Stocking Up on Hand Sanitizer: Pandemic Lessons for Retailers and Consumers

Xiaodan Pan[a,*], Martin Dresner[b], Guang Li[c], Benny Mantin[d]

a *John Molson School of Business, Concordia University, Montreal, QC, H3H 0A1, Canada*

b *Robert H. Smith School of Business, University of Maryland, College Park, MD, 20742, USA*

c *Stephen J.R. Smith School of Business, Queen's University, Kingston, ON, K7L 3N6, Canada*

d *Faculty of Law, Economics, and Finance, University of Luxembourg, L-1359, Luxembourg*

Abstract

This study investigates the influence of pandemic experiences on consumer behavior and retail operations, focusing on hand sanitizer during eight seasonal flu epidemics and the swine flu pandemic, covering the period from 2008 to 2017. Motivated by the need to understand the pandemic's impact on retail dynamics, this study fills a gap in knowledge about consumer and retailer adjustments in response to health crises. Using an empirical analysis of data from 38,000 U.S. stores, we find that both consumers and retailers appear to learn from their pandemic experiences. Consumers respond by substituting large pack sizes for small pack sizes of sanitizer, while retailers carry larger assortments of sanitizer products. Moreover, we note that the strategies employed by warehouse clubs and drug store chains—stocking large pack sizes and stocking wide assortments of hand sanitizers, respectively—are both attractive to consumers. Finally, we show that sanitizer sales patterns during the swine flu pandemic were similar to those during the early phases of the Covid-19 pandemic, indicated that lessons learned from one pandemic may be carried forward to subsequent pandemics. These findings contribute to the literature on retail management and consumer behavior during health emergencies, offering valuable insights for future pandemic preparedness.

Keywords epidemic and pandemic, consumer stockpiling, retail management

* Corresponding author. E-mail addresses: xiaodan.pan@concordia.ca (X. Pan), mdresner@umd.edu (M. Dresner), guang.li@queensu.ca (G. Li), benny.mantin@uni.lu (B. Mantin).

1 Introduction

"'*Where Do I Find Your Hand Sanitizer?' Sorry, We Have None*" (Creswell, 2020). A lasting memory of Covid-19 will likely be store shelves empty of essential items, including toilet paper, flour, and hand sanitizer. Sales surged for these products as pandemic emergencies were declared and Covid-19 cases multiplied, resulting in widespread stockouts and panic buying by shoppers. Although this situation was unfortunate for both retailers and consumers, there could be a "silver lining" if retailers and consumers were able to learn from their experiences. Gojo, the maker of the popular hand sanitizer, Purell, believes so. According to a Wall Street Journal report, Gojo "*significantly increased production to meet expected demand*" when the first Covid-19 cases were reported, stating that the demand surge for hand sanitizer was "not unprecedented" although more pronounced than the surges in previous pandemics, such as SARS in 2002-2003 and the swine flu (H1N1) in 2009-2010 (Terlep, 2020).

Leading a national task force on logistics and supply chain management during the pandemic, one of this paper's coauthors found that forecasting pandemic responses is critical to adequately preparing for changing demand. Industry discussions on the task force focused on responses of stakeholders to consumer stockpiling behavior. Retail managers felt that stakeholders would, or could, not sufficiently ration inventory to satisfy demand. Therefore, forecasting changing consumer behavior to anticipate surges in demand is a key to meeting service expectations during a pandemic emergency. Moreover, research is needed to inform pandemic forecasting to support retail decision-making.

The aim of this paper is to investigate the effects of pandemic experiences on consumer behavior and retailer operations, specifically examining the case of hand sanitizer during eight seasonal flu epidemics and the swine flu pandemic from 2008 to 2017. It's important to note that the difference between an epidemic and a pandemic is not marked by the severity of the disease but rather by its spatial distribution, with pandemics causing significant societal, economic, and wide-ranging challenges (Epidemic, Endemic, Pandemic, 2021). This study seeks to answer the following research questions: How does consumer buying behavior for hand sanitizer change with pandemic experience? How does retail management of hand sanitizer evolve with pandemic experience?

We first critically examine the underexplored area of consumer and retailer behaviors during pandemic emergencies, a pertinent subject following recent global health crises. The existing literature provides valuable insights into the dynamics of panic buying behavior (Eger et al., 2021; Islam et al., 2021; Laato et al., 2020; Naeem, 2021; Omar et al., 2020; Yuen et al., 2022) and the corresponding responses of various stakeholders (Chen et al., 2022; Kogan & Herbon, 2022; Prentice et al., 2020; Shan & Pi, 2023). Next, we examine retail strategies in light of these buyer behaviors. While the impact of supply disruption risk on retailers' procurement strategies has been recently discussed (Gheibi & Fay, 2021), the broader context of retail assortment adjustments in the face of such demand shocks remains largely uncharted (Sethuraman et al., 2022). Moreover, existing research indicates minimal price adjustments during emergencies (Cavallo et al., 2014; Gagnon & López-Salido, 2020), with significant concerns regarding the perception of fairness when prices are raised in crisis situations (Ferguson et al., 2011). Finally, we examine both buyer behavior and retailer response for “regular” flu seasons and compare both buyer behavior and retailer strategies to those during a pandemic emergency. Our research seeks to fill these gaps, offering a comparative analysis of consumer buying behaviors across different levels of health crises and assessing how retailers modify their strategies in various store formats to meet these unique challenges.

Our study utilizes a rigorous empirical approach, leveraging extensive operational data from over 38,000 stores across the United States. The data compilation involves two primary sources to provide a comprehensive view of the situation over a decade, from 2008 to 2017. Initially, we source data from the Centers for Disease Control and Prevention (CDC) FluView database. This database offers detailed insights into the severity and geographic distribution of flu activity in all fifty U.S. states, encompassing eight seasonal flu epidemics and the notable 2009-2010 swine flu pandemic. Complementing this, we acquire extensive data on hand sanitizer sales from the same period, utilizing the NielsenIQ Retail Scanner Data, which covers the transactional records from the aforementioned 38,000 stores. This dual-source approach enables a robust analysis of consumer behavior and retail strategy in response to flu outbreaks and pandemics, linking health data with actual retail performance metrics.

The main findings of our study are threefold, offering significant insights into the dynamics of consumer behavior and retail strategy during health crises. First, our analysis of the patterns of hand sanitizer purchases during eight seasonal flu epidemics and the two distinct waves of the swine flu pandemic reveals the differential consumer responses to seasonal flu outbreaks and the two stages of the pandemic. Second, our findings highlight learning effects in consumer behavior. Purchasing behaviors pioneered during the pandemic are carried through to subsequent flu seasons. These behaviors provide lessons to retailers as they forecast sales and assortments of flu-related products, such as hand sanitizer. Finally, the study underscores the significant impact of store format on responding to pandemic-induced demand shocks. We find that warehouse clubs and drug stores emerge from pandemics as “sales winners”, despite employing entirely different assortment and price strategies. These findings illustrate the nuanced ways in which different types of retailers can effectively respond to and benefit from the challenges posed by pandemic emergencies.

In conclusion, we contribute to retail management research on epidemics and pandemics (Gupta et al., 2022; Roggeveen & Sethuraman, 2020). We show how retailers adjust their strategies in response to consumer purchasing behavior during pandemics and seasonal flu epidemics. Importantly, we show that retailers gain from their pandemic experience to make changes in operational strategies, useful in meeting customer needs during subsequent seasonal flu outbreaks. Finally, we demonstrate operational variations between types of retail operations. Specifically, we compare product variety and pricing responses across retail formats to determine the types of retailers that are best able to respond to and learn from emergency situations.

2 Theoretical foundation

In this section, we survey relevant literature in the following areas: 1) consumer purchasing behavior due to pandemic emergencies, 2) assortment responses to demand shocks, 3) price responses to demand shocks, and 4) retailer responses by store formats.

2.1 Consumer buying behavior during pandemics

Consumer purchasing of essential products in a time of crisis is a widespread and adaptable phenomenon with several major causes. During a crisis such as a pandemic, individuals may experience stress or fear related to health or safety (Hobfoll, 1988; Hobson et al., 1998), contributing to behavioral changes. Previous studies on consumer purchasing behavior during emergencies mainly focus on natural disasters, such as earthquakes (Cavallo et al., 2014; Ballantine et al., 2014; Forbes, 2017) and hurricanes (Pan et al., 2020; Sneath et al., 2009). The studies on panic buying behavior due to pandemic emergencies were relatively scarce prior to the swine flu pandemic in 2009-2010 (Goodwin et al., 2009) but have significantly increased since the onset of the Covid-19 pandemic, with some research focusing on the dynamics of panic buying behavior (Eger et al., 2021; Islam et al., 2021; Laato et al., 2020; Naeem, 2021; Omar et al., 2021; Yuen et al., 2022) and other papers focusing on the corresponding responses of various stakeholders (Chen et al., 2022; Kogan & Herbon, 2022; Prentice et al., 2020; Shan & Pi, 2023).

As noted, some research papers have concentrated on the factors that influence panic buying behavior. For example, Laato et al. (2020) find that the perceived severity of the pandemic has a positive effect on an individual's intention to self-isolate and, consequently, to engage in stockpiling behavior. Omar et al. (2021) examine how psychological factors affect panic buying behavior. They find that anxiety fully mediates the relationship between uncertainty, perceived severity, and perceived scarcity on panic buying behavior. Naeem (2021) investigates the role of social media in shaping consumer panic buying during the COVID-19 pandemic, highlighting how factors such as uncertainties, social proof, and expert opinions on social media, contributed to panic buying behavior. Islam et al. (2021) explore scarcity messages during the COVID-19 pandemic. They reveal that scarcity messaging during COVID-19 heightened consumer arousal, leading to increased impulsive and obsessive buying. Eger et al. (2021) investigate consumer shopping behavior during the COVID-19 pandemic. Their study, focusing on Czech consumers across Baby Boomer, Generation X, and Generation Y, reveals notable generational differences in shopping behavior and preferences, underlining the varied impact of fear on shopping choices across these cohorts. Yuen et al. (2022) explain panic buying behavior in a social context. They state that non-coercive social influences, social norms, and observational learning directly influence perceived scarcity, which, in turn, causes or indirectly motivates panic buying behavior through anticipated regret.

Other studies center on responses of stakeholders to panic buying behavior. Prentice et al. (2020) investigate the relationship between government measures to combat COVID-19 and their unintended side effects. Their study reveals a connection between the timing of government actions and consumer panic buying behavior, cautioning against claiming a direct causal relationship between a pandemic emergency and consumer response. Chen et al. (2022) study group panic buying behavior. They point out that government intervention can play a crucial role in reducing the level of group panic buying.

Kogan and Herbon (2022) analyze retail responses to COVID-19 panic buying, noting that profit-driven retailers may use "wait and see" strategies, worsening market instability. Their study finds that while traditional measures, such as tax relief, are ineffective at keeping prices of essential products down, low price-caps can paradoxically boost supply. Shan and Pi (2023) explore strategies to mitigate panic buying during epidemics. They develop a tripartite game-theoretic model that analyzes the strategic choices of consumers, merchants, and the government to effectively respond to such crises.

Our research observes that existing studies on panic buying behavior typically concentrate on a single natural disaster or health emergency. Our study, on the other hand, compares consumer buying behavior during seasonal flu epidemics with behaviors during the swine flu pandemic. Specifically, we analyze the predictors of consumer purchases of hand sanitizer across two waves of the swine flu pandemic, as well as during seasonal flu epidemics, over a decade from 2008 to 2017.

2.2 Retailer responses to demand shocks

Assortment responses to demand shocks

Retailers may respond to demand shocks by modifying their assortments within product categories. Assortment size measures the number of distinct alternatives sold within a product category (Sethuraman et al., 2022). Sethuraman et al. (2022) conducted a thorough review of the impact of assortment size on consumer perceptions, choice, and sales based on 95 academic papers published during 1970-2021. They found that on one hand, a larger assortment may positively impact assortment evaluation, leading to a favorable perception of the resulting choices and an increase in retail sales and profits. On the other hand, a large assortment may impact consumer perceptions negatively due to information overload, inhibiting retail sales. Sethuraman et al. (2022) analyzed these results using a measure called the assortment size benefit elasticity. They find that assortment size benefits consumers and retailers in a U-shaped manner, and that the effects are dependent on environmental factors such as characteristics of brands, products, stores, consumers, and tasks.

Despite the abundance of literature on retail assortment, studies on assortment responses to demand shocks such as epidemics and pandemics are limited. Gheibi and Fay (2021) study the impact of supply disruption risk on a retailer's procurement strategies in the presence of substitute products. They identify two types of strategies. First, a retailer may increase total ordering quantities in anticipation of potential supply disruptions, ordering more units from a reliable supplier and fewer units from an unreliable one. Alternatively, a retailer may reduce total order quantities when there is disruption risk.

We study assortment decisions in the hand sanitizer product category during the swine flu pandemic and find that retailers learn during the pandemic and adjust their assortments to meet changing consumer behavior. In particular, retailers stock and sell greater quantities of large-pack-size products as the pandemic progresses. Moreover, assortment decisions are carried forward to address consumer needs during subsequent flu seasons.

Price responses to demand shocks

Emergencies may lead to demand surges and supply disruptions, with rising costs throughout the retail supply chain. As a result, retailers may increase prices to balance supply and demand and account for their higher costs. However, passing on higher costs to consumers through higher prices during pandemic emergencies may be challenging (Ferguson et al., 2011), due to perceptions of fairness in pricing. The principle of price fairness, "dual entitlement," notes that firms are entitled to reference profits, while consumers are entitled to a reference price (Kahneman et al., 1986, 2004). As stated by Kahneman et al. (1986): "it is acceptable for a firm to raise prices when profits are threatened and to maintain prices when costs diminish; however, it is unfair to exploit shifts in demand by raising prices." Consequently, raising retail prices during emergencies can induce negative perceptions of price fairness (Ferguson et al., 2011).

Previous studies find small price responses during emergencies. For example, Cavallo et al. (2014) examined supermarket prices following the 2010 earthquake in Chile and the 2011 earthquake in Japan. They find that product availability dropped immediately, but prices remained relatively stable for months after the disasters. Gagnon and López-Salido (2020) find that radical demand shocks have limited effects on retail price levels. When a crisis triggers retail price corrections, consumers react with suspicion as they become concerned about price fairness (Ferguson et al., 2011). Both papers attribute the relatively steady prices to retailers' fears of antagonizing customers who may perceive price increases as unfair. We examine pricing during both seasonal flu epidemics and the swine flu pandemic and find that adjustments in product assortment hold down average prices paid by consumers, even when listed prices rise.

Retailer responses by store formats

Retail format describes the nature of a retailer's operations to satisfy the needs of target markets (Bonfrer et al., 2022). Levy et al. (2019) define retail format as a mix representing the type of merchandise and services, pricing policy, advertising, promotion program, store design, visual merchandising, and geographic location. Bonfrer et al. (2022) perform a comprehensive review of 178 empirical papers related to physical store-based grocery retail formats and find that the main drivers of shoppers' choices among retail formats include intrinsic household characteristics, time value factors, shopping goals and motivations, and actionable retailer factors such as location, assortment, pricing, and promotion. Gauri et al. (2021) review literature on competition among retail formats across a diverse set of channels. They identify two potential paths for retail formats to stay competitive: enhancement in customer experience and reduction in inconvenience for customers. The authors state that changes in consumer behavior brought by a crisis such as the Covid-19 pandemic (for example, switching to online retail formats, touchless transactions, curbside delivery, etc.) are likely to persist post pandemic.

Despite the multitude of studies on retail store format, research on the variable responses across formats to crises are scarce.[1] This work contributes to the literature by analyzing retail assortment decisions and price responses to seasonal flu epidemics and to the swine flu pandemic across retail formats. We find that both the varied assortment strategy of drug stores and the large

[1] At the macro-economic level, Lamey (2014) finds that consumers shift towards discount stores during economic recessions in Western European countries. To stem the loss of customers, traditional retailers have developed counter strategies such as price matching or private label brands, to compete with the discounters.

pack-size strategy of warehouse clubs can be used successfully to attract customers during pandemic emergencies.

3 Research Methodology

3.1 Data collection

Our first data source is the Influenza Data reported by the Centers for Disease Control and Prevention (CDC).[2] Figure 1 illustrates the progression of eight seasonal flu epidemics and the swine flu pandemic from 2008 to 2017, which includes one seasonal flu epidemic (2008-2009) before and seven seasonal flu epidemics (2010-2017) after the swine flu pandemic (2009-2010).

