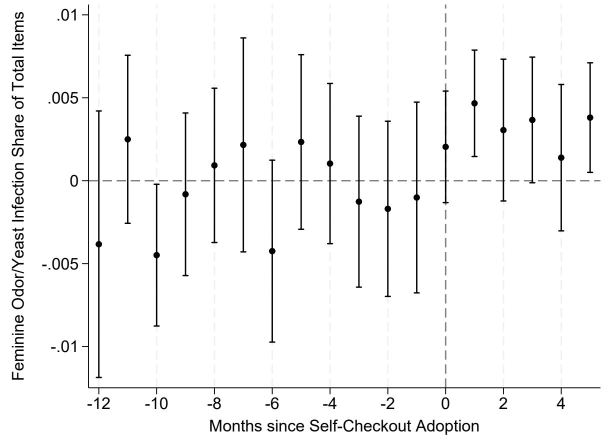
Note: This figure plots the DiD estimates for each department group listed in row, where each of the DiD estimates is obtained by collapsing the event study estimates into their DiD counterparts, using the Callaway and Sant'Anna (2021) estimator.

Figure 4: Effect of Self-checkout Register Adoption on Share of Stigma Items Sold

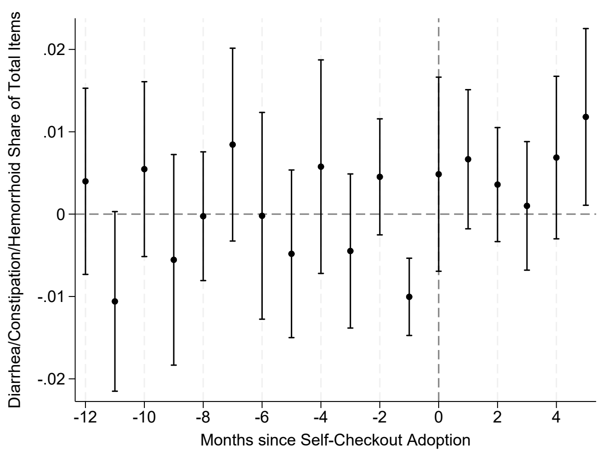
(a) Condoms



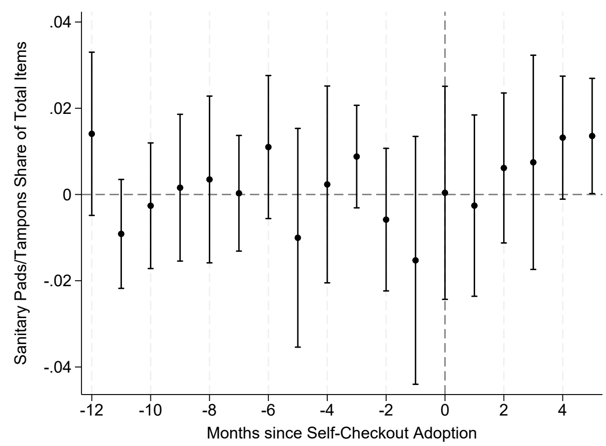
(b) Yeast Infection Treatments



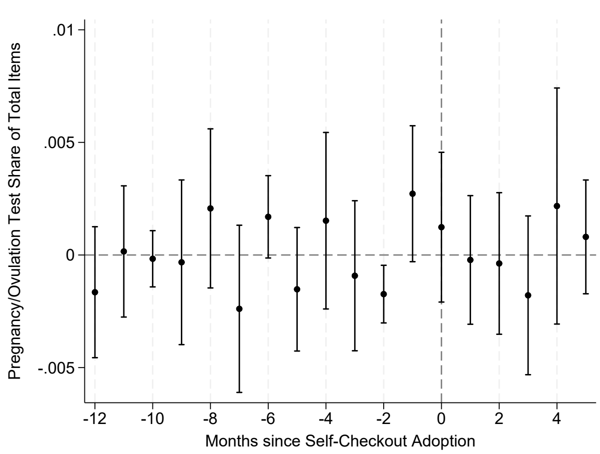
