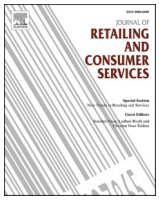
Journal of Retailing and Consumer Services 75 (2023) 103538

Contents lists available at ScienceDirect

Journal of Retailing and Consumer Services

journal homepage: www.elsevier.com/locate/jretconser



Unveiling the influence of COVID-19 on the online retail market: A comprehensive exploration☆

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ARTICLE INFO

Keywords:
Price changes
Demand changes
Supply chain disruption
Coronavirus SARS-CoV-2

ABSTRACT

The global economy has experienced significant disruptions due to the COVID-19 pandemic, profoundly impacting production and consumption patterns. This paper examines the effect of the pandemic on consumer goods prices, focusing on a sample of hand sanitizers, soap, disinfectants, and baking yeasts. The selection of these products was motivated by multiple and comprehensive criteria, where we considered various factors such as changes in consumption patterns during the pandemic, the relevance of these products in household consumption, consumer behavior, availability of historical price data, their significance in daily domestic life, and their utility in the prevention of the disease. Employing a time-series analysis, the study investigates the relationship between product prices and the S&P 500 index, as well as the presence of structural breaks in the time series. The results reveal a significant correlation between all prices in the sample and the S&P 500 index, indicating the index's efficacy as an indicator of the overall economic state. Moreover, the study identifies a single structural break in each price time series, coinciding with the onset of the COVID-19 pandemic. Notably, hand sanitizers, soap, and disinfectants exhibit particularly substantial price jumps near the time of the break. These findings offer crucial insights into the impact of the COVID-19 pandemic on consumer prices, which can guide policy decisions aimed at mitigating the pandemic's economic consequences.

1. Introduction

The SARS-CoV-2 virus was first discovered in December 2019 in Wuhan, China. It was officially declared a global pandemic by the World Health Organization (WHO) on March 11, 2020 (WHO, 2021b). Since then, the virus has rapidly spread to nearly every country worldwide. More than 761 million confirmed cases of the virus have been reported, resulting in over 6.8 million deaths globally (WHO, 2021a). Governments have implemented various restrictive measures, such as lockdowns, to reduce the spread of the virus and minimize deaths. However, these measures have had significant negative consequences on national economies, businesses, and individual employment (Pantano et al., 2020). As a result, the pandemic has evolved into not only a global health crisis but also a crisis for supply chains (SCs) (Karmaker et al., 2021). It has been recognized as one of the most disruptive events of the past few decades (Araz et al., 2020; Remko, 2020). Additionally, the global panic caused by the pandemic has posed challenges to the supply and value chains of various sectors and products (Coluccia et al., 2021; Ivanov, 2020; Pantano et al., 2020). Government-mandated lockdowns and travel restrictions have further intensified the disruptions to SCs at an alarming rate (Karmaker et al., 2021).

While most studies examining the pandemic's impact on SCs have focused on agriculture and food supply chains, which are crucial for ensuring the well-being of humanity (e.g., Coluccia et al., 2021; Nakat and Bou-Mitri, 2021; Weersink et al., 2020), it is important to note that the coronavirus pandemic has affected all supply chains to some extent,

☆ We thank Professor Soora Rasouli (Co-Editor) and two anonymous referees for their insightful comments and suggestions which were very useful in preparing the final version of the paper. We also thank Nidia Reyes and Daniel Pinedo for their comments on a previous version.

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https://doi.org/10.1016/j.jretconser.2023.103538
Received 23 June 2023; Received in revised form 1 August 2023; Accepted 18 August 2023
Available online 26 August 2023
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not just the agri-food sector. A survey conducted by Infosys Consulting found that the majority of supply chains experienced a 25% or greater reduction in operations due to the pandemic (Infosys, 2020). Other studies have indicated that approximately 94% of Fortune 1000 companies have faced supply chain disruptions caused by the coronavirus (Karmaker et al., 2021).

Common disruptions resulting from the COVID-19 pandemic include offline suppliers, vulnerable transportation systems, delayed deliveries, and material shortages. These issues, combined, have led to reduced productivity, service levels, and revenue for global supply chains (Karmaker et al., 2021; Remko, 2020). Moreover, these disruptions have caused significant shocks to both the supply and demand of products in retail companies and have resulted in wide price variations (Habib et al., 2021). While major e-commerce players like Amazon, Alibaba, and Walmart have experienced growth due to increased online shopping (Forbes, 2020), the CEO of Walmart has acknowledged that various industries and product categories, ranging from toilet paper to non-perishables, have faced extensive panic buying due to the pandemic (CNN-Business, 2020). As a result of significant shifts in supply relative to demand, prices across different product categories exhibited substantial fluctuations throughout 2020.