Pre-Pandemic	***Pandemic***	***Post-Pandemic***						
Seasonal Flu Epidemic	Swine Flu Pandemic	Seasonal Flu Epidemic						
08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17

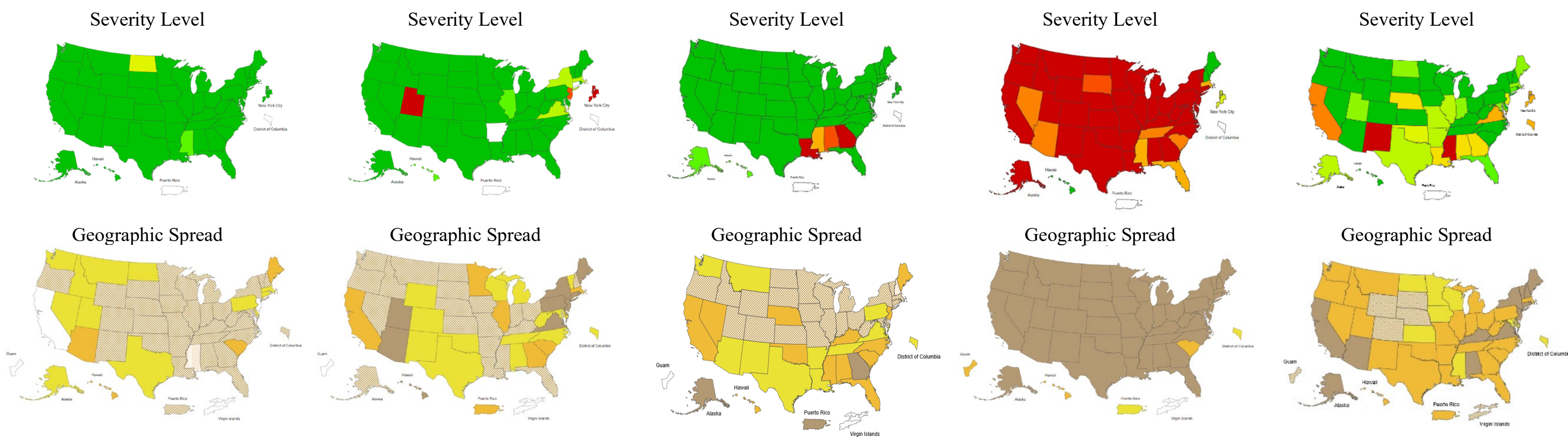
Figure 1: The progression of eight seasonal flu epidemics and the swine flu pandemic

Figure 2 illustrates the two waves of the 2009-2010 swine flu pandemic. The World Health Organization (WHO) declared a public health emergency of international concern on April 25, 2009. The United States Government declared 2009 H1N1 a Public Health Emergency of International Concern on April 26. The first wave of the swine flu pandemic lasted for 16 weeks, while the second wave began in the U.S. on August 20, 2009, lasting a further 16 weeks. The WHO announced the end of the pandemic on August 11, 2010.

[2] The flu seasons is available at www.cdc.gov/flu/season/past-flu-seasons.htm.

2009 Swine Flu Pandemic Timeline

First Wave (16 Weeks)			Second Wave (16 Weeks)	
April 26, 2009	June 11, 2009	August 20, 2009	October 24, 2009	December 5, 2009
Public Health Emergency	WHO Worldwide Pandemic	Second Wave Began	Second Wave Peaked	Second Wave Ended



Pandemic Timeline

2009-04-21	CDC publicly reported the first two infections
2009-04-22	CDC activated Emergency Operations Center
2009-04-26	U.S. declared a public health emergency
2009-06-11	WHO declared a pandemic
2009-06-25	CDC estimated at least 1 million cases in U.S.
2009-08-20	U.S. second wave of activity began.
2009-10-24	U.S. second wave of activity peaked
2009-12-05	U.S. second wave of activity ended
2010-08-14	WHO announced the end of the pandemic

Severity Level

Geographic Spread

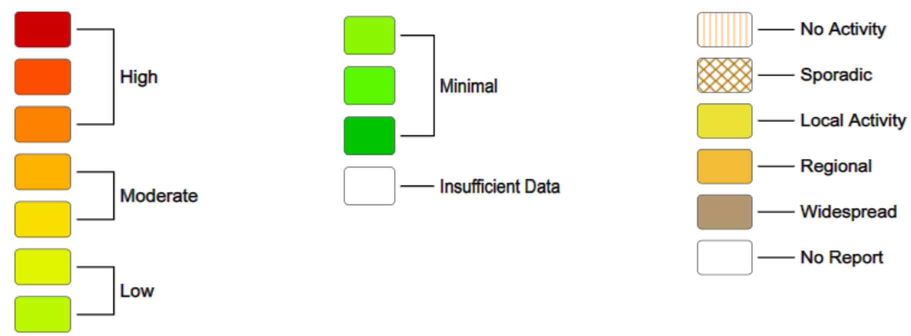


Figure 2: The timeline of the 2009-2010 swine flu pandemic

Our second data source is NielsenIQ Retail Scanner Data.[3] This database consists of information on weekly pricing, sales volume, and store characteristics. The data are generated by point-of-sale systems from more than 90 participating retail chains across all geographic markets in the United States.[4] The database provides store chain code, channel type, and area location, with retailer names masked to protect identities. The database also provides information on product characteristics available from retail outlets, such as UPC code, product category and description, brand name, pack size, and content size. From this database, we collect information on weekly sales hand sanitizer, a high-demand product during flu epidemics and pandemics, used to prevent the spread viruses (Paul & Chowdhury, 2021). Our dataset includes sales of various sizes and brands of hand sanitizer from more than 38,000 stores during the ten-year data collection period.

Our third data source, used mainly in our robustness checks, is the CDC FluView Data.[5] This database consists of weekly influenza surveillance reports prepared by the influenza division of the Centers for Disease Control and Prevention. We focus on the influenza-like illness (ILI) activity map and the influenza geographic spread map. Specifically, the ILI activity map uses the proportion of outpatient visits to healthcare providers for influenza-like illnesses to measure the ILI activity level within a jurisdiction. The geographic spread map indicates the geographic spread of influenza viruses. We collect severity level and geographic spread data for all fifty U.S. states over a ten-year period from 2008 to 2017.

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

[4] The NielsenIQ data description is available at https://www.chicagobooth.edu/research/kilts/research-data/nielseniq.

[5] The FluView Interactive interface is available at https://www.cdc.gov/flu/weekly/fluviewinteractive.htm.

3.2 Variable definitions

Our main models estimate sales, product assortment and prices during seasonal flu epidemics and the swine flu pandemic from 2008 to 2017. The base period for our estimations is the seasonal flu epidemic of 2008-2009. Therefore, our models demonstrate how consumer behavior and retail management changed during the swine flu pandemic that occurred the following year, and the extent that these changes were maintained during seven subsequent seasonal flu seasons. Variable definitions are provided in Table 1, and a correlation table is presented in Table A1 in the Appendix.

The dependent variables include category sales volume, category assortment depth, store-level Universal Product Code (UPC) unit price, and average price paid. Note that the average price per ounce of hand sanitizer assesses the average price paid by consumers, while the UPC price indicates the average price per unit charged at the stock-keeping unit level. Stores may increase the UPC-level price on individual items, but the average per-unit price paid may decrease if the sales mix of sanitizer products gravitates towards cheaper UPCs. In all cases, weekly data are used.

We consider two sets of explanatory variables: 1) flu seasons (i.e., eight seasonal flu epidemics and the swine flu pandemic), and 2) pandemic diffusion course (first and second waves of the swine flu pandemic). We also control market competition, retail chain network characteristics, county-level geodemographic characteristics, price gouging regulations, county-level effects, state-level effects, and retail chain effects in all the estimation models.

For our estimations of category assortment depth, ideally, an inventory count of the stock-keeping units of hand sanitizer at a store outlet would be measured; however, inventory counts are not available to the researchers. Similar to Gallino, Moreno, and Stamatopoulos (2017) and Pan et al. (2020), we approximate category assortment depth using retail sales data; that is, we count the number of sanitizer products (UPCs) sold at a store during a week.

Table 1: Data description

Variables	Unit	Mean	Std. Dev.	Min	Max	Definition
Dependent Variables						
Category Sales Volume						
CAT_SALES_VOL$_{k,l,c,s,y,t}$	OZ	128.29	236.49	0.08	27491.84	Weekly sales volume of hand sanitizer category of a store outlet.
CAT_SALES_VOL_DOLLAR$_{k,l,c,s,y,t}$	OZ	31.32	31.81	0.25	4563.60	Weekly sales volume of hand sanitizer category of a dollar store outlet.
CAT_SALES_VOL_DIST$_{k,l,c,s,y,t}$	OZ	375.26	469.42	0.17	27491.84	Weekly sales volume of hand sanitizer category of a discount store outlet.
CAT_SALES_VOL_DRUG$_{k,l,c,s,y,t}$	OZ	104.60	150.72	0.08	15307.22	Weekly sales volume of hand sanitizer category of a drug store outlet.
CAT_SALES_VOL_GROC$_{k,l,c,s,y,t}$	OZ	130.79	166.59	0.17	15246.80	Weekly sales volume of hand sanitizer category of a grocery store outlet.
CAT_SALES_VOL_WHSE$_{k,l,c,s,y,t}$	OZ	841.80	879.48	12.00	25680.00	Weekly sales volume of hand sanitizer category of a warehouse club store outlet.
Category Assortment Depth						
CAT_ASSORT_DEPTH$_{k,l,c,s,y,t}$	UPCs	5.49	4.38	1.00	35.00	Weekly assortment depth of hand sanitizer category of a store outlet.
CAT_ASSORT_DEPTH_DOLLAR$_{k,l,c,s,y,t}$	UPCs	2.44	1.18	1.00	17.00	Weekly assortment depth of hand sanitizer category of a dollar store outlet.
CAT_ASSORT_DEPTH_DIST$_{k,l,c,s,y,t}$	UPCs	11.48	7.78	1.00	35.00	Weekly assortment depth of hand sanitizer category of a discount store outlet.
CAT_ASSORT_DEPTH_DRUG$_{k,l,c,s,y,t}$	UPCs	5.96	3.23	1.00	31.00	Weekly assortment depth of hand sanitizer category of a drug store outlet.
CAT_ASSORT_DEPTH_GROC$_{k,l,c,s,y,t}$	UPCs	5.14	3.08	1.00	27.00	Weekly assortment depth of hand sanitizer category of a grocery store outlet.
CAT_ASSORT_DEPTH_WHSE$_{k,l,c,s,y,t}$	UPCs	2.11	0.79	1.00	5.00	Weekly assortment depth of hand sanitizer category of a warehouse club store outlet.
UPC Unit Price						
UPC_UNIT_PRICE$_{i,k,l,c,s,y,t}$	\$/OZ	0.64	0.94	0.00	149.75	Weekly unit price of a hand sanitizer UPC of a store outlet.
UPC_UNIT_PRICE_DOLLAR$_{i,k,l,c,s,y,t}$	\$/OZ	0.43	0.44	0.00	73.53	Weekly unit price of a hand sanitizer UPC of a dollar store outlet.
UPC_UNIT_PRICE_DIST$_{i,k,l,c,s,y,t}$	\$/OZ	0.61	0.78	0.00	20.06	Weekly unit price of a hand sanitizer UPC of a discount store outlet.
UPC_UNIT_PRICE_DRUG$_{i,k,l,c,s,y,t}$	\$/OZ	0.73	1.07	0.00	149.75	Weekly unit price of a hand sanitizer UPC of a drug store outlet.
UPC_UNIT_PRICE_GROC$_{i,k,l,c,s,y,t}$	\$/OZ	0.59	0.97	0.00	149.75	Weekly unit price of a hand sanitizer UPC of a grocery store outlet.
UPC_UNIT_PRICE_WHSE$_{i,k,l,c,s,y,t}$	\$/OZ	0.26	0.11	0.04	1.00	Weekly unit price of a hand sanitizer UPC of a warehouse club store outlet.
Average Price Paid						
AVG_PRICE_PAID$_{k,l,c,s,y,t}$	\$/OZ	0.35	0.24	0.00	16.00	Weekly average unit price of hand sanitizer category of a store outlet.
AVG_PRICE_PAID_DOLLAR$_{k,l,c,s,y,t}$	\$/OZ	0.31	0.19	0.00	13.24	Weekly average unit price of hand sanitizer category of a dollar store outlet.
AVG_PRICE_PAID_DIST$_{k,l,c,s,y,t}$	\$/OZ	0.37	0.27	0.00	13.47	Weekly average unit price of hand sanitizer category of a discount store outlet.
AVG_PRICE_PAID_DRUG$_{k,l,c,s,y,t}$	\$/OZ	0.41	0.23	0.00	16.00	Weekly average unit price of hand sanitizer category of a drug store outlet.
AVG_PRICE_PAID_GROC$_{k,l,c,s,y,t}$	\$/OZ	0.32	0.26	0.00	15.82	Weekly average unit price of hand sanitizer category of a grocery store outlet.
AVG_PRICE_PAID_WHSE$_{k,l,c,s,y,t}$	\$/OZ	0.23	0.05	0.05	0.51	Weekly average unit price of hand sanitizer category of a warehouse club store outlet.
Category Sale Volume by Pack Size						
CAT_SALES_VOL_SMALL_PACK$_{k,l,c,s,y,t}$	OZ	105.21	201.01	1.00	25679	Weekly sales volume of small-pack hand sanitizer of a store outlet.
CAT_SALES_VOL_LARGE_PACK$_{k,l,c,s,y,t}$	OZ	23.17	52.32	0.04	13.24	Weekly sales volume of large-pack hand sanitizer of a store outlet.
Independent Variables						
Pandemic and Epidemic						
EPIDEMIC_0809$_{y,t}$	Dummy	-		0.00	1.00	Dummy variable indicates a calendar week during the seasonal flu epidemic in 2008-2009.
PANDEMIC_0910$_{y,t}$	Dummy	-	-	0.00	1.00	Dummy variable indicates a calendar week during the swine flu pandemic in 2009-2010.
$\overline{\text{EPIDEMIC\_POST}_{y,t}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables indicates a calendar week belongs to a seasonal flu epidemic after the swine flu pandemic in 2010-2017.
Pandemic Waves						
$\overline{\text{PANDEMIC\_0910\_WAVE1\_BIW}_{y,t}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables indicates a biweekly period belongs to the first pandemic wave.
$\overline{\text{PANDEMIC\_0910\_WAVE2\_BIW}_{y,t}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables indicates a biweekly period belongs to the second pandemic wave.
PANDEMIC_0910_WAVE2_POST$_{y,t}$	Dummy	-	-	0.00	1.00	Dummy variable indicates calendar weeks during the post second pandemic wave.
Control Variables						

CAT_SALES_VOL_ANNUAL$_{k,l,c,s,y}$	10K OZ	0.69	1.14	0.34	33.76	Annual sales volume of hand sanitizer category of a store outlet.
INTRA_STORE_COMP$_{k,l,c,s,y,t}$	Index	0.47	0.26	0.05	1.00	HHI that measures intra-store competition calculated based on sales volume.
INTER_STORE_COMP$_{k,l,c,s,y,t}$	Index	0.06	0.12	0.00	1.00	HHI that measures inter-store competition calculated based on sales volume.
STORE_NTW_COUNTY$_{k,l,c,y}$	Stores	22.69	37.85	1.00	278.00	Number of stores that belong to a retail chain in a county.
STORE_NTW_STATE$_{k,l,s,y}$	Stores	252.39	236.87	1.00	1072.00	Number of stores that belong to a retail chain in a state.
COUNTY_CAPITA_INCOME$_{c,y}$	10K $	4.43	1.44	1.56	22.78	Per capita income of a county where a store outlet locates.
COUNTY_POP_DENSITY$_{c,y}$	K Person	1.96	6.74	0.00	72.24	Population density of a county where a store outlet locates.
COUNTY_LAND_AREA$_{c,y}$	100 Sq Miles	13.13	22.18	0.02	200.57	Land area of a county where a store outlet locates.
COUNTY_WATER_AREA$_{c,y}$	100 Sq Miles	1.23	2.39	0.00	41.32	Water area of a county where a store outlet locates.
PRICE_GOUGING_REG$_{s,y,t}$	Dummy	-	-	0.00	1.00	Dummy variable indicates a state has price gouging regulations.
$\overline{\text{RETAIL\_CHAIN\_FE}_{l}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables capturing the fix effects of retail chains.
$\overline{\text{PRODUCT\_UPC\_FE}_{i}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables capturing the fix effects of UPCs.
$\overline{\text{STATE\_FE}_{c}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables capturing the fix effects of states.
$\overline{\text{COUNTY\_FE}_{c}}$	Dummy	-	-	0.00	1.00	A vector of dummy variables capturing the fix effects of counties.