(c) Bowel Treatments



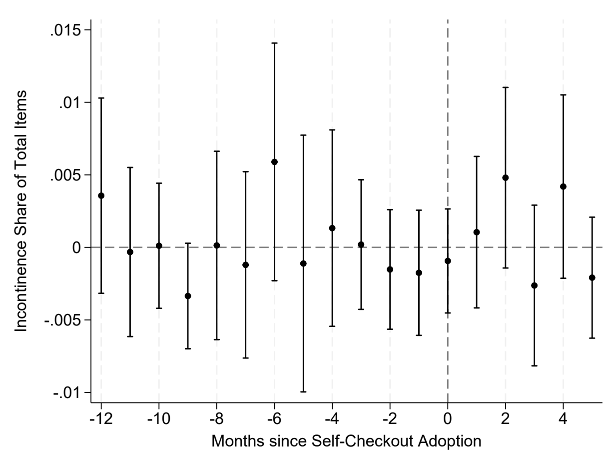
(d) Sanitary Pads



(e) Pregnancy Tests

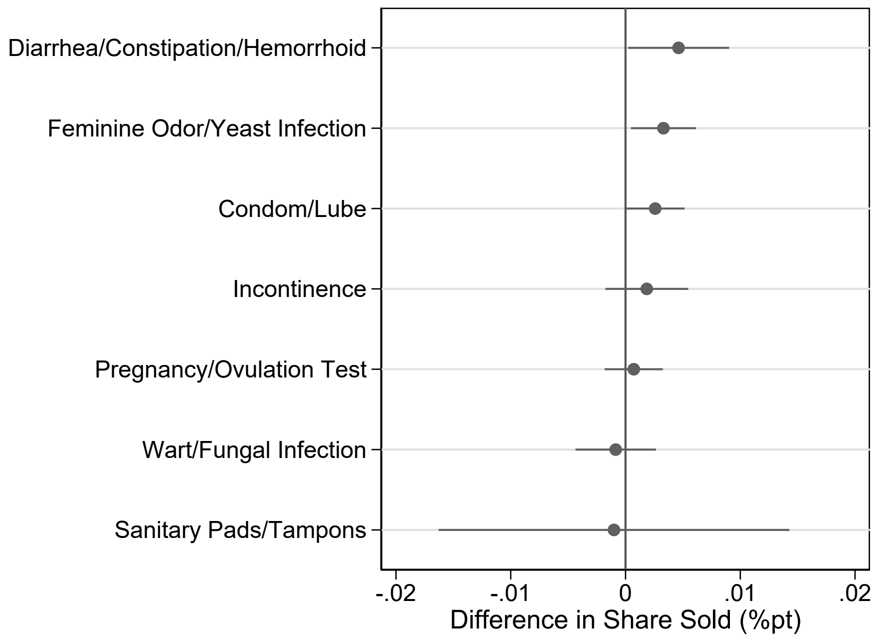


(f) Incontinence Products



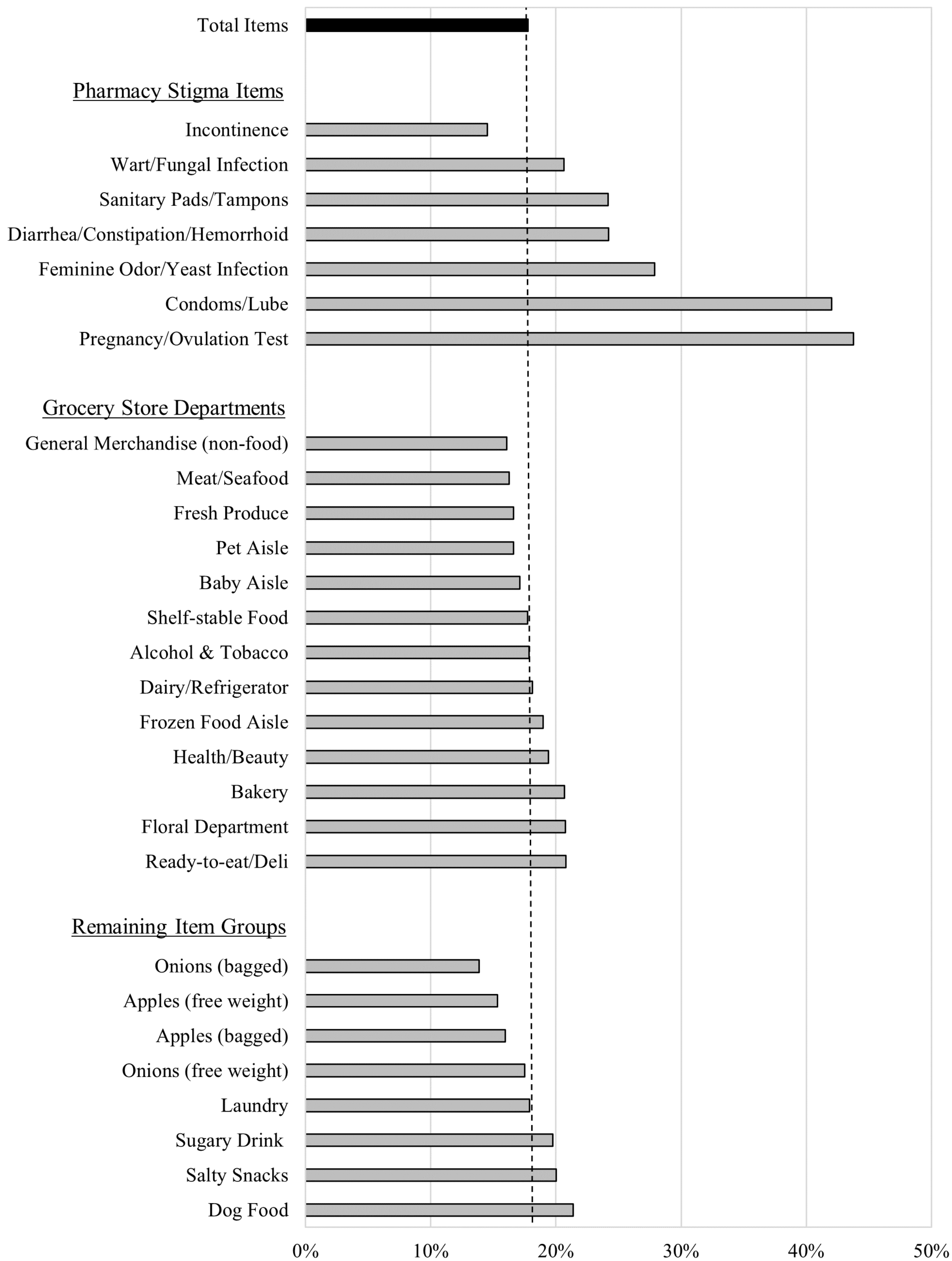
Note: This figure shows the event studies for condoms and sexual lubricants (panel a), feminine odor and yeast infections (panel b), diarrhea, constipation, and hemorrhoid treatments (panel c), sanitary napkins and tampons (panel d), pregnancy and ovulation tests (panel e), and adult incontinence products (panel f).