Given this context, a crucial research question arises: what is the impact of price changes and how do they relate to supply and demand during the COVID-19 pandemic in 2020? Understanding these effects and impacts is essential for adjusting and preparing supply chains not only for the future but also for future disruptions. The pandemic also serves as a valuable testing ground for comprehending the influence of consumer sentiment and fear on market performance and prices (Tran, 2021). Therefore, the objective of this study is to analyze the impact of COVID-19 on the retail market, specifically evaluating its effect on product prices across different sectors and market niches. To achieve this, we examine price fluctuations for three categories and eight products from various market niches (i.e., low cost, normal cost, and premium) on Amazon. Amazon, valued at $415.86 billion in 2020 and holding the largest market share in the US (50% in 2021) (Statista, 2021a, 2021b), is the world's most popular and leading online retailer. Analyzing the behavior of this dominant company allows us to estimate and understand the dynamics of most of the market.

To the best of our knowledge, this paper offers a perspective that contributes to the existing literature in two significant ways. Firstly, it expands beyond previous studies focusing on specific sectors, such as agriculture and food supply chains, by comprehensively analyzing price changes across various sectors and market niches, including low-cost, normal-cost, and premium items. The specific objectives of this study are to analyze the impact of COVID-19 on the retail market and examine the dynamics of product prices across different sectors and market niches. This clear focus on understanding the effects of the pandemic on product prices provides a framework for the research.

The paper provides a novel perspective on the impact of the COVID-19 pandemic on product prices, contributing to the existing literature in several significant ways. It comprehensively analyzes price changes across various sectors and market niches, encompassing low-cost, normal-cost, and premium items. Additionally, the study explores the relevance of these price dynamics to supply chain management, providing valuable insights for practitioners. It also investigates the pricing of unique products essential for combating the pandemic, shedding light on their significance to households during the crisis. Lastly, the research emphasizes a time-series analysis and the investigation of structural breaks in price data, going beyond simple correlations and offering a more nuanced understanding of price dynamics over time. Together, these aspects form an innovative research framework that advances our comprehension of the pandemic's impact on consumer goods prices.

This broad analysis fills a significant gap in the existing literature by comprehensively understanding the dynamics and implications of price fluctuations during the COVID-19 pandemic. While previous research has predominantly focused on specific sectors, this study aims to address this limitation by examining price changes across various market niches. By exploring the relationship between price changes, supply and demand, and the influence of consumer sentiment, this research offers insights into the resilience and adaptability (Remko, 2020) of retail markets during global crises. By highlighting the gaps or limitations in the existing literature, this study contributes to the understanding of price dynamics within supply and demand, providing a foundation for future research and strategies to navigate similar challenges. This broad analysis provides a comprehensive understanding of the dynamics and implications of price fluctuations during the COVID-19 pandemic, addressing a gap in existing research that has predominantly focused on specific sectors. By exploring the relationship between price changes, supply and demand, and the influence of consumer sentiment, this research offers valuable insights into the resilience and adaptability of retail markets during global crises, underscoring the significance of studying price dynamics within supply and demand.

The remainder of the paper is organized as follows. Section 2 provides the study's background. Section 3 outlines the methodology employed to examine price variations on Amazon during 2020. Section 4 analyzes the obtained results and discusses the main findings from the data. Finally, Section 5 concludes the study and suggests potential avenues for further research.

2. Literature review

In this section, we provide a comprehensive overview of the research papers focusing on the impact of the pandemic on supply chains (SCs), with a particular emphasis on the retail sector. We highlight the significance of analyzing price changes as a direct outcome of shifts in supply and demand.

2.1. COVID-19, SCs and the retail sector

The COVID-19 pandemic has had a global impact on supply chains (SCs) over the past year, leading to recessions in countries, lockdowns, changes in consumer behavior, and price fluctuations in various products (Habib et al., 2021). The sudden disruption in demand for essential goods like toilet paper and pasta has had negative effects on the performance of retail supply chains (Coluccia et al., 2021; Ivanov, 2020; Pantano et al., 2020). However, there has been limited research investigating the specific impact of COVID-19 on retail SCs. Pantano et al. (2020) synthesized the challenges faced by retailers during the pandemic from the perspectives of consumers and managers. They suggested four key areas of focus for retailers: agile retailing, recognizing personnel as essential workers, prioritizing customer satisfaction disclosure, and providing real-time customer assistance. Ivanov (2020) used a simulation-based methodology to predict the impacts of the pandemic on SCs. They observed that the timing of facility closures and reopenings at different levels of the supply chain could play a crucial role in determining the impact on SC performance, rather than just the duration of disruptions or the speed of the epidemic's spread. Hall et al. (2020) evaluated retail consumption displacement in the Canterbury region of New Zealand, examining the shift in consumption patterns resulting from the effects of COVID-19 on the services sector. They found evidence of increased spending in certain consumption categories, indicating panic buying behaviors. Finally, Tran (2021) developed a model of perceived effectiveness of e-commerce platforms (PEEP) and analyzed its impact on consumers' sustainable consumption behavior. The study concluded that firms should strategically build and operate e-commerce platforms alongside offline methods to meet consumer demands and facilitate sustainable consumption behavior.