3.3 Estimation models

We present estimation models in Equations (1) and (2). The models are estimated at two different levels. At the product category level, the dependent variables represent sales volume/assortment depth/average price paid per ounce for hand sanitizer at store outlet k of chain l in county c of state s in week t of year y. At the UPC level, the dependent variable represents UPC i in store outlet k of chain l in county c of state s in week t of year y. Note that in the equations below, $\bar{x}$ indicates a vector of variables. In Equations (1) and (2), state-effects, county-effects, and chain-effects are considered at both the category and UPC levels, while UPC-effects are added for the UPC estimations.

We adopt the seemingly unrelated regression (SUR) methodology (Zellner, 1962; Zellner and Huang, 1962; Zellner, 1963). This approach is relevant when estimating multiple regression models that, while ostensibly independent, are interconnected through their error terms. By jointly estimating these regressions, the SUR technique provides efficient coefficient estimates by leveraging the correlation structure among the error terms. The consideration of efficiency gains through correlation analysis is imperative in our study given the relationship between our dependent variables. Overall, the adoption of the SUR approach is instrumental in enhancing the robustness and credibility of the statistical conclusions drawn from this research.

In Equation (1), we investigate dynamic patterns across eight seasonal flu epidemics and the swine flu pandemic; that is, one seasonal flu epidemic prior to the swine flu pandemic ($\mathrm{EPIDEMIC\_0809}_{y,t}$), the swine flu pandemic ($\mathrm{PANDEMIC\_0910}_{y,t}$), and seven seasonal flu epidemics after the swine flu pandemic ($\overline{\mathrm{EPIDEMIC\_POST}_{y,t}}$). The estimation allows us to explore learning effects from retailer experiences.

$$
\begin{aligned}
\mathrm{LN(X)} = {} & \beta_0 \\
& + \beta_1 \cdot \mathrm{EPIDEMIC\_0809}_{y,t} \\
& + \beta_2 \cdot \mathrm{PANDEMIC\_0910}_{y,t} \\
& + \overline{\beta_3} \cdot \overline{\mathrm{EPIDEMIC\_POST}_{y,t}} \\
& + \beta_4 \cdot \mathrm{CAT\_SALES\_VOL\_ANNUAL}_{k,l,c,s,y} \\
& + \overline{\beta_5} \cdot \overline{\mathrm{MARKET\_COMP}_{k,l,c,s,y,t}} \\
& + \overline{\beta_6} \cdot \overline{\mathrm{RETAIL\_CHAIN\_NTW}_{k,l,c,s,y}} \\
& + \overline{\beta_7} \cdot \overline{\mathrm{COUNTY\_DEMO}_{c,y}} \\
& + \overline{\beta_8} \cdot \overline{\mathrm{COUNTY\_GEO}_{c,y}} \\
& + \beta_9 \cdot \mathrm{PRICE\_GOUGING\_REG}_{s,y,t} \\
& + \overline{\beta_{10}} \cdot \overline{\mathrm{STATE\_FE}_{s}} \\
& + \overline{\beta_{11}} \cdot \overline{\mathrm{COUNTY\_FE}_{c}} \\
& + \overline{\beta_{12}} \cdot \overline{\mathrm{RETAIL\_CHAIN\_FE}_{l}} \\
& (+\overline{\beta_{13}} \cdot \overline{\mathrm{PRODUCT\_UPC\_FE}_{l}}) \\
& + \varepsilon_{i,k,l,c,s,t} \qquad \text{Equation (1)}
\end{aligned}
$$

where

$X \in \{\mathrm{CAT\_SALES\_VOL}_{k,l,c,s,y,t}, \mathrm{CAT\_ASSORT\_DEPTH}_{k,l,c,s,y,t}, \mathrm{UPC\_UNIT\_PRICE}_{i,k,l,c,s,y,t}, \mathrm{AVG\_PRICE\_PAID}_{k,l,c,s,y,t}\}$

$\overline{\mathrm{EPIDEMIC\_POST}_{y,t}} = \{\mathrm{EPIDEMIC\_1011}_{y,t}, \mathrm{EPIDEMIC\_1112}_{y,t}, \ldots, \mathrm{EPIDEMIC\_1617}_{y,t}\}$

$\overline{\mathrm{MARKET\_COMP}_{k,l,c,s,y,t}} = \{\mathrm{INTRA\_STORE\_COMP}_{k,l,c,s,y,t}, \mathrm{INTER\_STORE\_COMP}_{k,l,c,s,y,t}\}$

$\overline{\mathrm{RETAIL\_CHAIN\_NTW}_{k,l,c,s,y}} = \{\mathrm{STORE\_NTW\_COUNTY}_{k,l,c,y}, \mathrm{STORE\_NTW\_STATE}_{k,l,s,y}\}$

$\overline{\mathrm{COUNTY\_DEMO}_{c,y}} = \{\mathrm{COUNTY\_CAPITA\_INC}_{c,y}, \mathrm{COUNTY\_POP\_DENSITY}_{c,y}\}$

$\overline{\mathrm{COUNTY\_GEO}_{c,y}} = \{\mathrm{COUNTY\_WATER\_AREA}_{c,y}, \mathrm{COUNTY\_LAND\_AREA}_{c,y}\}$

In Equation (2), we focus on the two waves of the swine flu pandemic. We refine our estimation model from Equation (1) by including biweekly time effects to track dynamic changes during the first and second pandemic waves. Figure 2 illustrates the progression of the two swine flu infection waves. While pandemic infections may be swiftly contained, in some cases, there are subsequent spreads of the infection. The swine flu pandemic followed this pattern: after the first wave of infection that lasted about 16 weeks, a second wave of similar duration followed. The second wave was characterized by greater geographic spread, with almost every U.S. state reporting widespread infection. Moreover, the second wave exhibited more severe infection levels, with most states experiencing the highest level of severity.

$$
\begin{aligned}
&\mathrm{LN}(\mathrm{X}) = \beta_0 \\
&+\beta_1 \cdot \mathrm{EPIDEMIC\_0809}_{y,\mathrm{t}} \\
&+\overline{\beta_2} \cdot \overline{\mathrm{PANDEMIC\_WAVE1\_BIW}_{\mathrm{y,t}}} \\
&+\overline{\beta_3} \cdot \overline{\mathrm{PANDEMIC\_WAVE2\_BIW}_{\mathrm{y,t}}} \\
&+\beta_4 \cdot \mathrm{PANDEMIC\_WAVE2\_POST}_{\mathrm{y,t}} \\
&+\overline{\beta_5} \cdot \overline{\mathrm{EPIDEMIC\_POST}_{y,\mathrm{t}}} \\
&+\beta_6 \cdot \mathrm{CAT\_SALES\_VOL\_ANNUAL}_{\mathrm{k,l,c,s,y}} \\
&+\overline{\beta_7} \cdot \overline{\mathrm{MARKET\_COMP}_{\mathrm{k,l,c,s,y,t}}} \\
&+\overline{\beta_8} \cdot \overline{\mathrm{RETAIL\_CHAIN\_NTW}_{\mathrm{k,l,c,s,y}}} \\
&+\overline{\beta_9} \cdot \overline{\mathrm{COUNTY\_DEMO}_{\mathrm{c,y}}} \\
&+\overline{\beta_{10}} \cdot \overline{\mathrm{COUNTY\_GEO}_{\mathrm{c,y}}} \\
&+\beta_{11} \cdot \mathrm{PRICE\_GOUGING\_REG}_{\mathrm{s,y,t}} \\
&+\overline{\beta_{12}} \cdot \overline{\mathrm{STATE\_FE}_{\mathrm{s}}} \\
&+\overline{\beta_{13}} \cdot \overline{\mathrm{COUNTY\_FE}_{\mathrm{c}}} \\
&+\overline{\beta_{14}} \cdot \overline{\mathrm{RETAIL\_CHAIN\_FE}_{\mathrm{l}}} \\
&(+\overline{\beta_{15}} \cdot \overline{\mathrm{PRODUCT\_UPC\_FE}_{\mathrm{l}}}) \\
&+\varepsilon_{\mathrm{i,k,l,c,s,t}} \qquad \text{Equation (2)}
\end{aligned}
$$

where

$$\overline{\mathrm{PANDEMIC\_WAVE1\_BIW}_{\mathrm{y,t}}}$$

$$= \{\mathrm{PANDEMIC\_WAVE1\_BIW1}_{\mathrm{y,t}}, \mathrm{PANDEMIC\_WAVE1\_BIW2}_{\mathrm{y,t}}, \dots, \mathrm{PANDEMIC\_WAVE1\_BIW8}_{\mathrm{y,t}}\}$$

$$\overline{\mathrm{PANDEMIC\_WAVE2\_BIW}_{\mathrm{y,t}}}$$

$$= \{\mathrm{PANDEMIC\_WAVE2\_BIW1}_{\mathrm{y,t}}, \mathrm{PANDEMIC\_WAVE2\_BIW2}_{\mathrm{y,t}}, \dots, \mathrm{PANDEMIC\_WAVE2\_BIW8}_{\mathrm{y,t}}\}$$

4 Estimation results: seasonal flu epidemics and the swine flu pandemic

In this section, we first describe changes in sales, prices, and assortment depth across the seasonal flu epidemics and the swine flu pandemic, demonstrating the learning effects induced by the swine flu pandemic.

Since we apply semilogarithmic models, and accordingly, we interpret the coefficients of the dummy variables and calculate the relative effects from the coefficients following Halvorsen and Palmquist (1980). According to their methodology, let g be the relative effect on Y of the presence of the factor represented by the dummy variable. Thus $g = (Y_1 - Y_0)/Y_0$ where Y_1 and Y_0 are the values of the dependent variable when the dummy variable is equal to one and zero, respectively. Therefore, the coefficient of the dummy variable is $c = ln(1 + g)$. The relative effect on Y is $g = exp(c) - 1$, and the percentage effect is equal to $100 \cdot g = 100 \cdot \{exp(c) - 1\}$. For illustration purposes, we interpret estimation results using percentage effects and demonstrate our estimation results graphically.

Table 2 presents the estimation results from Equation 1. As noted above, we employ the 2008-2009 seasonal flu epidemic (that preceded the swine flu pandemic) as our base case to compare sales, assortment, and price changes during the pandemic and subsequent seasonal flu epidemics. In Table 2, the coefficient for PANDEMIC_0910 is 0.47; thus, $g = exp(0.47) - 1 = 0.60$. As shown in Figure 3, the swine flu pandemic resulted in a 60% increase in weekly sales volume of hand sanitizer relative to the base case, the 2008-2009 flu seasonal pandemic. An important insight from the figure is that this surge in demand triggered long-lasting behavioral effects. While subsequent seasonal flu epidemics showed a steady decline in sales, it took four seasons for sales to return to pre-pandemic levels. Figure 3 shows that the swine flu pandemic also changed retail product assortments. It is associated with a 10% increase in assortment depth in the hand sanitizer category compared to the base case. This assortment depth, however, was not maintained. It subsided to pre-pandemic levels in two years, although it spiked again during the 2014-2015 flu epidemic.

While one might expect the surge in demand during the pandemic to induce an increase in price, this was not recorded at the UPC level or the aggregate product category level. Figure 4 indicates that the UPC unit price was lower during the pandemic (about 2.7%) and for subsequent flu epidemics (ranging between 3.0% and 9.8%), compared to the base case. Meanwhile, the average price paid for sanitizer (per ounce) by consumers during the pandemic was about 9.6% below the base case (the 2008-2009 epidemic). Post-pandemic, the average price paid continued to creep downwards, registering low values during the 2010-2011, 2011-2012, and the 2016-2017 flu seasons. The proliferation of products in the hand sanitizer category during the pandemic likely induced product-switching behavior towards lower-priced UPCs, accounting, in part, for the decline in category-level average price paid (we will elaborate on this point in §5).

Table 2: Estimation results using Equation (1): Changes across seasonal flu epidemics and the swine flu pandemic

Dependent Variable	**Category Sales Volume (OZ)**	**Category Assortment Depth (UPCs)**	**UPC Unit Price ($/OZ)**	**Average Price Paid ($/OZ)**
	Model 1.1	Model 1.2	Model 1.3	Model 1.4
Swine Flu Pandemic				
$PANDEMIC\_0910_{y,t}$	0.472*** (0.001)	0.091*** (0.000)	-0.027*** (0.000)	-0.101*** (0.001)
Seasonal Flu Epidemic				
$EPIDEMIC\_1011_{y,t}$	0.248*** (0.001)	0.062*** (0.000)	-0.101*** (0.000)	-0.224*** (0.001)
$EPIDEMIC\_1112_{y,t}$	0.116*** (0.001)	-0.006*** (0.000)	-0.103*** (0.000)	-0.217*** (0.001)
$EPIDEMIC\_1213_{y,t}$	0.104*** (0.001)	0.003*** (0.000)	-0.051*** (0.000)	-0.143*** (0.001)
$EPIDEMIC\_1314_{y,t}$	0.004** (0.001)	0.023*** (0.000)	-0.042*** (0.000)	-0.128*** (0.001)
$EPIDEMIC\_1415_{y,t}$	0.080*** (0.001)	0.052*** (0.001)	-0.036*** (0.000)	-0.123*** (0.001)
$EPIDEMIC\_1516_{y,t}$	0.021*** (0.002)	-0.018*** (0.001)	-0.030*** (0.000)	-0.190*** (0.001)
$EPIDEMIC\_1617_{y,t}$	0.041*** (0.002)	-0.063*** (0.001)	-0.060*** (0.000)	-0.239*** (0.001)
Control Variables	Included	Included	Included	Included
Constant	4.340*** (0.028)	2.106*** (0.010)	0.152*** (0.038)	-1.011*** (0.014)
Observations	9,943,324	9,943,324	54,701,943	9,943,324
R_Square	0.744	0.869	0.843	0.206

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001
Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

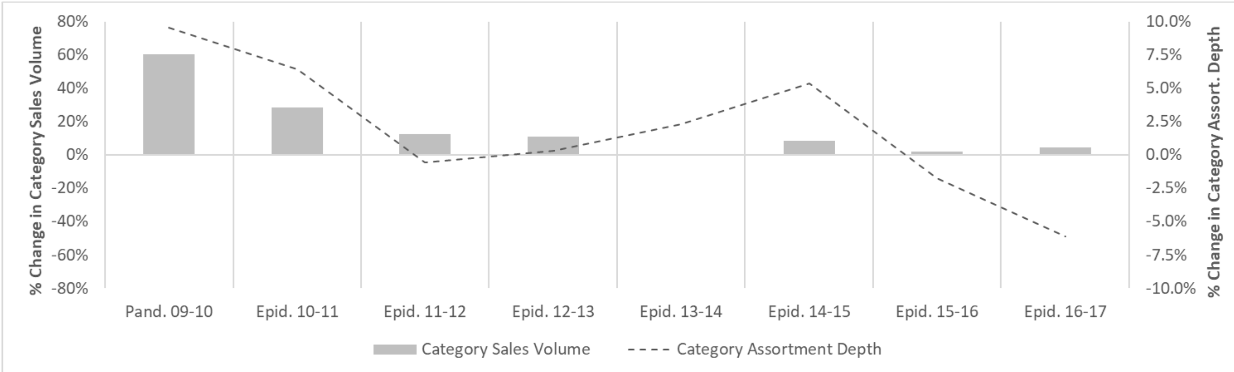


Figure 3: Percentage change in category sales volume and assortment depth with respect to the 2008-2009 epidemic (based on Models 1.1 and 1.2 of Table 2)

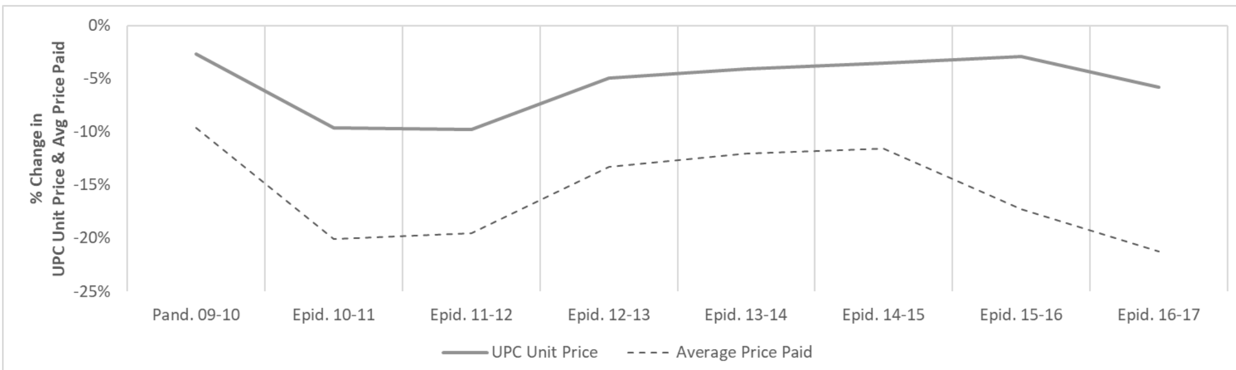


Figure 4: Percentage change in UPC unit price and average price paid with respect to the 2008-2009 epidemic (based on Models 1.3 and 1.4 of Table 2)

5 Estimation results: the two waves of the 2009-2010 swine flu pandemic

Another way to assess learning behavior and changing retail operations is to analyze progress through the two waves of the swine flu pandemic. Therefore, we investigate how consumer behavior evolved during the swine flu pandemic and how hand sanitizer sales, prices, and assortments progressed across the two waves of the pandemic. We further demonstrate how responses varied across retail formats.