Figure 5: Effect of Self-checkout Register Adoption on Share of Stigma Pharmacy Items Sold (DiD)



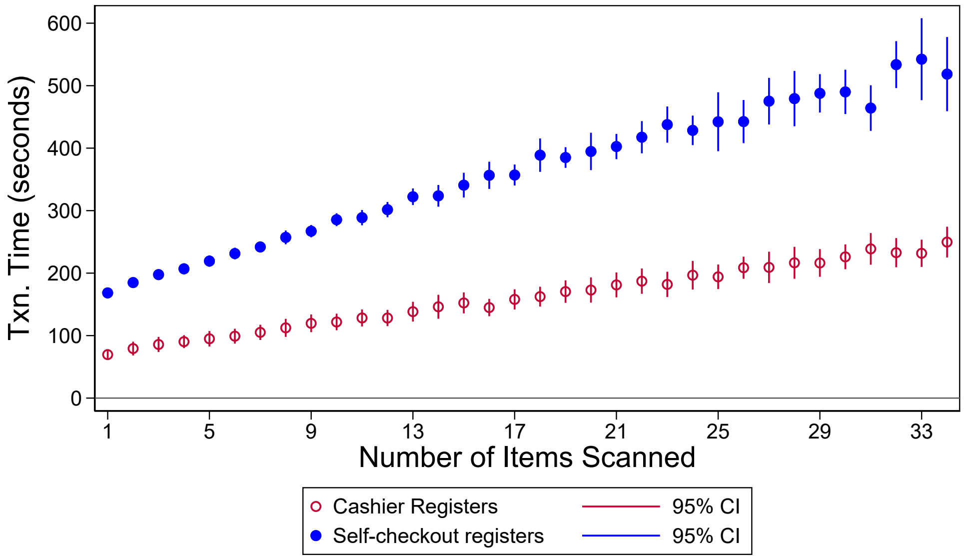
Note: This figure plots the DiD estimates for each stigma item listed in row, where each of the DiD estimates is obtained by collapsing the event study estimates from Figure 4 into their DiD counterparts, using the Callaway and Sant'Anna (2021) estimator.

Figure 6: Share of Items Sold at Self-Checkout vs Full-Service Registers



Note: This figure plots the share of items sold at self-checkout for different products. We use the *Evenings* data set (including pre-sample adopters) and drop stores and time periods without self-checkout. We calculate the share of item x sold at self-checkout by dividing the total quantity of item x sold at self-checkout by the total quantity of item x sold at any register.

Figure 7: Average transaction time by transaction size, cashier vs. self-checkout registers



Note: This figure shows the relationship between transaction size (measured by the number of items scanned in a transaction) and the average length of time spent processing a transaction, at regular registers with cashiers vs self-checkout registers.