Accounts of changes in consumption and consumer behavior during disasters often use terms like "panic buying" and "hoarding" (stockpiling). However, shifts in consumption are the result of a complex interplay between changes in consumer demand and the availability of

supply (Hall et al., 2020). On one hand, temporary unavailability of factories, suppliers, distribution centers, and transportation links has caused material shortages and delivery delays, resulting in decreased revenue, service levels, and productivity (Ivanov, 2020). On the other hand, consumption displacement, influenced by panic buying, new lifestyles, and fear of contagion, has occurred (Laato et al., 2020; Prentice et al., 2020; Tran, 2021).

Consequently, basic consumer goods saw price increases of up to 53% in the early stages of the outbreak in the US (Xu et al., 2020). The reduced accessibility of physical stores, combined with heightened health concerns among consumers, led to an immediate surge in demand for alternative distribution channels (Pantano et al., 2020). The COVID-19 pandemic has democratized e-commerce, with over 18 million US consumers turning to online shopping since March. Online shoppers have adjusted their purchasing behavior within the online channel to meet their ever-changing pandemic-related needs, leading to a significant increase in omnichannel shopping, with almost half of the purchases resulting in e-commerce transactions (Nielsen, 2020). Pantano et al. (2020) highlighted that consumers perceive the safety offered by the internet and online technologies, leading to an increasing preference for purchasing products and services through online platforms. Consequently, the US Department of Commerce reported a 44.5% increase in e-commerce estimates for the second quarter of 2020 compared to the same period in 2019 (US Department of Commerce, 2020).

The availability of goods and panic stockpiling have also influenced consumers' price sensitivity. Previous literature has extensively examined various factors affecting consumers' price elasticity, and it is not surprising that many consumers have accepted price increases of up to 300% for certain product categories during the emergency period (Pantano et al., 2020). In this context, analyzing price fluctuations considering shifts in both consumer demand and supply availability becomes crucial for understanding and measuring the impact of COVID-19. The next subsection will present the key components to be considered in conducting the price analysis.

2.2. Price analysis

Price plays a crucial role in the consumer decision-making process (Monroe, 2003) and significantly influences consumer perceptions of a brand (Huang et al., 2017). However, it is important to note that prices and quantities sold in a market are determined by shifts in both demand and supply. Marsh (2003) established the general law of demand, which states that as the price of a product decreases, the quantity demanded increases. On the other hand, Smith (1976) argued that suppliers reduce the quantity of a product as its price decreases until it reaches its natural price. These concepts are quantitatively measured using a metric known as price elasticity.

Price elasticity is a numerical representation of consumer price sensitivity towards a specific brand or product and is typically negative. This means that when the price of a brand increases, the sales decrease, and vice versa. However, in rare cases (Huang et al., 2017), price elasticities can be positive, such as in the case of the COVID-19 pandemic. This unique situation has resulted in a noticeable shift in consumer buying behavior.

To study shifts in demand, Marsh (2003) applies an approach that defines a shift in demand as the difference between the observed price and the expected price.

3. Methodology

In our base line scenario, we identified the effects of the COVID-19 pandemic in the prices of some of the products sold on Amazon® in the US claimed by CNN-Business (2020) to suffer changes in consumption during some of the first weeks of the pandemic. These products were selected among the ones found to have sufficient data available (records prior to December 2017), which were not many (this limited both the number of products compared and the quantity of records considered). One major disadvantage for the study was the fact that many "biosecurity" supplies-essential to combat the pandemic-were created from new companies or companies that had to "reinvent themselves" (CNBC, 2020), starting to sell products such as hand sanitizers, face masks, etc., thus making it difficult to find brands with records of prices to allow a significant study (a valid comparison could not be made from new brands: no price variation would have been seen). Another criterion for selecting products was also influenced by the effectiveness of certain items in fighting against COVID-19, such as soap and hand sanitizers (Golin et al., 2020; Leung, 2021; Rundle et al., 2020). These products played a crucial role in maintaining hygiene and preventing the spread of the virus. Additionally, we included baking yeast in our analysis due to its relevance in households during the pandemic (Easterbrook-Smith, 2021).

To this end, we analyzed the relation between the Standard & Poor's 500 (S&P 500) index and the prices of each product from December 2017 to February 2021 to find a *structural point of change*, which was hypothesized to be near the dates of the corresponding week in CNN-Business (2020).