While the seasonal flu generally starts in early October (in the northern hemisphere), peaks between December and February, and ends around May, a pandemic does not necessarily follow the same pattern. Pandemics can arise at any time after official declaration by the World Health Organization and national health authorities, such as the CDC in the U.S. Public health emergency declarations can capture media attention and trigger consumer responses.

In Tables 3, 4, 5, and 6, we compare demand patterns and retail management responses during the two waves of the 2009-2010 swine flu pandemic, based on results from Equation (2). We distinguish between the management responses from the following retail formats: dollar stores, discount stores, drug stores, grocers, and warehouse clubs. These retail formats manage vastly different product assortments and cater to diverse segments of consumers and needs. For each dependent variable—category sales volume (Table 3), assortment depth (Table 4), UPC unit price (Table 5), and average price paid (Table 6)—we estimate six models based on Equation (2). In each Table, we first include all store formats (Column 1), then focus on dollar stores (Column 2), discount stores (Column 3), drug stores (Column 4), grocery stores (Column 5), and warehouse clubs (Column 6).

Category sales volume and assortment depth

Figure 5 illustrates how sales volume and assortment depth evolved throughout the pandemic at an aggregate level. As the first wave hit, there was a substantial surge in sanitizer purchases. Following the emergency declaration (Week1-Week2), we witness a surge in consumer purchases: 250% higher hand sanitizer sales compared to the 2008-2009 seasonal flu epidemic. By contrast, the second wave can be characterized by gradual, sustained growth in demand. Multiple factors may contribute to this changed behavior. For instance, the first wave likely caught people by surprise and, hence, there was a sudden rush to purchase or stockpile sanitizer when the pandemic emergency was declared. By the second wave, consumers had time to digest the new reality. They may have also accumulated sanitizer from the first pandemic wave and had more confidence in retailers to maintain supplies. As a result, there was no need to rush to the stores when the virus spread and severity increased.

Figure 5 further suggests that the first two weeks (W1-W2) following the emergency declaration are associated with retailers offering a category assortment about 30% higher than during the 2008-2009 seasonal flu epidemic. This result supports the notion that retailers and suppliers alike can move inventory to consumers and expand product offerings once an emergency is declared. After the initial expansion of assortment, we note a consistent and sustained drop in available products to 4% below the base case level, a decline that lasted roughly through the entire first wave. Decreased assortment may be a proxy for product stockouts as inventory of the most popular products is depleted. These findings suggest that during the early stages of the pandemic, retailers were understocked and needed time to replenish inventory. As expected, assortment depth significantly increased to 8%-26% above the base case level during the second wave of the pandemic. The steady rise in both category sales volume and assortment depth during the onset of the second wave suggests that both retailers and consumers learned from their first wave experiences: retailers were prepared with a larger assortment and greater inventory of sanitizer products; consumers, used to the new norm and aware that retailers had adequate supplies of essential goods, purchased more hand sanitizer because of their needs, but likely realized that "panic" buying was not necessary.

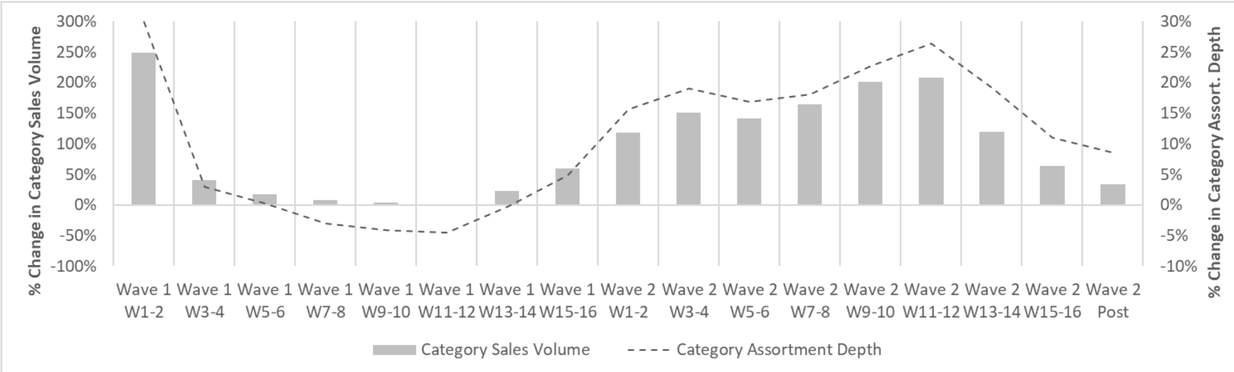
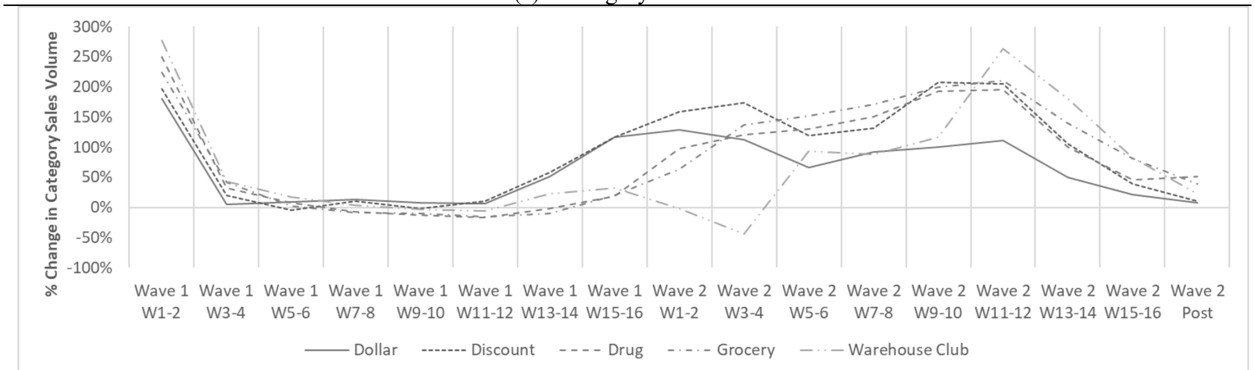


Figure 5: Percentage change in category sales volume and assortment depth during the first and second waves of swine flu pandemic with respect to the 2008-2009 epidemic

(based Model 2.1 of Table 3 and Model 3.1 of Table 4)

Figure 6 illustrates the percentage changes in category sales volume and assortment depth of hand sanitizer by retail format. In these figures, changes are measured with respect to the base case, the 2008-2009 seasonal flu epidemic. We find substantial differences across formats in sales and assortment during the pandemic waves. Compared to other retail formats, warehouse clubs and drug stores experienced the highest sales increases following the emergency declaration (W1-W2). For example, we observe that sales at warehouse clubs and drug stores were higher by 278% and 250%, respectively, compared to the 2008-2009 seasonal flu epidemic. Overall, the sales volume surge at warehouse clubs and drug stores indicates significant consumer purchasing at stores with either large pack-size products (i.e., the club stores) or with broad assortments of hand sanitizer (i.e., drug stores).

(a) Category Sales Volume



(b) Category Assortment Depth

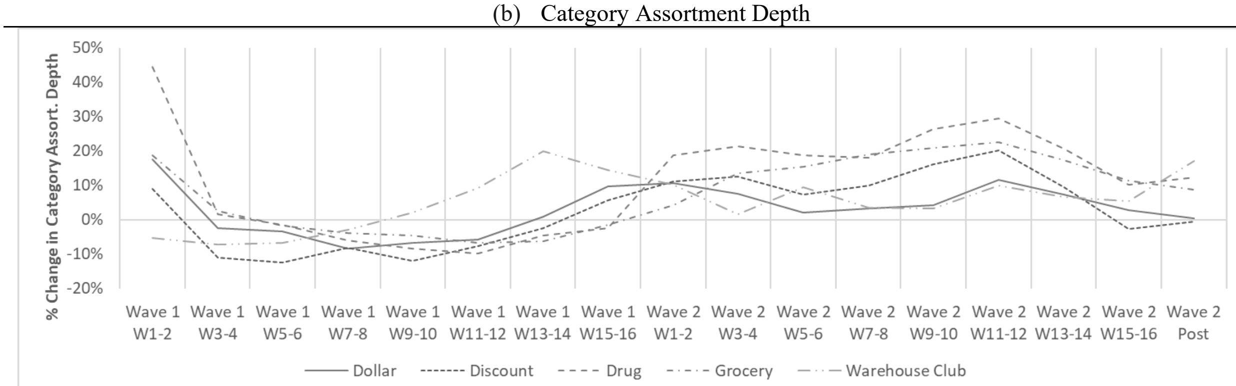


Figure 6: Percentage change in category sales volume and assortment depth by retail format during the first and second waves of swine flu pandemic with respect to the 2008-2009 epidemic

(based on Models 2.2-2.6 of Table 3 and Models 3.2-3.6 of Table 4)

In contrast to the other retail formats, drug stores employed a unique assortment strategy. During the first two weeks (W1-W2) of the first pandemic wave, their assortment depth was 45% higher than the assortment depth during the 2008-2009 seasonal flu epidemic. On the other hand, the assortment depth of the warehouse clubs was about 5% lower than the base case, while the assortment depth of the other retail formats was around 10%-20% higher than the base case.

After the initial demand surge, warehouse clubs were the first format to raise assortment depth above the pre-pandemic level (likely due to their low initial assortment levels), followed by dollar and discount stores, and then drug and grocery stores. We note that drug stores maintained high assortment levels throughout the second wave of the pandemic relative to the base case. The high drug store assortment depth may be attributed to their relationships with healthcare suppliers.[6]

In general, we observe that category sales volume is positively correlated with assortment depth within each retail format. Consistent with Sethuraman et al. (2022), our results show that during a crisis such as the swine flu pandemic, product assortment works in favor of increased sales; that is, carrying a larger assortment of UPCs is an effective way to generate higher sales for retailers.

[6] CVS Pharmacy Suppliers, https://cvssuppliers.com/, accessed March 2, 2021.

Table 3: Estimations results using Equation (2): category sales volume during pandemic waves

Dependent Variable	Category Sales Volume (OZ)					
	All Stores	**Dollar Store**	**Discount Store**	**Drug Store**	**Grocery Store**	**Warehouse Club**
	Model 2.1	Model 2.2	Model 2.3	Model 2.4	Model 2.5	Model 2.6
Swine Flu Pandemic						
First Wave						
$PANDEMIC\_WAVE1\_BIW1_{y,t}$	1.251*** (0.004)	1.031*** (0.009)	1.089*** (0.009)	1.252*** (0.006)	1.177*** (0.006)	1.329*** (0.034)
$PANDEMIC\_WAVE1\_BIW2_{y,t}$	0.340*** (0.004)	0.055*** (0.009)	0.186*** (0.009)	0.275*** (0.006)	0.346*** (0.006)	0.354*** (0.034)
$PANDEMIC\_WAVE1\_BIW3_{y,t}$	0.157*** (0.004)	0.091*** (0.009)	-0.042*** (0.009)	0.079*** (0.006)	0.026*** (0.006)	0.163*** (0.034)
$PANDEMIC\_WAVE1\_BIW4_{y,t}$	0.080*** (0.004)	0.128*** (0.009)	0.103*** (0.009)	-0.078*** (0.006)	-0.092*** (0.006)	0.035 (0.034)
$PANDEMIC\_WAVE1\_BIW5_{y,t}$	0.033*** (0.004)	0.080*** (0.009)	-0.024* (0.009)	-0.130*** (0.006)	-0.112*** (0.006)	-0.025 (0.033)
$PANDEMIC\_WAVE1\_BIW6_{y,t}$	0.004 (0.004)	0.058*** (0.009)	0.097*** (0.009)	-0.188*** (0.006)	-0.167*** (0.006)	-0.060* (0.033)
$PANDEMIC\_WAVE1\_BIW7_{y,t}$	0.202*** (0.004)	0.416*** (0.009)	0.456*** (0.009)	-0.016** (0.006)	-0.108*** (0.006)	0.200*** (0.033)
$PANDEMIC\_WAVE1\_BIW8_{y,t}$	0.466*** (0.004)	0.773*** (0.009)	0.771*** (0.009)	0.173*** (0.006)	0.177*** (0.006)	0.280*** (0.033)
Second Wave						
$PANDEMIC\_WAVE2\_BIW1_{y,t}$	0.781*** (0.004)	0.829*** (0.009)	0.952*** (0.009)	0.680*** (0.006)	0.488*** (0.006)	-0.013 (0.034)
$PANDEMIC\_WAVE2\_BIW2_{y,t}$	0.919*** (0.004)	0.755*** (0.009)	1.008*** (0.009)	0.793*** (0.006)	0.861*** (0.006)	-0.569*** (0.041)
$PANDEMIC\_WAVE2\_BIW3_{y,t}$	0.883*** (0.004)	0.510*** (0.009)	0.786*** (0.009)	0.833*** (0.006)	0.922*** (0.006)	0.663*** (0.034)
$PANDEMIC\_WAVE2\_BIW4_{y,t}$	0.971*** (0.004)	0.654*** (0.009)	0.841*** (0.009)	0.921*** (0.006)	0.995*** (0.006)	0.634*** (0.034)
$PANDEMIC\_WAVE2\_BIW5_{y,t}$	1.103*** (0.004)	0.692*** (0.009)	1.123*** (0.009)	1.073*** (0.006)	1.098*** (0.006)	0.775*** (0.035)
$PANDEMIC\_WAVE2\_BIW6_{y,t}$	1.126*** (0.004)	0.750*** (0.009)	1.115*** (0.009)	1.082*** (0.006)	1.134*** (0.006)	1.289*** (0.033)
$PANDEMIC\_WAVE2\_BIW7_{y,t}$	0.786*** (0.004)	0.405*** (0.009)	0.719*** (0.009)	0.696*** (0.006)	0.873*** (0.006)	1.030*** (0.033)
$PANDEMIC\_WAVE2\_BIW8_{y,t}$	0.493*** (0.004)	0.193*** (0.009)	0.329*** (0.009)	0.375*** (0.006)	0.594*** (0.006)	0.599*** (0.033)
Post Second Wave						
$PANDEMIC\_WAVE2\_POST_{y,t}$	0.293*** (0.002)	0.080*** (0.006)	0.097*** (0.005)	0.410*** (0.004)	0.326*** (0.003)	0.200*** (0.021)
Seasonal Flu Epidemic						
$EPIDEMIC\_1011_{y,t}$	0.245*** (0.001)	-0.071*** (0.003)	0.167*** (0.003)	0.332*** (0.002)	0.315*** (0.002)	-0.060*** (0.011)
$EPIDEMIC\_1112_{y,t}$	0.109*** (0.001)	-0.037*** (0.003)	-0.045*** (0.003)	0.186*** (0.002)	0.153*** (0.002)	-0.036** (0.012)
$EPIDEMIC\_1213_{y,t}$	0.096*** (0.001)	0.014*** (0.003)	-0.132*** (0.003)	0.096*** (0.002)	0.237*** (0.002)	-0.043*** (0.012)
$EPIDEMIC\_1314_{y,t}$	-0.007*** (0.001)	-0.146*** (0.003)	-0.177*** (0.004)	-0.002 (0.002)	0.132*** (0.002)	-0.175*** (0.013)
$EPIDEMIC\_1415_{y,t}$	0.066*** (0.001)	-0.102*** (0.003)	-0.050*** (0.004)	0.038*** (0.002)	0.256*** (0.002)	-0.038** (0.014)
$EPIDEMIC\_1516_{y,t}$	0.004** (0.002)	-0.025*** (0.004)	-0.104*** (0.004)	-0.145*** (0.002)	0.174*** (0.003)	-0.223*** (0.015)
$EPIDEMIC\_1617_{y,t}$	0.021*** (0.002)	0.010** (0.004)	-0.098*** (0.005)	-0.076*** (0.003)	0.195*** (0.003)	-0.359*** (0.017)
Control Variables	Included	Included	Included	Included	Included	Included
Constant	4.265*** (0.027)	3.050*** (0.085)	5.275*** (0.058)	3.086*** (0.045)	3.734*** (0.047)	13.013*** (1.224)
Observations	9,943,324	2,188,015	1,016,712	3,800,491	2,876,549	61,557
R_Square	0.744	0.558	0.875	0.727	0.690	0.647