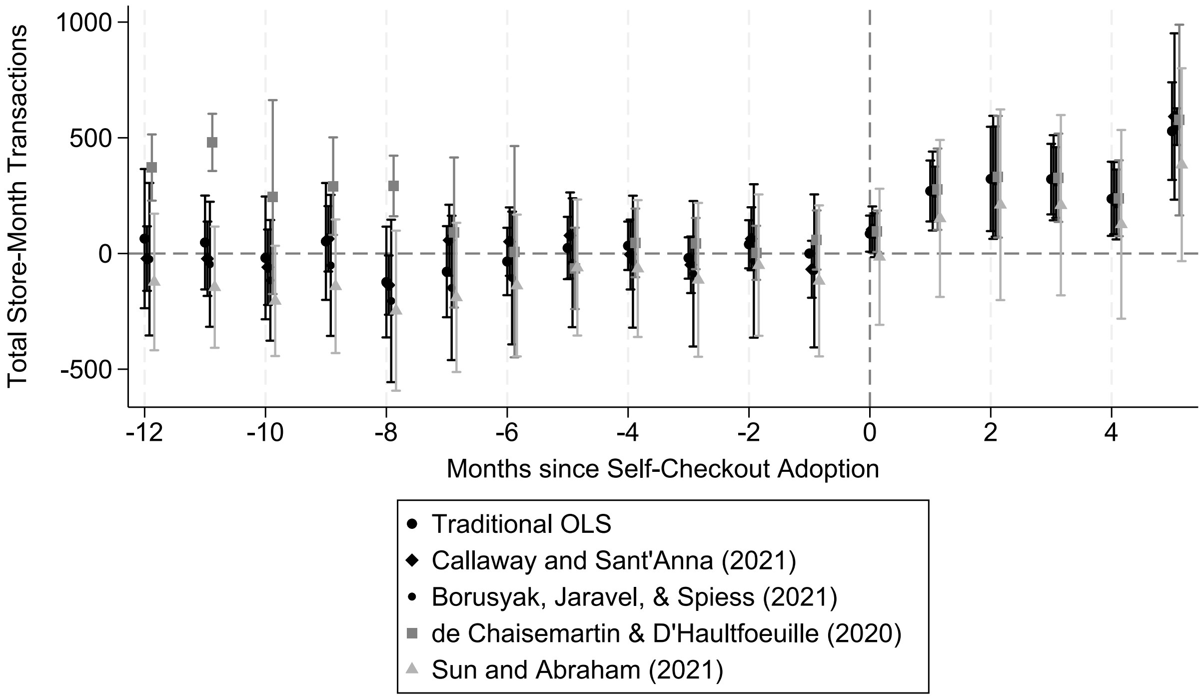
Appendix: Additional Tables and Figures

Table A1: Share of Total Items Sold Pre-self-checkout adoption (Dec 2008 - Jul 2009)

% of Total Items Sold	Never Treated	Treated Mid-sample	P-value of Diff
Grocery Store Departments			
Shelf-stable Grocery Dept.	33.422	32.388	0.345
Fresh Produce Dept.	17.913	17.711	0.875
Dairy/Refrig Dept.	13.817	13.953	0.820
Frozen Dept.	6.784	7.239	0.144
Meat/Seafood Dept.	6.771	6.485	0.660
General Merch. Dept.	6.603	6.469	0.623
Bakery Dept.	5.722	5.907	0.678
Ready-to-eat/Deli Dept.	2.963	3.715	0.153
Health/Beauty Dept.	2.562	3.034	0.056*
Pet Food Dept.	1.494	1.371	0.479
Baby Dept.	0.755	0.842	0.537
Alcohol/Tobacco Dept.	0.705	0.468	0.546
Floral Dept.	0.488	0.418	0.508
Pharmacy Stigma Items			
Sanitary Pads/Tampons	0.128	0.141	0.365
Diarrhea/Constipation/Hemorrhoid	0.033	0.042	0.093*
Incontinence	0.017	0.013	0.209
Condom/Lube	0.014	0.015	0.786
Feminine Odor/Yeast Infection	0.012	0.015	0.293
Wart/Fungal Infection	0.008	0.009	0.402
Pregnancy/Ovulation Test	0.003	0.005	0.072*
Remaining Item Groups			
Sugary Drink	5.005	5.093	0.831
Salty Snack	2.525	2.469	0.777
Apples (free weight)	0.650	0.646	0.955
Onions (free weight)	0.642	0.685	0.490
Laundry	0.571	0.520	0.317
Magazine	0.286	0.293	0.754
Apples (bagged)	0.143	0.129	0.301
Onions (bagged)	0.125	0.128	0.856
Dog Food	0.026	0.025	0.879

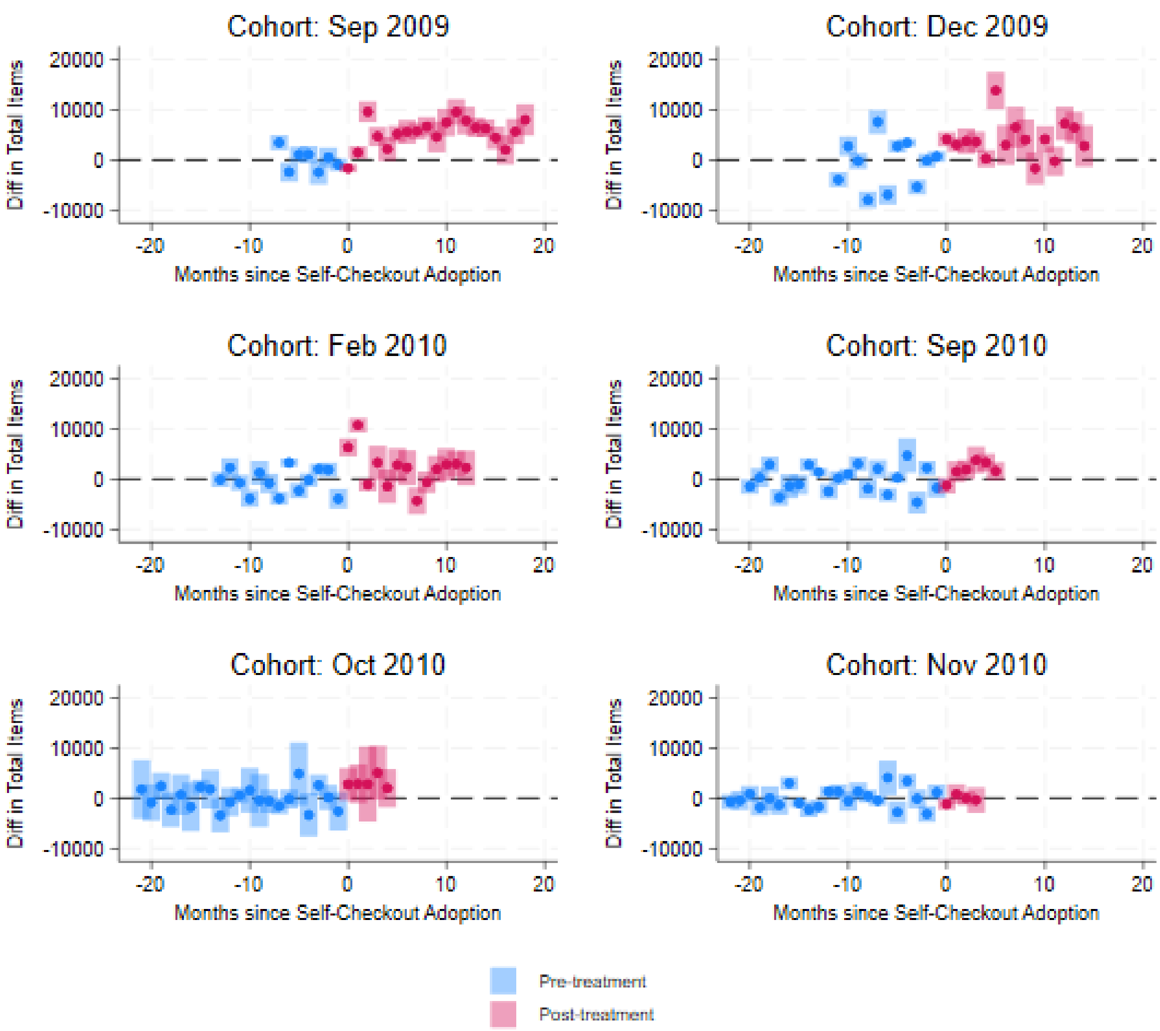
Notes: This table presents the percent shares of total items sold for each product group under consideration, in the pre-adoption period for all stores (Dec 2008–July 2009).

Figure A1: Effect of Self-checkout Register Adoption on Store-month Sales - DiD Estimator Comparison



Note: This figure shows the robustness of the event study results to the use of various DiD estimators: traditional OLS with two-way fixed effects (`reghdfe`), Callaway and Sant'Anna (2021) (`csdid`), Borusyak et al. (2021) (`did_imputation`), de Chaisemartin and D'Haultfœuille (2020) (`did_multiplegt`), and Sun and Abraham (2021) (`eventstudyinteract`). The outcome variable is store-month sales, measured as the total number of transactions processed. The 95% confidence intervals are presented.

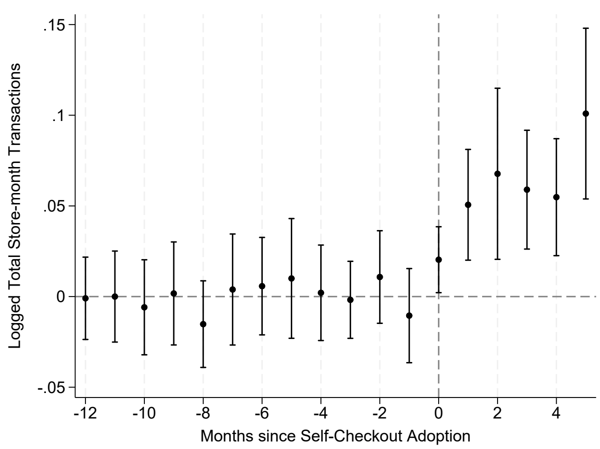
Figure A2: Effect of Self-checkout Register Adoption on Store-month Sales - By Adoption Cohort