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001

Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

Table 4: Estimations results using Equation (2): assortment depth during pandemic waves

	Category Assortment Depth (UPCs)					
	All Stores	**Dollar Store**	**Discount Store**	**Drug Store**	**Grocery Store**	**Warehouse Club**
	Model 3.1	Model 3.2	Model 3.3	Model 3.4	Model 3.5	Model 3.6
Swine Flu Pandemic						
First Wave						
$PANDEMIC\_WAVE1\_BIW1_{y,t}$	0.262*** (0.001)	0.162*** (0.003)	0.087*** (0.003)	0.369*** (0.002)	0.172*** (0.002)	-0.055*** (0.009)
$PANDEMIC\_WAVE1\_BIW2_{y,t}$	0.029*** (0.001)	-0.024*** (0.003)	-0.115*** (0.003)	0.016*** (0.002)	0.026*** (0.002)	-0.073*** (0.010)
$PANDEMIC\_WAVE1\_BIW3_{y,t}$	0.003* (0.001)	-0.033*** (0.003)	-0.132*** (0.003)	-0.014*** (0.002)	-0.018*** (0.002)	-0.070*** (0.010)
$PANDEMIC\_WAVE1\_BIW4_{y,t}$	-0.030*** (0.001)	-0.088*** (0.003)	-0.085*** (0.003)	-0.061*** (0.002)	-0.040*** (0.002)	-0.028** (0.010)
$PANDEMIC\_WAVE1\_BIW5_{y,t}$	-0.042*** (0.001)	-0.068*** (0.003)	-0.127*** (0.003)	-0.088*** (0.002)	-0.047*** (0.002)	0.022* (0.009)
$PANDEMIC\_WAVE1\_BIW6_{y,t}$	-0.046*** (0.001)	-0.058*** (0.003)	-0.080*** (0.003)	-0.102*** (0.002)	-0.070*** (0.002)	0.089*** (0.009)
$PANDEMIC\_WAVE1\_BIW7_{y,t}$	-0.003* (0.001)	0.010*** (0.003)	-0.025*** (0.003)	-0.047*** (0.002)	-0.065*** (0.002)	0.182*** (0.009)
$PANDEMIC\_WAVE1\_BIW8_{y,t}$	0.047*** (0.001)	0.093*** (0.003)	0.055*** (0.003)	-0.025*** (0.002)	-0.014*** (0.002)	0.136*** (0.009)
Second Wave						
$PANDEMIC\_WAVE2\_BIW1_{y,t}$	0.145*** (0.001)	0.101*** (0.003)	0.107*** (0.003)	0.172*** (0.002)	0.043*** (0.002)	0.097*** (0.010)
$PANDEMIC\_WAVE2\_BIW2_{y,t}$	0.174*** (0.001)	0.074*** (0.003)	0.118*** (0.003)	0.195*** (0.002)	0.128*** (0.002)	0.017 (0.012)
$PANDEMIC\_WAVE2\_BIW3_{y,t}$	0.156*** (0.001)	0.022*** (0.003)	0.072*** (0.003)	0.173*** (0.002)	0.144*** (0.002)	0.090*** (0.010)
$PANDEMIC\_WAVE2\_BIW4_{y,t}$	0.166*** (0.001)	0.032*** (0.003)	0.096*** (0.003)	0.166*** (0.002)	0.174*** (0.002)	0.036*** (0.010)
$PANDEMIC\_WAVE2\_BIW5_{y,t}$	0.205*** (0.001)	0.042*** (0.003)	0.149*** (0.003)	0.235*** (0.002)	0.191*** (0.002)	0.033** (0.010)
$PANDEMIC\_WAVE2\_BIW6_{y,t}$	0.234*** (0.001)	0.111*** (0.003)	0.184*** (0.003)	0.259*** (0.002)	0.203*** (0.002)	0.095*** (0.009)
$PANDEMIC\_WAVE2\_BIW7_{y,t}$	0.175*** (0.001)	0.071*** (0.003)	0.090*** (0.003)	0.188*** (0.002)	0.160*** (0.002)	0.065*** (0.009)
$PANDEMIC\_WAVE2\_BIW8_{y,t}$	0.104*** (0.001)	0.027*** (0.003)	-0.026*** (0.003)	0.098*** (0.002)	0.109*** (0.002)	0.054*** (0.009)
Post Second Wave						
$PANDEMIC\_WAVE2\_POST_{y,t}$	0.082*** (0.001)	0.005** (0.002)	-0.004* (0.002)	0.117*** (0.001)	0.085*** (0.001)	0.159*** (0.006)
Seasonal Flu Epidemic						
$EPIDEMIC\_1011_{y,t}$	0.062*** (0.000)	-0.015*** (0.001)	0.081*** (0.001)	0.051*** (0.001)	0.096*** (0.001)	0.349*** (0.003)
$EPIDEMIC\_1112_{y,t}$	-0.006*** (0.000)	-0.033*** (0.001)	0.082*** (0.001)	0.002** (0.001)	-0.025*** (0.001)	0.342*** (0.003)
$EPIDEMIC\_1213_{y,t}$	0.003*** (0.000)	0.033*** (0.001)	0.072*** (0.001)	-0.014*** (0.001)	-0.013*** (0.001)	0.301*** (0.003)
$EPIDEMIC\_1314_{y,t}$	0.022*** (0.000)	-0.033*** (0.001)	-0.009*** (0.001)	0.091*** (0.001)	-0.022*** (0.001)	0.294*** (0.004)
$EPIDEMIC\_1415_{y,t}$	0.052*** (0.001)	0.021*** (0.001)	0.094*** (0.001)	0.090*** (0.001)	0.008*** (0.001)	0.033*** (0.004)
$EPIDEMIC\_1516_{y,t}$	-0.018*** (0.001)	-0.085*** (0.001)	0.069*** (0.001)	-0.006*** (0.001)	-0.019*** (0.001)	0.063*** (0.004)
$EPIDEMIC\_1617_{y,t}$	-0.064*** (0.001)	-0.090*** (0.001)	-0.075*** (0.002)	-0.055*** (0.001)	-0.044*** (0.001)	0.080*** (0.005)
Control Variables	Included	Included	Included	Included	Included	Included
Constant	2.098*** (0.010)	1.663*** (0.026)	2.806*** (0.020)	1.812*** (0.017)	2.163*** (0.018)	0.871* (0.345)
Observations	9,943,324	2,188,015	1,016,712	3,800,491	2,876,549	61,557
R_Square	0.869	0.820	0.939	0.801	0.862	0.877

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001
Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

UPC unit price and average price paid

Figure 7 shows changes in UPC unit price and average price paid over the two waves of the pandemic. The first wave resulted in a price spike that slowly diminished over time, completely disappearing by the end of the first wave. During the first two weeks of the first wave, UPC prices held at levels about 2.6% above prices during the 2008-2009 seasonal flu epidemic. Once the second wave hit, UPC unit prices decreased to levels as low as 7.5% below the base case levels.

The average price paid for sanitizer showed greater fluctuations than UPC prices. During the first wave of the pandemic, average prices were about 6% above the base level. A possible explanation for the higher average prices (relative to UPC prices) is the substitution effect due to stockouts of the least expensive items in the product category. Indeed, average price paid dramatically dropped below the base case level throughout the second wave, with prices as low as 15% below the base case. Presumably, supply chains recovered and allowed for renewed supplies at retail outlets. These results may be further linked to the portfolio of sanitizer products, as elaborated in §5.

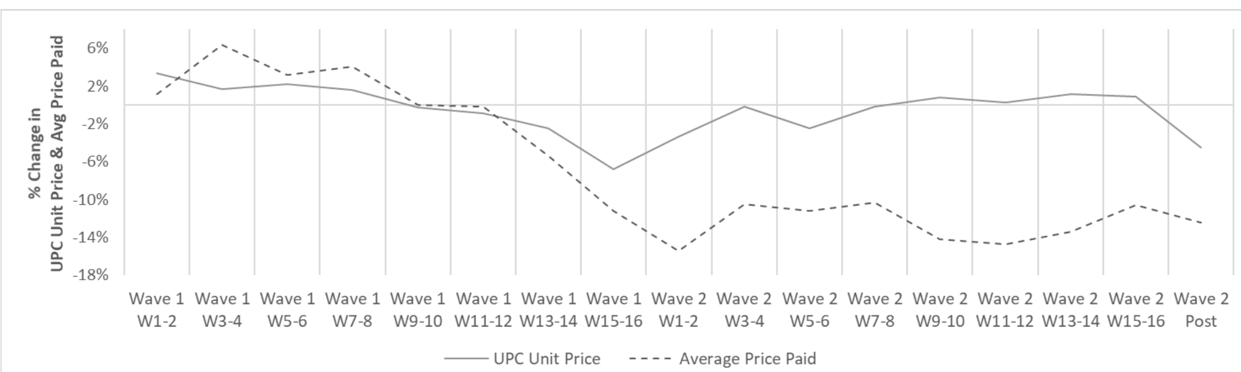


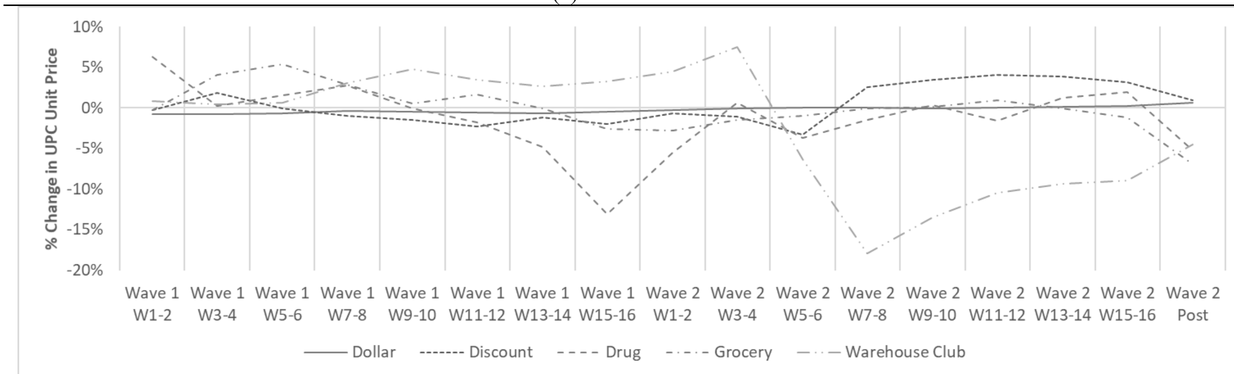
Figure 7: Percentage change in UPC unit price and average price paid during the first and second waves of swine flu pandemic with respect to the 2008-2009 epidemic

(based on Model 4.1 of Table 5 and Model 5.1 of Table 6)

Figure 8 illustrates changes in UPC unit price and average price paid for hand sanitizer at each retail format with respect to the base case, the 2008-2009 seasonal flu epidemic. While dollar stores kept UPC unit prices relatively steady during the pandemic, stores in other retail formats varied their UPC unit prices throughout the pandemic. For example, grocery stores increased their UPC prices to about 5% above the base case during the first six weeks of the first wave; drug stores' UPC prices exhibited the highest percentage increase above the base case during the first two weeks of the first wave, but quickly dropped to at or below the base level. For most retail formats, such as the dollar, discount, drug, and grocery stores, the changes in average price paid were more gradual than the changes in the UPC prices, reflecting consumers' ability to substitute products.

Warehouse club UPC prices experienced larger swings during the two pandemic waves, and consumers paid significantly higher average prices for hand sanitizer, almost 80% higher than the base case, during the third and fourth weeks of the second wave. Since warehouse clubs carry relatively small product assortments, small changes to assortment size (e.g., due to a stockout of a low-priced product) may result in significant fluctuations to both the UPC price and the price paid by consumers.

(a) UPC Unit Price



(b) Average Price Paid

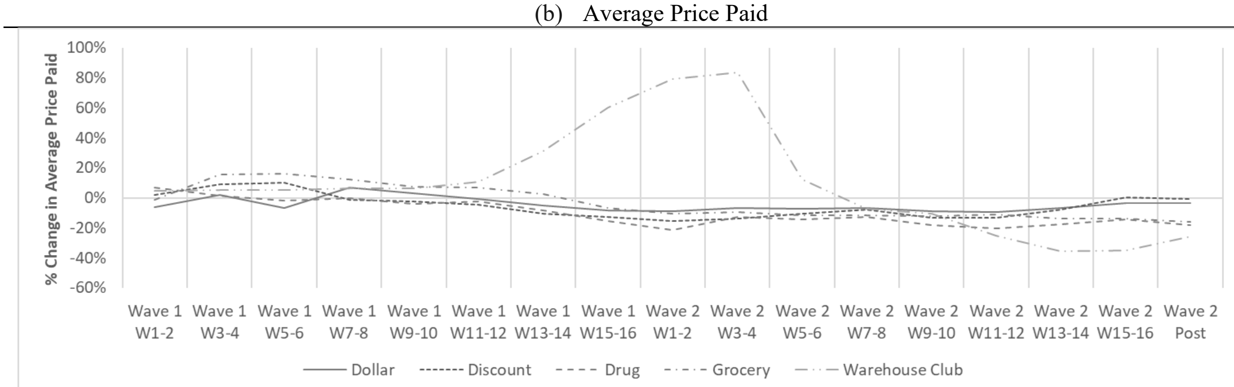
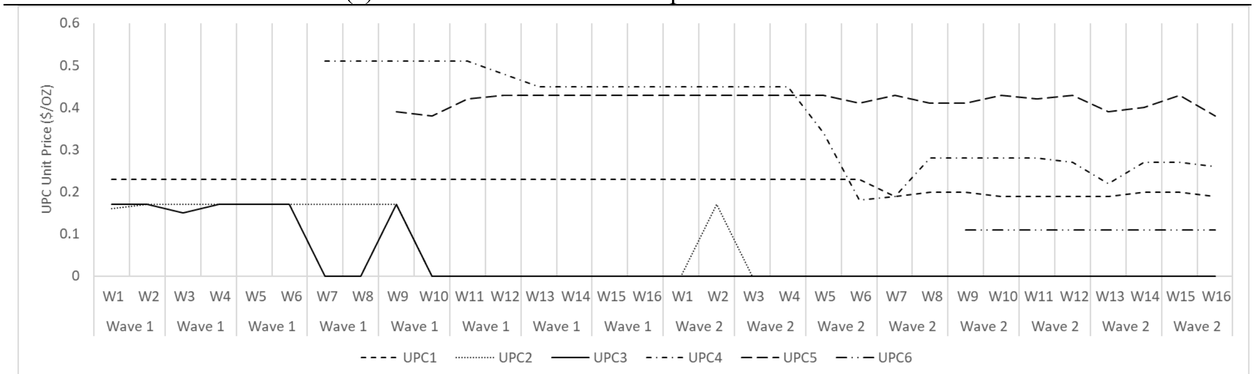


Figure 8: Percentage change in UPC unit price and average price paid during the first and second waves of the swine flu pandemic with respect to the 2008-2009 epidemic by retail format

(based on Models 4.2-4.6 of Table 5 and Models 5.2-5.6 of Table 6)

As a case example, Figure 9 demonstrates the UPC unit price and UPC sales volume of an assortment of six products carried by a sample warehouse club chain during the 2009-2010 swine flu pandemic (first and second waves). A zero UPC price or zero sales volume indicates either a stockout or absence of the product in the assortment. We observe that the warehouse club kept the UPC price of each product relatively constant (except for UPC4, whose price decreased after week 6 of the second wave). The sales volume at this warehouse club chain was mainly driven by UPC1. But from week 7 of the first wave to week 4 of the second wave, the sample warehouse club chain experienced significant stockouts of the lower-priced product, UPC2. Consequently, the chain introduced higher-priced alternatives, UPC4 and UPC5, before restocking UPC2 at the beginning of the second week. These product substitutions contributed to the price fluctuations in hand sanitizer products at the warehouse club chain.