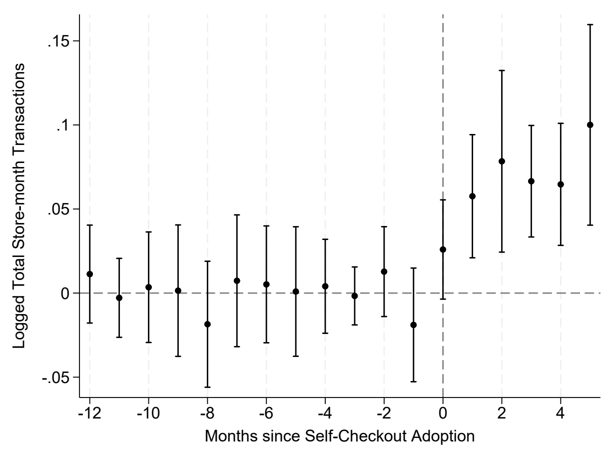
Note: This figure shows the event study estimates from the Callaway and Sant'Anna (2021) estimator, estimated separately by adoption cohort.

Figure A3: Effect of Self-checkout Register Adoption on Store-month Sales - Dropping Multi-store Customers

(a) Whole Sample



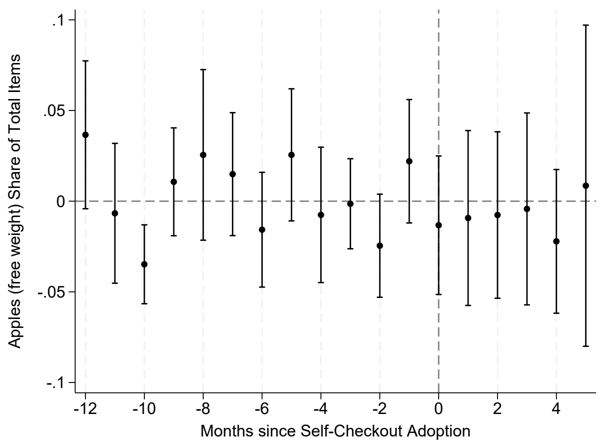
(b) Without Multi-store Customers



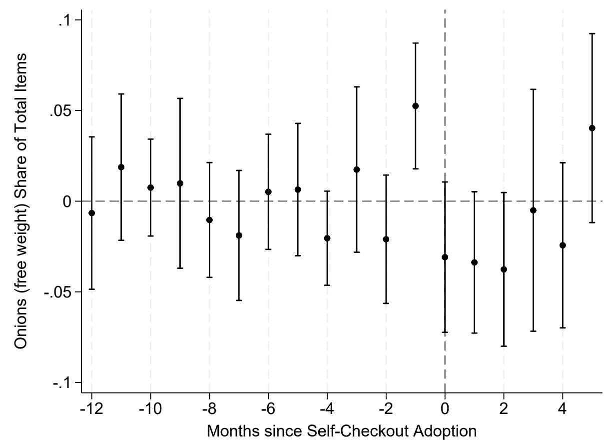
Note: This figure shows the event study results of self-checkout adoption on logged store-month sales, measured as the total number of transactions processed. Panel (a) includes the whole sample whereas panel (b) drops customer loyalty cards that are used at multiple stores in the sample.

Figure A4: Effect of Self-checkout Register Adoption on Share of Items Requiring Effort to Scan and Share of Unhealthy Items Sold

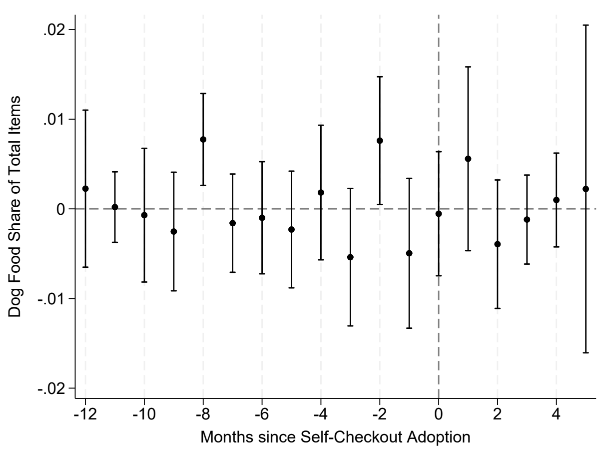
(a) Free Weight Apples



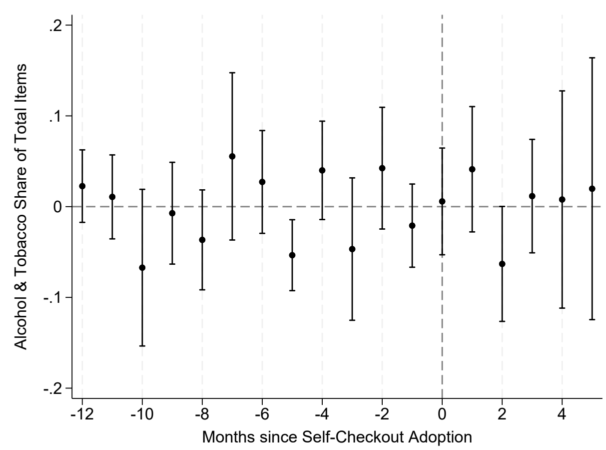
(b) Free Weight Onions



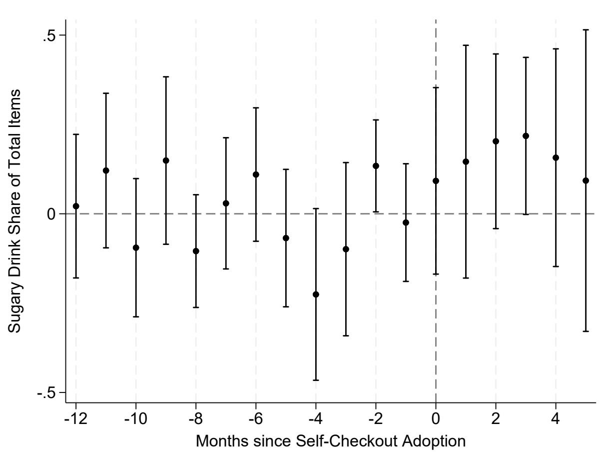
(c) Dog Food



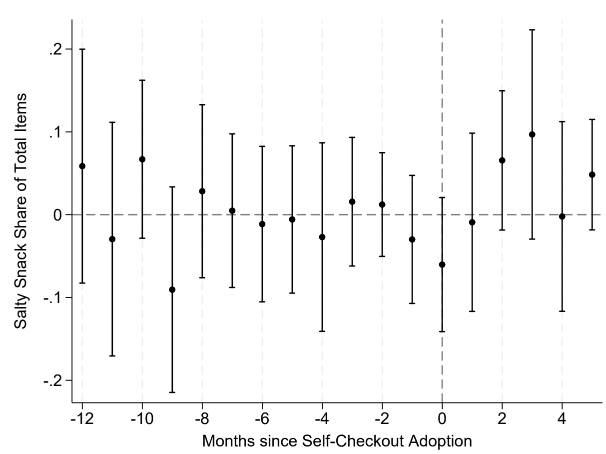
(d) Alcohol & Tobacco



(e) Sugary Drinks

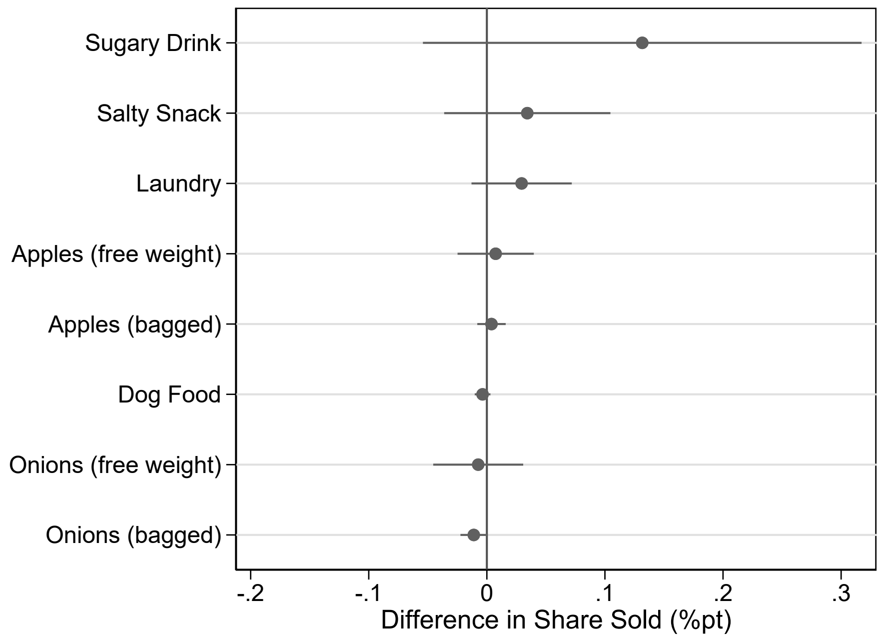


(f) Salty Snacks



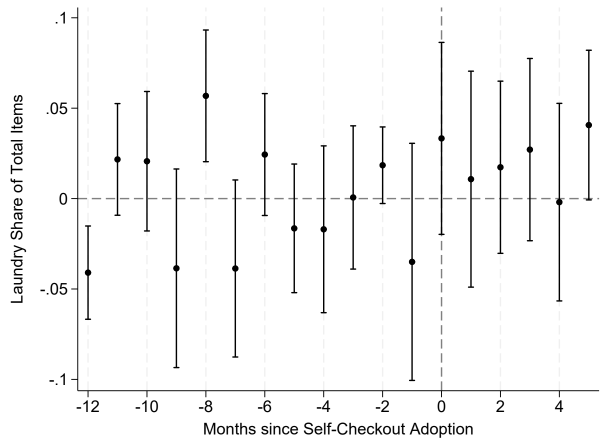
Note: This figure shows the event study estimates for free-weight apples (panel a), free-weight onions (panel b), dog food (panel c), alcohol and tobacco (panel d), sugary drinks (panel e), and salty snacks (panel f).

Figure A5: Effect of Self-checkout Register Adoption on Share of Remaining Item Groups Considered (DiD)



Note: In this Figure we plot the DiD estimates for each hard-to-scan and unhealthy item listed in row, where each of the DiD estimate is obtained by collapsing the event study estimates into their DiD counterparts, using the Callaway and Sant'Anna (2021) estimator.

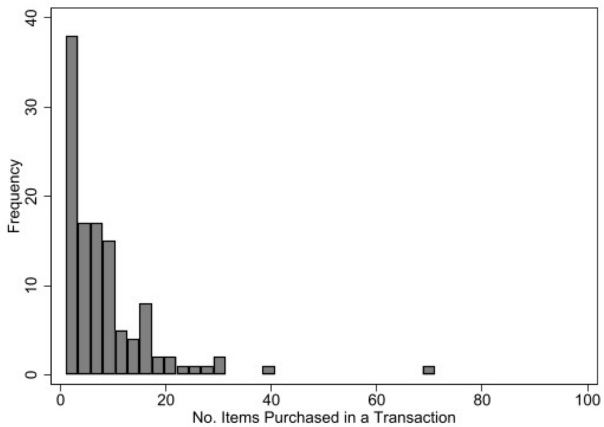
Figure A6: Placebo Analysis: Effect of Self-checkout Register Adoption on Share of Laundry Items Sold



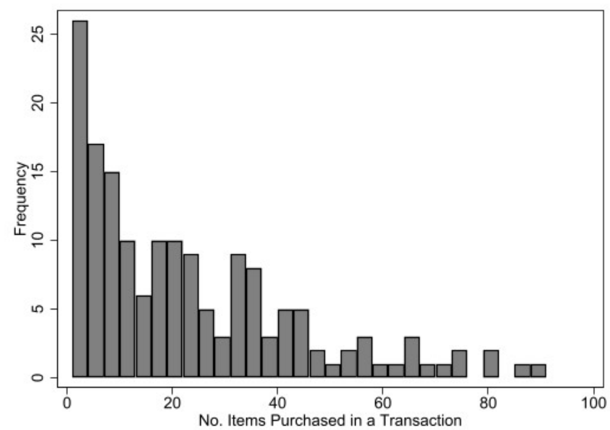