(a) UPC Unit Prices in a Sample Warehouse Club Chain



(b) UPC Sales Volume in a Sample Warehouse Club Chain

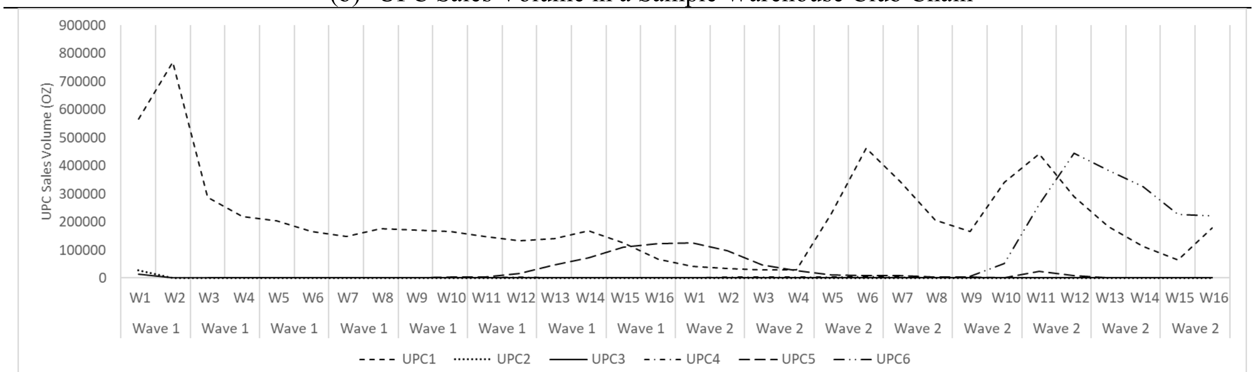


Figure 9: Weekly UPC unit price and sales volume at a sample warehouse club chain during 1st and 2nd waves of swine flu pandemic

In summary, we find that retailers adjusted their pricing strategies as pandemic progressed from the first wave, the second wave, to the post-pandemic period. Although the first wave resulted in a spike in UPC unit prices, the average price paid dramatically dropped throughout the second wave.

Table 5: Estimations results using Equation (2): UPC Unit Price during pandemic waves

Dependent Variable	UPC Unit Price ($/OZ)					
	All Stores	**Dollar Store**	**Discount Store**	**Drug Store**	**Grocery Store**	**Warehouse Club**
	Model 4.1	Model 4.2	Model 4.3	Model 4.4	Model 4.5	Model 4.6
Swine Flu Pandemic						
First Wave						
$PANDEMIC\_WAVE1\_BIW1_{y,t}$	0.033*** (0.001)	-0.008*** (0.001)	-0.003*** (0.001)	0.061*** (0.001)	-0.003*** (0.001)	0.008* (0.004)
$PANDEMIC\_WAVE1\_BIW2_{y,t}$	0.017*** (0.001)	-0.008*** (0.001)	0.018*** (0.001)	0.002 (0.001)	0.040*** (0.001)	0.004 (0.004)
$PANDEMIC\_WAVE1\_BIW3_{y,t}$	0.022*** (0.001)	-0.007*** (0.001)	-0.001 (0.001)	0.015*** (0.001)	0.052*** (0.001)	0.006 (0.004)
$PANDEMIC\_WAVE1\_BIW4_{y,t}$	0.016*** (0.001)	-0.004*** (0.001)	-0.010*** (0.001)	0.027*** (0.001)	0.028*** (0.001)	0.030*** (0.004)
$PANDEMIC\_WAVE1\_BIW5_{y,t}$	-0.003*** (0.001)	-0.005*** (0.001)	-0.015*** (0.001)	-0.001 (0.001)	0.005*** (0.001)	0.047*** (0.004)
$PANDEMIC\_WAVE1\_BIW6_{y,t}$	-0.009*** (0.001)	-0.006*** (0.001)	-0.023*** (0.001)	-0.018*** (0.001)	0.016*** (0.001)	0.034*** (0.004)
$PANDEMIC\_WAVE1\_BIW7_{y,t}$	-0.025*** (0.001)	-0.007*** (0.001)	-0.012*** (0.001)	-0.049*** (0.001)	-0.001 (0.001)	0.026*** (0.003)
$PANDEMIC\_WAVE1\_BIW8_{y,t}$	-0.070*** (0.001)	-0.005*** (0.001)	-0.020*** (0.001)	-0.140*** (0.001)	-0.026*** (0.001)	0.032*** (0.004)
Second Wave						
$PANDEMIC\_WAVE2\_BIW1_{y,t}$	-0.034*** (0.001)	-0.003*** (0.001)	-0.007*** (0.001)	-0.057*** (0.001)	-0.028*** (0.001)	0.044*** (0.004)
$PANDEMIC\_WAVE2\_BIW2_{y,t}$	-0.002* (0.001)	-0.001 (0.001)	-0.011*** (0.001)	0.006*** (0.001)	-0.015*** (0.001)	0.072*** (0.005)
$PANDEMIC\_WAVE2\_BIW3_{y,t}$	-0.025*** (0.001)	0.000 (0.001)	-0.034*** (0.001)	-0.038*** (0.001)	-0.010*** (0.001)	-0.065*** (0.004)
$PANDEMIC\_WAVE2\_BIW4_{y,t}$	-0.002** (0.001)	-0.000 (0.001)	0.025*** (0.001)	-0.015*** (0.001)	-0.001 (0.001)	-0.197*** (0.004)
$PANDEMIC\_WAVE2\_BIW5_{y,t}$	0.008*** (0.001)	-0.001 (0.001)	0.034*** (0.001)	0.003* (0.001)	0.001 (0.001)	-0.145*** (0.004)
$PANDEMIC\_WAVE2\_BIW6_{y,t}$	0.003*** (0.001)	-0.000 (0.001)	0.040*** (0.001)	-0.016*** (0.001)	0.009*** (0.001)	-0.110*** (0.003)
$PANDEMIC\_WAVE2\_BIW7_{y,t}$	0.011*** (0.001)	0.001 (0.001)	0.038*** (0.001)	0.012*** (0.001)	-0.001 (0.001)	-0.098*** (0.003)
$PANDEMIC\_WAVE2\_BIW8_{y,t}$	0.009*** (0.001)	0.002** (0.001)	0.031*** (0.001)	0.019*** (0.001)	-0.012*** (0.001)	-0.094*** (0.003)
Post Second Wave						
$PANDEMIC\_WAVE2\_POST_{y,t}$	-0.046*** (0.000)	0.006*** (0.001)	0.009*** (0.000)	-0.054*** (0.001)	-0.072*** (0.000)	-0.046*** (0.002)
Seasonal Flu Epidemic						
$EPIDEMIC\_1011_{y,t}$	-0.105*** (0.000)	-0.039*** (0.000)	-0.014*** (0.000)	-0.142*** (0.000)	-0.108*** (0.000)	-0.056*** (0.001)
$EPIDEMIC\_1112_{y,t}$	-0.107*** (0.000)	-0.063*** (0.000)	-0.006*** (0.000)	-0.162*** (0.001)	-0.095*** (0.000)	-0.088*** (0.002)
$EPIDEMIC\_1213_{y,t}$	-0.056*** (0.000)	-0.038*** (0.000)	-0.013*** (0.000)	-0.026*** (0.001)	-0.103*** (0.000)	-0.092*** (0.002)
$EPIDEMIC\_1314_{y,t}$	-0.046*** (0.000)	0.015*** (0.000)	-0.057*** (0.000)	0.010*** (0.001)	-0.093*** (0.000)	-0.098*** (0.002)
$EPIDEMIC\_1415_{y,t}$	-0.041*** (0.000)	0.076*** (0.000)	-0.016*** (0.000)	-0.005*** (0.001)	-0.091*** (0.000)	-0.101*** (0.002)
$EPIDEMIC\_1516_{y,t}$	-0.035*** (0.000)	0.026*** (0.000)	0.020*** (0.000)	0.015*** (0.001)	-0.096*** (0.000)	-0.089*** (0.002)
$EPIDEMIC\_1617_{y,t}$	-0.066*** (0.000)	0.042*** (0.000)	-0.037*** (0.000)	-0.029*** (0.001)	-0.108*** (0.001)	-0.092*** (0.002)
Control Variables	Included	Included	Included	Included	Included	Included
Constant	0.147*** (0.038)	-0.782*** (0.009)	-0.865*** (0.159)	0.105 (0.117)	0.225*** (0.030)	-2.456*** (0.114)
Observations	5,4701,943	5,409,453	11,674,482	22,664,621	14,823,160	130,227
R_Square	0.843	0.962	0.951	0.755	0.910	0.970

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001
Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

Table 6: Estimations results using Equation (2): average price paid during pandemic waves

	Average Price Paid ($/OZ)					
	All Stores	**Dollar Store**	**Discount Store**	**Drug Store**	**Grocery Store**	**Warehouse Club**
	Model 5.1	Model 5.2	Model 5.3	Model 5.4	Model 5.5	Model 5.6
Swine Flu Pandemic						
First Wave						
$PANDEMIC\_WAVE1\_BIW1_{y,t}$	0.011*** (0.002)	-0.063*** (0.004)	0.019*** (0.005)	0.069*** (0.003)	-0.013*** (0.003)	0.045*** (0.008)
$PANDEMIC\_WAVE1\_BIW2_{y,t}$	0.062*** (0.002)	0.019*** (0.004)	0.087*** (0.005)	0.016*** (0.003)	0.145*** (0.003)	0.052*** (0.008)
$PANDEMIC\_WAVE1\_BIW3_{y,t}$	0.031*** (0.002)	-0.069*** (0.004)	0.097*** (0.005)	-0.020*** (0.003)	0.150*** (0.003)	0.054*** (0.008)
$PANDEMIC\_WAVE1\_BIW4_{y,t}$	0.040*** (0.002)	0.068*** (0.004)	-0.014** (0.005)	-0.002 (0.003)	0.117*** (0.003)	0.061*** (0.008)
$PANDEMIC\_WAVE1\_BIW5_{y,t}$	0.000 (0.002)	0.029*** (0.004)	-0.023*** (0.005)	-0.043*** (0.003)	0.072*** (0.003)	0.064*** (0.008)
$PANDEMIC\_WAVE1\_BIW6_{y,t}$	-0.002 (0.002)	-0.005 (0.004)	-0.045*** (0.005)	-0.024*** (0.003)	0.069*** (0.003)	0.102*** (0.008)
$PANDEMIC\_WAVE1\_BIW7_{y,t}$	-0.055*** (0.002)	-0.051*** (0.004)	-0.111*** (0.005)	-0.089*** (0.003)	0.028*** (0.003)	0.274*** (0.008)
$PANDEMIC\_WAVE1\_BIW8_{y,t}$	-0.119*** (0.002)	-0.088*** (0.004)	-0.137*** (0.005)	-0.167*** (0.003)	-0.071*** (0.003)	0.472*** (0.008)
Second Wave						
$PANDEMIC\_WAVE2\_BIW1_{y,t}$	-0.168*** (0.002)	-0.093*** (0.004)	-0.170*** (0.005)	-0.242*** (0.003)	-0.113*** (0.003)	0.583*** (0.008)
$PANDEMIC\_WAVE2\_BIW2_{y,t}$	-0.111*** (0.002)	-0.072*** (0.004)	-0.149*** (0.005)	-0.137*** (0.003)	-0.097*** (0.003)	0.607*** (0.010)
$PANDEMIC\_WAVE2\_BIW3_{y,t}$	-0.119*** (0.002)	-0.074*** (0.004)	-0.113*** (0.005)	-0.153*** (0.003)	-0.122*** (0.003)	0.117*** (0.008)
$PANDEMIC\_WAVE2\_BIW4_{y,t}$	-0.109*** (0.002)	-0.070*** (0.004)	-0.080*** (0.005)	-0.136*** (0.003)	-0.121*** (0.003)	-0.074*** (0.008)
$PANDEMIC\_WAVE2\_BIW5_{y,t}$	-0.153*** (0.002)	-0.093*** (0.004)	-0.142*** (0.005)	-0.203*** (0.003)	-0.132*** (0.003)	-0.111*** (0.008)
$PANDEMIC\_WAVE2\_BIW6_{y,t}$	-0.159*** (0.002)	-0.097*** (0.004)	-0.139*** (0.005)	-0.230*** (0.003)	-0.119*** (0.003)	-0.292*** (0.008)
$PANDEMIC\_WAVE2\_BIW7_{y,t}$	-0.144*** (0.002)	-0.068*** (0.004)	-0.080*** (0.005)	-0.195*** (0.003)	-0.150*** (0.003)	-0.439*** (0.008)
$PANDEMIC\_WAVE2\_BIW8_{y,t}$	-0.112*** (0.002)	-0.032*** (0.004)	0.006 (0.005)	-0.154*** (0.003)	-0.146*** (0.003)	-0.429*** (0.008)
Post Second Wave						
$PANDEMIC\_WAVE2\_POST_{y,t}$	-0.133*** (0.001)	-0.037*** (0.002)	-0.009*** (0.003)	-0.202*** (0.002)	-0.174*** (0.002)	-0.297*** (0.005)
Seasonal Flu Epidemic						
$EPIDEMIC\_1011_{y,t}$	-0.224*** (0.001)	0.004** (0.001)	-0.136*** (0.002)	-0.352*** (0.001)	-0.229*** (0.001)	0.026*** (0.003)
$EPIDEMIC\_1112_{y,t}$	-0.219*** (0.001)	-0.019*** (0.001)	0.010*** (0.002)	-0.354*** (0.001)	-0.238*** (0.001)	0.157*** (0.003)
$EPIDEMIC\_1213_{y,t}$	-0.145*** (0.001)	0.095*** (0.001)	0.051*** (0.002)	-0.217*** (0.001)	-0.270*** (0.001)	0.170*** (0.003)
$EPIDEMIC\_1314_{y,t}$	-0.130*** (0.001)	0.006*** (0.001)	-0.018*** (0.002)	-0.144*** (0.001)	-0.235*** (0.001)	0.179*** (0.003)
$EPIDEMIC\_1415_{y,t}$	-0.126*** (0.001)	0.044*** (0.001)	0.038*** (0.002)	-0.152*** (0.001)	-0.258*** (0.001)	0.041*** (0.003)
$EPIDEMIC\_1516_{y,t}$	-0.194*** (0.001)	-0.173*** (0.002)	-0.005* (0.002)	-0.128*** (0.001)	-0.296*** (0.001)	0.029*** (0.004)
$EPIDEMIC\_1617_{y,t}$	-0.243*** (0.001)	-0.198*** (0.002)	-0.001 (0.003)	-0.213*** (0.001)	-0.338*** (0.001)	0.020*** (0.004)
Control Variables	Included	Included	Included	Included	Included	Included
Constant	-1.023*** (0.014)	-1.099*** (0.038)	-0.911*** (0.032)	-0.354*** (0.024)	-0.774*** (0.024)	-2.312*** (0.289)
Observations	9,943,324	2,188,015	1,016,712	3,800,491	2,876,549	61,557
R_Square	0.843	0.085	0.161	0.209	0.278	0.621

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001

Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

6 Product substitution of large and small pack sizes

To gain deeper insight into consumer behavior and retail operations during the swine flu pandemic and subsequent seasonal flu seasons, we split sanitizer sales into large and small pack sizes. For simplicity, we distinguish between large and small pack sizes at the mean package size of 6 ounces. As expected, the average UPC unit price of small-packs at $0.92/OZ is considerably higher than the average large-pack unit price at $0.28/OZ, reflecting a premium for small containers.

Table 7 presents regression results with dependent variables for category sales volume of small-pack and large-pack products. Figure 10 demonstrates how sales patterns changed over time with respect to the 2008-2009 seasonal flu epidemic. Specifically, we observe that the pandemic recorded a spike in sales for both small and large size packs, with clear gravitation toward larger packs (reflected by the 43% increase in large-pack sales versus the 24% increase in small-pack sales). Large-pack sales steadily declined relative to the base case during subsequent flu epidemics and were below the base case by the 2015-2016 flu epidemic.

On closer inspection, the 43% and 24% spikes in large and small pack-size sales, respectively, were not uniformly experienced during the swine flu pandemic. Figure 11 illustrates the dynamics of sales during the pandemic. During the first wave, small pack-size sales dominated, but during the second wave, large packs dominated. At the beginning of the pandemic, in the first two weeks following the CDC public health emergency declaration, sales of large-pack sanitizer were 55% higher than during the 2008-2009 seasonal flu epidemic. Sales of small-pack hand sanitizer, however, were staggeringly 138% higher. As the emergency progressed, sales of large-pack and small-pack hand sanitizer quickly declined to base case levels. As the second wave unfolded, sales of both large and small-pack hand sanitizer again quickly increased; yet with one key difference: sales shifted heavily to the cheaper large-pack hand sanitizer. The price disparity between the large and small size packs clearly contributed to the decline in average price paid during the second wave of the pandemic. Further, this analysis suggests that in the face of rising consumer demand, retailers may have rationed large-pack inventories early during the first wave. Finally, warehouse clubs that specialize in large pack sizes may have been a major beneficiary of changing customer preference towards the large pack sizes.