Note: This figure shows the event study estimates for laundry items.

Figure A7: Total Number of Items Purchased in Transactions that include Condoms/Pregnancy Tests

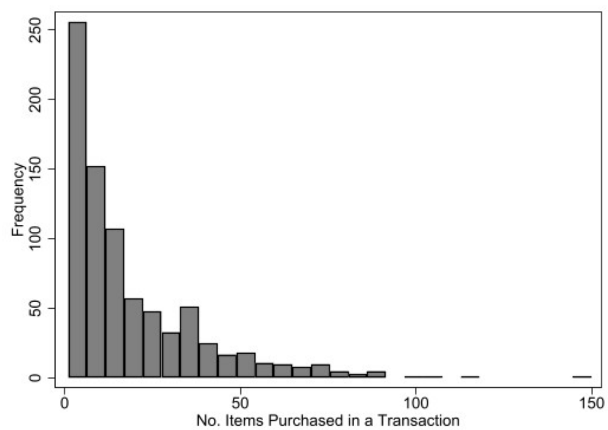
(a) At self-checkout registers



(b) At regular registers in stores WITH self-checkout



(c) At regular registers in stores WITHOUT self-checkout



Note: This figure shows the distribution of transaction size – based on total number of items purchased in a transaction – in the *Evenings* data (including stores that always had self-checkout and those that adopted mid-sample), only for transactions that include at least one condom/lubricant item or at least one pregnancy/ovulation test. Panel (a) shows the distribution at self-checkout registers, panel (b) shows the distribution at regular registers when self-checkout was available in the store, and panel (c) shows the distribution at regular registers when self-checkout was not available in the store. For reference, out of the 1,097 transactions including at least one condom or pregnancy test item, 1,000 contain only one of these items and the rest contain at most 5 of these items.