Table 7: Estimation results using Equation (1) and Equation (2): product substitution during first and second waves of swine flu pandemic

Dependent Variable	Category Sales Volume (OZ)			
	Small Pack	**Big Pack**	**Small Pack**	**Big Pack**
	Model 6.1	Model 6.2	Model 7.1	Model 7.2
Swine Flu Pandemic				
$PANDEMIC\_0910_{y,t}$	0.214*** (0.001)	0.357*** (0.001)		
First Wave				
$PANDEMIC\_WAVE1\_BIW1_{y,t}$			0.869*** (0.003)	0.439*** (0.004)
$PANDEMIC\_WAVE1\_BIW2_{y,t}$			0.368*** (0.003)	0.217*** (0.004)
$PANDEMIC\_WAVE1\_BIW3_{y,t}$			0.184*** (0.003)	0.211*** (0.004)
$PANDEMIC\_WAVE1\_BIW4_{y,t}$			0.223*** (0.003)	0.122*** (0.004)
$PANDEMIC\_WAVE1\_BIW5_{y,t}$			0.104*** (0.003)	0.153*** (0.004)
$PANDEMIC\_WAVE1\_BIW6_{y,t}$			0.042*** (0.003)	0.122*** (0.004)
$PANDEMIC\_WAVE1\_BIW7_{y,t}$			0.081*** (0.003)	0.267*** (0.004)
$PANDEMIC\_WAVE1\_BIW8_{y,t}$			0.133*** (0.003)	0.430*** (0.004)
Second Wave				
$PANDEMIC\_WAVE2\_BIW1_{y,t}$			0.279*** (0.003)	0.544*** (0.004)
$PANDEMIC\_WAVE2\_BIW2_{y,t}$			0.476*** (0.003)	0.635*** (0.004)
$PANDEMIC\_WAVE2\_BIW3_{y,t}$			0.443*** (0.003)	0.629*** (0.004)
$PANDEMIC\_WAVE2\_BIW4_{y,t}$			0.443*** (0.003)	0.677*** (0.004)
$PANDEMIC\_WAVE2\_BIW5_{y,t}$			0.473*** (0.003)	0.713*** (0.004)
$PANDEMIC\_WAVE2\_BIW6_{y,t}$			0.453*** (0.003)	0.702*** (0.004)
$PANDEMIC\_WAVE2\_BIW7_{y,t}$			0.321*** (0.003)	0.621*** (0.004)
$PANDEMIC\_WAVE2\_BIW8_{y,t}$			0.215*** (0.003)	0.485*** (0.004)
Post Second Wave				
$PANDEMIC\_WAVE2\_POST_{y,t}$			0.099*** (0.001)	0.272*** (0.002)
Seasonal Flu Epidemic				
$EPIDEMIC\_1011_{y,t}$	-0.055*** (0.001)	0.291*** (0.002)	-0.055*** (0.001)	0.292*** (0.002)
$EPIDEMIC\_1112_{y,t}$	-0.071*** (0.001)	0.100*** (0.002)	-0.074*** (0.001)	0.098*** (0.002)
$EPIDEMIC\_1213_{y,t}$	-0.121*** (0.001)	0.105*** (0.002)	-0.125*** (0.001)	0.103*** (0.002)
$EPIDEMIC\_1314_{y,t}$	-0.138*** (0.001)	0.038*** (0.002)	-0.146*** (0.001)	0.033*** (0.002)
$EPIDEMIC\_1415_{y,t}$	0.003* (0.001)	-0.005* (0.002)	-0.005*** (0.001)	-0.010*** (0.002)
$EPIDEMIC\_1516_{y,t}$	-0.038*** (0.002)	-0.077*** (0.002)	-0.050*** (0.002)	-0.085*** (0.002)
$EPIDEMIC\_1617_{y,t}$	-0.114*** (0.002)	-0.035*** (0.002)	-0.127*** (0.002)	-0.045*** (0.002)
Control Variables	Included	Included	Included	Included
Constant	2.615*** (0.027)	3.958*** (0.036)	2.563*** (0.027)	3.919*** (0.036)
Observations	9,943,324	9,943,324	9,943,324	9,943,324
R_Square	0.649	0.572	0.652	0.574

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001

Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

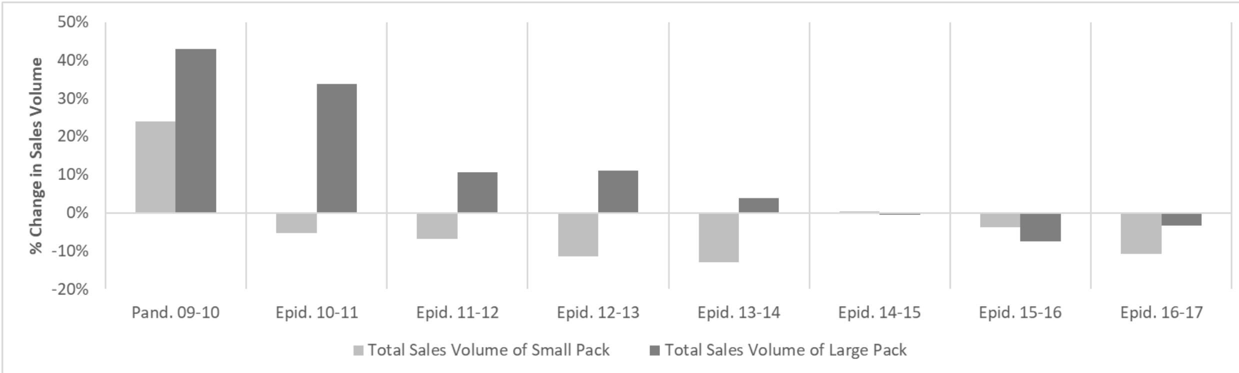


Figure 10: Percentage change in sales volume of small and large pack with respect to the 2008-2009 epidemic

(based on Models 6.1 and 6.2 of Table 7)

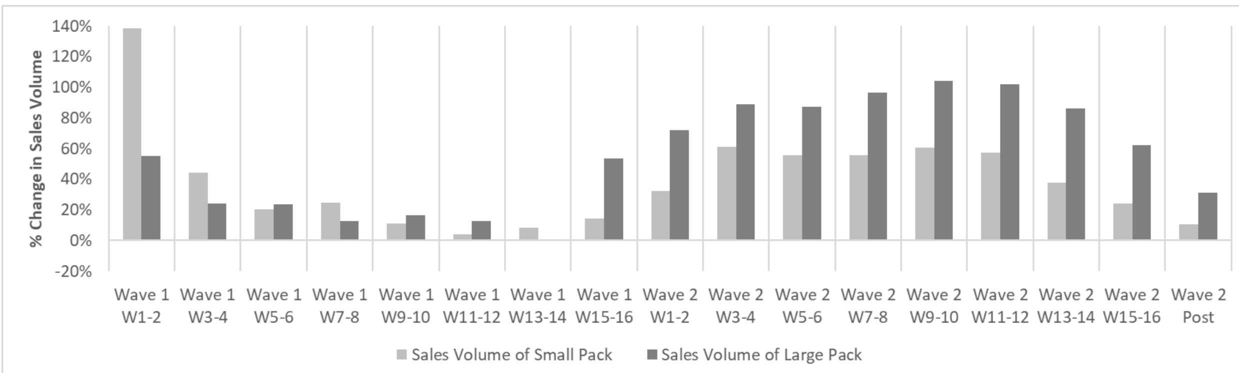


Figure 11: Percentage change in sales volume of small and large pack during waves of swine flu pandemic with respect to the 2008-2009 epidemic

(based on Models 7.1 and 7.2 of Table 7)

7 Robustness Checks

As a robustness check, we measure the level of flu activity using spread and severity at the state level instead of using biweekly dummies. In Equation (3), we estimate how flu activity impacted our dependent variables during seasonal flu epidemics and the swine flu pandemic, $\overline{\mathrm{FLU\_SEV\_LEVEL}}_{s,y,t}$ and $\overline{\mathrm{FLU\_GEO\_SPREAD}}_{s,y,t}$. Figure 2 illustrates the severity and spread during the swine flu pandemic. According to the CDC, flu severity includes four levels—minimal, low, moderate, and high, while flu spread includes five levels—no activity, sporadic, local, regional, and widespread. The CDC recorded flu activities for both seasonal flu epidemics and the swine flu pandemic. To identify the differences between seasonal flu epidemic and the swine flu pandemic, we use the swine flu pandemic season as the moderating variable in the estimation model.

$$
\begin{aligned}
&\mathrm{LN(X)} = \beta_0 \\
&+\beta_1 \cdot \mathrm{EPIDEMIC\_0809}_{y,t} \\
&+\beta_2 \cdot \mathrm{PANDEMIC\_0910}_{y,t} \\
&+\overline{\beta_3} \cdot \overline{\mathrm{EPIDEMIC\_POST}_{y,t}} \\
&+\overline{\beta_4} \cdot \overline{\mathrm{FLU\_SEV\_LEVEL}_{s,y,t}} \\
&+\overline{\beta_5} \cdot \overline{\mathrm{FLU\_SEV\_LEVEL}_{s,y,t}} \cdot \mathrm{PANDEMIC\_0910}_{y,t} \\
&+\overline{\beta_6} \cdot \overline{\mathrm{FLU\_GEO\_SPREAD}_{s,y,t}} \\
&+\overline{\beta_7} \cdot \overline{\mathrm{FLU\_GEO\_SPREAD}_{s,y,t}} \cdot \mathrm{PANDEMIC\_0910}_{y,t} \\
&+\beta_8 \cdot \mathrm{CAT\_SALES\_VOL\_ANNUAL}_{k,l,c,s,y} \\
&+\overline{\beta_9} \cdot \overline{\mathrm{MARKET\_COMP}_{k,l,c,s,y,t}} \\
&+\overline{\beta_{10}} \cdot \overline{\mathrm{RETAIL\_CHAIN\_NTW}_{k,l,c,s,y}} \\
&+\overline{\beta_{11}} \cdot \overline{\mathrm{COUNTY\_DEMO}_{c,y}} \\
&+\overline{\beta_{12}} \cdot \overline{\mathrm{COUNTY\_GEO}_{c,y}} \\
&+\beta_{13} \cdot \mathrm{PRICE\_GOUGING\_REG}_{s,y,t} \\
&+\overline{\beta_{14}} \cdot \overline{\mathrm{STATE\_FE}_{s}} \\
&+\overline{\beta_{15}} \cdot \overline{\mathrm{COUNTY\_FE}_{c}} \\
&+\overline{\beta_{16}} \cdot \overline{\mathrm{RETAIL\_CHAIN\_FE}_{l}} \\
&(+\overline{\beta_{17}} \cdot \overline{\mathrm{PRODUCT\_UPC\_FE}_{l}}) \\
&+\varepsilon_{i,k,l,c,s,t}
\end{aligned}
$$

Equation (3)

where

$$\overline{\mathrm{FLU\_SEV\_LEVEL}_{s,y,t}} = \{\mathrm{ILI\_MINIMAL}_{s,y,t}, \mathrm{ILI\_LOW}_{s,y,t}, \mathrm{ILI\_MOD}_{s,y.t}, \mathrm{ILI\_HIGH}_{s,y,t}\}$$

$$\overline{\mathrm{FLU\_GEO\_SPREAD}_{s,y,t}} = \{\mathrm{NO\_ACTY}_{s,y,t}, \mathrm{GEO\_SPORADIC}_{s,y,t}, \mathrm{GEO\_LOCAL}_{s,y,t}, \mathrm{GEO\_REGIONAL}_{s,y,t}, \mathrm{GEO\_WIDESPREAD}_{s,y,t}\}$$

In Table 8, we present the estimation results. For each dependent variable—category sales volume (Column 1), assortment depth (Column 2), UPC unit price (Column 3), and average price paid by consumers (Column 4)—we estimate the impact of flu activity levels during the swine flu pandemic and seasonal flu epidemics.

In Figure 12 and Figure 13, we illustrate the impact of flu severity and spread for the swine flu pandemic and the 2008-2009 seasonal flu epidemic at the category and UPC levels, respectively. Each figure is split into 4 panels, with each of the vertical panels focusing on a dependent variable (category sales volume, category assortment depth, UPC unit price, and average price paid) and each of the horizontal panels distinguishing between epidemic and pandemic results. Within each panel, we highlight the compound effects of flu spread (across the five relevant levels—no activity, sporadic, local, regional, and widespread) and flu severity (across the four relevant levels—minimal, low, moderate, and high) relative to the base case; that is, no flu spread and minimal severity levels for seasonal flu epidemics.

Figure 12 reveals the compound effects of the spread and severity of the flu on category sales volume and assortment depth. Consider Panels (a) and (c). Generally, the higher the geographic spread and the more severe the flu, the greater the impact on demand for hand sanitizer. With widespread flu and high severity, the combined effects tally to 161.7% greater sales volume during the pandemic than the base case (no flu activity and minimal flu spread during the preceding flu epidemic). The same high level of severity and widespread flu during the 2008-2009 flu epidemic only resulted in 10.8% greater sanitizer sales compared to the base case. Consider Panels (b) and (d). High flu severity was associated with retailers offering a slightly higher sanitizer assortment (about 3-4%) during the 2008-2009 epidemic, while spread appears to have little impact (Panel (b)). During the swine flu pandemic, the assortment offered by retailers increased with severity and spread. With widespread and high severity flu symptoms, the combined effects result in a 23.4% greater assortment compared to the seasonal flu epidemic base case (Panel (d)).

Figure 13 shows the compound impact of flu severity and spread on UPC unit price and average price paid by consumers during the 2008-2009 seasonal flu epidemic and the swine flu pandemic. As shown in Panels (a) and (c), impacts of severity and spread on UPC unit price during the 2008-2009 epidemic were negligible, while flu spread was associated with a significant increase in UPC-level price during the pandemic. However, even with high severity and widespread flu during the pandemic, UPC prices were about the same as UPC prices during the base case (no flu activity, minimal severity during the 2008-2009 flu season). Panels (b) and (d) show that during the 2008-2009 epidemic, there were only small changes in average price paid by consumers that could be attributed to the severity and spread of flu symptoms. On the other hand, the geographic spread of the pandemic had a significant, positive impact on average price paid, while the severity level, surprisingly, had a diminishing impact.

Table 8: Estimation results using Equation (3): Impact of flu severity level and geographic spread

Dependent Variable	Category Sales Volume (OZ)	Category Assortment Depth (UPCs)	UPC Unit Price ($/OZ)	Average Price Paid ($/OZ)
	Model 8.1	Model 8.2	Model 8.3	Model 8.4
Swine Flu Pandemic				
$PANDEMIC\_0910_{y,t}$	0.118*** (0.003)	0.035*** (0.001)	-0.080*** (0.001)	-0.158*** (0.002)
Seasonal Flu Epidemic				
$EPIDEMIC\_1011_{y,t}$	0.241*** (0.001)	0.061*** (0.000)	-0.103*** (0.001)	-0.225*** (0.001)
$EPIDEMIC\_1112_{y,t}$	0.124*** (0.001)	-0.003*** (0.000)	-0.105*** (0.001)	-0.219*** (0.001)
$EPIDEMIC\_1213_{y,t}$	0.084*** (0.001)	-0.001* (0.000)	-0.053*** (0.001)	-0.146*** (0.001)
$EPIDEMIC\_1314_{y,t}$	-0.004** (0.001)	0.022*** (0.000)	-0.044*** (0.001)	-0.131*** (0.001)
$EPIDEMIC\_1415_{y,t}$	0.061*** (0.001)	0.049*** (0.001)	-0.039*** (0.001)	-0.127*** (0.001)
$EPIDEMIC\_1516_{y,t}$	0.016*** (0.002)	-0.017*** (0.001)	-0.033*** (0.001)	-0.194*** (0.001)
$EPIDEMIC\_1617_{y,t}$	0.019*** (0.002)	-0.066*** (0.001)	-0.064*** (0.001)	-0.243*** (0.001)
Flu Severity Level				
$ILI\_LOW_{s,y,t}$	0.037*** (0.001)	0.009*** (0.000)	-0.000* (0.000)	0.003*** (0.001)
$ILI\_MOD_{s,y,t}$	0.089*** (0.001)	0.022*** (0.000)	-0.005*** (0.000)	-0.010*** (0.001)
$ILI\_HIGH_{s,y,t}$	0.132*** (0.001)	0.036*** (0.000)	-0.004*** (0.000)	0.000 (0.001)
$ILI\_LOW_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.157*** (0.003)	0.051*** (0.001)	0.004*** (0.000)	-0.046*** (0.001)
$ILI\_MOD_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.164*** (0.003)	0.056*** (0.001)	0.009*** (0.000)	-0.041*** (0.002)
$ILI\_HIGH_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.382*** (0.003)	0.094*** (0.001)	0.013*** (0.000)	-0.097*** (0.001)
Flu Geographic Spread				
$GEO\_SPORADIC_{s,y,t}$	-0.049*** (0.001)	-0.015*** (0.000)	0.001*** (0.000)	0.010*** (0.001)
$GEO\_LOCAL_{s,y,t}$	-0.073*** (0.001)	-0.023*** (0.000)	0.002*** (0.000)	0.018*** (0.001)
$GEO\_REGIONAL_{s,y,t}$	-0.072*** (0.001)	-0.018*** (0.000)	0.003*** (0.000)	0.023*** (0.001)
$GEO\_WIDESPREAD_{s,y,t}$	-0.029*** (0.001)	-0.010*** (0.000)	0.001*** (0.000)	0.008*** (0.001)
$GEO\_SPORADIC_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.205*** (0.003)	0.039*** (0.001)	0.029*** (0.001)	0.026*** (0.002)
$GEO\_LOCAL_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.274*** (0.004)	0.033*** (0.001)	0.060*** (0.001)	0.087*** (0.002)
$GEO\_REGIONAL_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.319*** (0.004)	0.032*** (0.001)	0.062*** (0.001)	0.095*** (0.002)
$GEO\_WIDESPREAD_{s,y,t} \cdot PANDEMIC\_0910_{y,t}$	0.359*** (0.004)	0.029*** (0.001)	0.072*** (0.001)	0.132*** (0.002)
Control Variables	Included	Included	Included	Included
Constant	4.304*** (0.027)	2.102*** (0.010)	0.148*** (0.038)	-1.027*** (0.014)
Observations	9,943,324	9,943,324	54,701,943	9,943,324
R_Square	0.738	0.869	0.843	0.207

Note 1: The table shows estimated coefficients. Standard errors in parentheses. * p<0.1, ** p<0.01, *** p<0.001

Note 2: The base case is the 2008-2009 seasonal flu epidemic that preceded the 2009-2010 swine flu pandemic.

(a) Category Sales Volume (2008-2009 Seasonal Flu Epidemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	0.0%	-4.8%	-7.0%	-6.9%	-2.9%
Low	3.8%	-1.2%	-3.5%	-3.4%	0.8%
Moderate	9.3%	4.1%	1.6%	1.7%	6.2%
High	14.1%	8.7%	6.1%	6.2%	10.8%

(b) Category Assortment Depth (2008-2009 Seasonal Flu Epidemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	0.0%	-1.5%	-2.3%	-1.8%	-1.0%
Low	0.9%	-0.6%	-1.4%	-0.9%	-0.1%
Moderate	2.2%	0.7%	-0.1%	0.4%	1.2%
High	3.7%	2.1%	1.3%	1.8%	2.6%

(c) Category Sales Volume (2009-2010 Swine Flu Pandemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	12.5%	31.5%	37.6%	44.1%	56.5%
Low	36.6%	59.7%	67.0%	74.9%	90.0%
Moderate	44.9%	69.4%	77.2%	85.5%	101.6%
High	88.1%	119.9%	130.0%	140.8%	161.7%

(d) Category Assortment Depth (2009-2010 Swine Flu Pandemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	6.3%	8.9%	7.4%	7.8%	8.3%
Low	12.9%	15.6%	14.0%	14.5%	15.0%
Moderate	14.9%	17.7%	16.1%	16.5%	17.1%
High	21.0%	24.0%	22.3%	22.8%	23.4%

Figure 12. Impact of flu activity in seasonal flu epidemic (panels a and b) and the swine flu pandemic (panels c and d)
(based on Models 8.1 and 8.2 of Table 8)

(a) UPC Unit Price (2008-2009 Seasonal Flu Epidemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	0.0%	0.1%	0.2%	0.3%	0.1%
Low	0.0%	0.1%	0.2%	0.3%	0.1%
Moderate	-0.5%	-0.4%	-0.3%	-0.2%	-0.4%
High	-0.4%	-0.3%	-0.2%	-0.1%	-0.3%

(b) Average Price Paid (2008-2009 Seasonal Flu Epidemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	0.0%	1.0%	1.8%	2.3%	0.8%
Low	0.3%	1.3%	2.1%	2.6%	1.1%
Moderate	-1.0%	0.0%	0.8%	1.3%	-0.2%
High	0.0%	1.0%	1.8%	2.3%	0.8%

(c) UPC Unit Price (2009-2010 Swine Flu Pandemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	-7.7%	-4.9%	-1.8%	-1.5%	-0.7%
Low	-7.3%	-4.5%	-1.4%	-1.1%	-0.3%
Moderate	-7.3%	-4.5%	-1.4%	-1.1%	-0.3%
High	-6.9%	-4.0%	-0.9%	-0.6%	0.2%

(d) Average Price Paid (2009-2010 Swine Flu Pandemic)

	No Activity	Sporadic	Local	Regional	Widespread
Minimal	-14.6%	-11.5%	-5.2%	-3.9%	-1.8%
Low	-18.2%	-15.2%	-9.2%	-8.0%	-5.9%
Moderate	-18.9%	-15.9%	-9.9%	-8.7%	-6.7%
High	-22.5%	-19.7%	-13.9%	-12.8%	-10.9%

Figure 13: Impact of flu activity in seasonal flu epidemic (panels a and b) and the swine flu pandemic (panels c and d)
(based on Models 8.3 and 8.4 of Table 8)

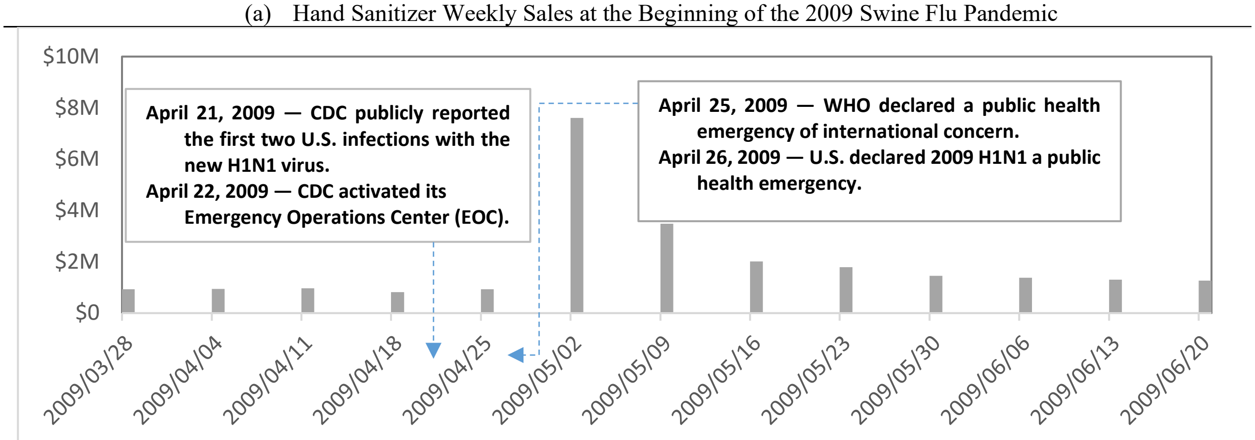
8 Management and Policy Implications

Could the lessons learned during the swine flu pandemic have been applied to the Covid-19 pandemic? Figure 14 compares hand sanitizer sales during the swine flu pandemic to sales during the initial stages of the Covid-19 pandemic. Notably, while there is a more pronounced surge in sales during Covid-19, similarities in sales patterns are evident. These findings corroborate the hypothesis that experiences from prior health crises can inform future pandemic responses. Proactive adjustments in supply chains and inventory management, in anticipation of heightened demand following initial viral reports, could significantly benefit all stakeholders. This foresight facilitates measures for increasing supply and informed and timely purchasing decisions for consumers, enhancing overall market stability.

For retail management, this study implies that a sophisticated approach to inventory planning for emergency essentials could be advantageous. This includes leveraging advanced predictive analytics to deeply understand consumer behavior during health crises. Such insights should guide tailored inventory strategies, emphasizing a diverse, flexible product assortments and efficient stock management. Additionally, the formation of robust, adaptable supplier relationships and the utilization of cutting-edge technology for inventory tracking and customer behavior analytics are vital to increasing sales and reducing stockouts. Implementing these strategies can optimize operational efficiency and customer satisfaction, fostering agility and responsiveness in dynamic market conditions.

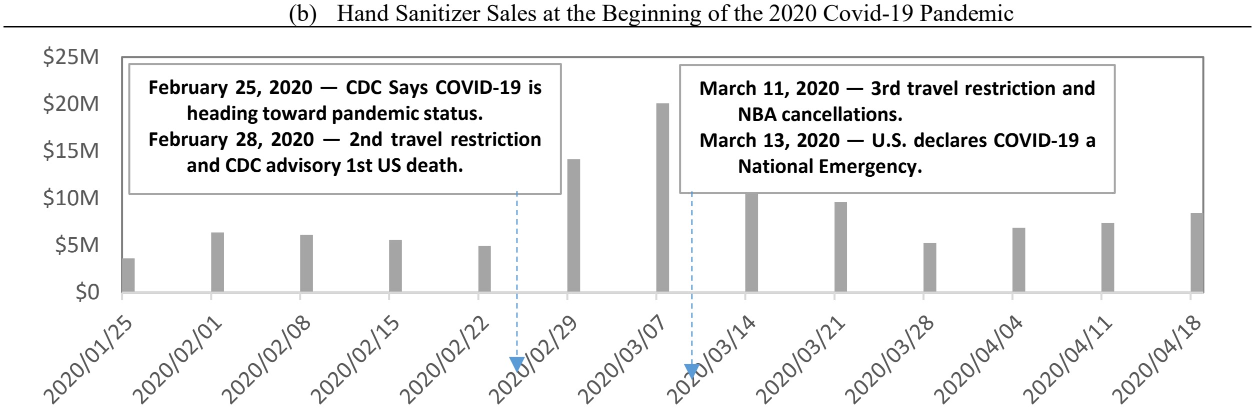
On the policy front, our studies do not show a need for anti-price gouging measures to maintain accessibility and affordability of essentials like hand sanitizers, even during periods of panic buying. Retailers appeared unwilling to significantly increase list prices. Moreover, consumers were able to substitute lower-priced large pack purchases for higher-priced small pack purchases. However, governments may have a role in fostering collaborative public education campaigns, jointly with business and consumer groups, to reduce panic buying and hoarding behavior. Furthermore, governments can focus on keeping supply chains open, thus allowing retailers to concentrate on effective inventory management, supply chain coordination, and transparent communication with customers, enhancing preparedness and response efficiency in crisis scenarios.

(a) Hand Sanitizer Weekly Sales at the Beginning of the 2009 Swine Flu Pandemic



Note: Calculated by authors based on Nielsen Retail Scanner data

(b) Hand Sanitizer Sales at the Beginning of the 2020 Covid-19 Pandemic



Source: https://www.tabsanalytics.com/covid-19-total-store-impact-tracker

Figure 14: Hand sanitizer sales (US$) at the beginning of the 2009 swine flu pandemic and the 2020 Covid-19 pandemic

9 Conclusion and Future Research

Each year, during the annual flu seasons, there are spikes in sales of products designed to mitigate the spread of the flu. Among these products is hand sanitizer. Given the regular occurrence of flu seasons, retailers can plan for demand increases for hand sanitizer and facilitate the supply of the products. Occurrences of pandemics, however, are less predictable and retailers, therefore, are less prepared. However, both consumers and retailers can learn from their pandemic experience and carry practices over to subsequent flu seasons.

This study details how consumer purchasing behavior and retail operational management evolved during the 2009-2010 swine flu pandemic and seven subsequent flu seasons. We track price and assortment changes of sanitizer during the annual flu seasons and the pandemic. Moreover, we compare sales, product assortment, and price across categories of retailers to differentiate the strategies undertaken by the various types of retailers. We summarize our main findings as follows.

First, consumers and retailers learn from their pandemic experiences. A comparison between the first and second waves of the swine flu pandemic shows that during the second wave, retailers were prepared with a larger assortment of sanitizer products, including large pack sizes favored by consumers. These learned behaviors, by retailers and their customers, appear to have carried forward through the next five flu epidemics. Sales of large pack-size products stayed above base case levels for the next five years (although by diminishing amounts) before returning to their pre-pandemic base levels.

Second, prices were held down during the second wave, despite the higher demand for sanitizer products. The changing assortments and purchasing patterns that favored large pack sized products over small pack sized products led to significantly lower per-unit prices paid for sanitizer during the second pandemic wave.

Third, store format matters. During the swine flu pandemic, warehouse clubs had higher sales increases in hand sanitizer compared to other types of stores, even though warehouse clubs offered a smaller assortment of sanitizer products for sale. By offering large-sized packages of sanitizer at a low per-unit price point, warehouse clubs won business as consumers switched from higher cost-per-unit small-pack sizes to lower cost-per-unit large-pack sizes. Drug stores emerged as winners as well, although with an entirely different strategy. By significantly expanding assortments, drug stores won customers by providing a larger array of sanitizer options.

As with all research, this paper has its limitations leading to the potential for future research. First, we study only one essential product – hand sanitizer. Although sanitizer may be deemed an essential product during epidemics and pandemics, it may not represent the sales of other essential products. Analysis of other products, such as toilet paper, flour, and face masks, would help to generalize our findings. Second, our measure of assortment depth, based on sales rather than on inventory, may provide a biased representation of actual products on hand. Studies that use actual inventory counts of stock-keeping units may provide a more accurate depiction of how retailers change available assortment during pandemics. Third, the impact of digital transformation in the retail sector, especially accelerated by the pandemic, represents a significant area of interest. However, this study's focused scope precluded a detailed discussion of this aspect, marking it as a limitation and a potential avenue for future research.

In conclusion, this study contributes to the retail management research on epidemics and pandemics (Gupta et al., 2022; Roggeveen & Sethuraman, 2020). We study consumer purchasing behavior and retail management during seasonal flu epidemics and the swine flu pandemic. We find that sanitizer sales during viral emergencies may be predicable. Consumers stockpile sanitizer following an emergency declaration, preferring stores with low-cost and large-size packs and stores with a large selection of product assortment. Although at the beginning of the pandemic, retailers may be caught short of supply, as the pandemic progresses, retailers appear to adjust to meet consumer demand in terms of supply, assortment, and prices. Finally, the impact of a pandemic on retail sales may last for several years returning to pre-pandemic levels, illustrating a learning effect from the pandemic experience.

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APPENDIX

Table A1: Correlation

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1	CAT_SALES_VOL	1.00												
2	UPC_ASSORT_DEPTH	0.83	1.00											
3	AVG_PRICE_PAID	-0.30	0.04	1.00										
4	UPC_UNIT_PRICE	-0.01	0.11	0.35	1.00									
5	EPIDEMIC_0809	-0.06	-0.04	0.11	0.06	1.00								
6	PANDEMIC_0910	0.14	0.02	0.04	0.05	-0.14	1.00							
7	EPIDEMIC_1011	0.02	0.01	-0.06	-0.02	-0.10	-0.17	1.00						
8	EPIDEMIC_1112	-0.02	-0.03	-0.05	-0.04	-0.10	-0.16	-0.11	1.00					
9	EPIDEMIC_1213	0.00	0.00	-0.02	-0.02	-0.10	-0.17	-0.12	-0.11	1.00				
10	EPIDEMIC_1314	-0.04	0.00	0.00	0.00	-0.10	-0.17	-0.12	-0.11	-0.12	1.00			
11	EPIDEMIC_1415	-0.01	0.06	0.03	0.02	-0.11	-0.18	-0.13	-0.12	-0.13	-0.13	1.00		
12	EPIDEMIC_1516	-0.02	0.03	-0.01	-0.02	-0.10	-0.17	-0.12	-0.12	-0.12	-0.12	-0.13	1.00	
13	EPIDEMIC_1617	-0.06	-0.05	-0.05	-0.04	-0.09	-0.15	-0.11	-0.10	-0.11	-0.11	-0.11	-0.11	1.00