A structural break occurs when a time series abruptly changes at a point in time. This change could involve a change in mean, a change in variance, a change in both mean and variance, or a change in any other parameter of the process that produce the series. The sudden change in the series may obey to different reasons. When economic time series, such as prices or asset returns are considered, a structural break may respond to changes in the macroeconomic environment, i.e., changes in macroeconomic variables which can cause variation in market conditions.

The Covid-19 outbreak is a clear-cut example of a major success with the ability to change fundamentally market outcomes. In this study we are interested in evaluating the potentially differential effect of the pandemic on market prices for different types of products. While the outbreak had an impact on virtually every single economic market, arguably impacts may depend on aspects such as price- and income-demand elasticities, the capacity of producers to sell their products online, transaction costs, sudden preference variations due to the pandemic, and interactions among them.

A simple way of evaluating the impact of the pandemic on different products consists in testing for the presence of structural breaks on various products' price time series and observing their timing and sign changes. Time series models are utilized to estimate the interdependencies among variables observed over a specific timeframe. Numerous models operate under the assumption that the relationship between these variables remains consistent throughout the entire period. Nevertheless, there are instances where external factors trigger variations in the fundamental relationship between the variables in the model. A prime example of this is the Covid-19 pandemic. Structural break models specifically address such scenarios by incorporating abrupt changes in the model's parameters. A structural break refers to a sudden and significant change in a time series at a specific point in time. In this study, the term time series refers to the temporal evolution of a product's price. This change may involve alterations in the mean or higher-order moments (e.g., the variance) governing the generation of the series. Accurate identification of structural breaks in time series enables us to gain valuable insights into the problem under investigation. Employing structural break tests aids us in determining the presence and significance of any notable changes within our data.

Despite the World Health Organization (WHO) officially declaring the outbreak of the novel coronavirus (COVID-19) as a global pandemic on a specific date, March 11, 2020, the prices of various products incorporated potentially relevant information at different points in time. For instance, the demand for cleaning products such as alcohol and disinfectants began to surge worldwide even before that date, as people in different countries grew concerned about the virus's spread and

associated mortality. Consequently, in this study, we do not presume a predetermined date for a structural change. Instead, we enable the detection of any such endogenous structural change, if it exists, as part of our analysis.

After providing an intuitive understanding of the structural change tests employed in this study, we now proceed to provide a comprehensive and rigorous description of the specific tests utilized. The test for structural breaks implemented in this study constructs a test statistic for a structural break without imposing a known break date. This is done by combining the test statistics computed for each possible break date in the sample. Concretely, at each possible break date a Wald test for detecting a structural change in the series is implemented. Then, a supremum test is implemented for identifying statistically the date in which the break occurred, if any. Each supremum test statistic is the maximum value of the test statistic that is obtained from a series of Wald tests over a range of possible break dates.

Let w denote a possible break in the window $[w_1, w_2]$ for a sample of size T, and let $K_T(w)$ be the Wald test statistic evaluated at a potential break date w. The test statistic for the null hypothesis of no structural change within the window is given by:

$$Sup\ K_T = Sup_{w\in[w_1,w_2]} K_T(w) \tag{1}$$

Note that this supremum exists for all windows $[w_1, w_2]$ as the set of Wald statistics is nonempty and bounded above. The limiting distribution of the test statistic is given by:

$$Sup\ K_T \underset{d}{\rightarrow} Sup_{\lambda\in[u_1,u_2]}\ K(\lambda) \tag{2}$$

where $K(\lambda)$ is a function of a vector of independent Brownian motions, $u_1 = \frac{w_1}{T}, u_2 = \frac{w_2}{T}$, and $\lambda = \frac{u_2(1-u_1)}{u_1(1-u_2)}$. The limiting distribution of each of this test statistic is known but nonstandard as it is a function of many sample statistics and of the unknown break date which is unidentified under the null.

Supremum tests were performed for the different price series using weekly data and allowed the endogenous identification of one or more breaks in the price series. The identification of structural breaks followed a two-step procedure: in the first step, least square regressions were performed to each product's price time series as a function of a constant and the S&P 500 index. We used the Huber/White/sandwich estimator of the variance-covariance matrix of the estimators, which is robust to heteroskedasticity of the errors.[1] The S&P 500 Index was included as a short-run control for macroeconomic fundamentals, since it is the most used benchmark for determining the state of the overall economy: various studies show this index outperforms several other widely used indicators of the overall state of the macroeconomy (see, for instance, (Buraschi and Jiltsov, 2006), and (Tsiakas et al., 2020)). Many investors also use the S&P 500 as a benchmark for their individual portfolios. In the second step, the supremum of Wald tests described in the methodology section is used to determine the number of breaks (if any) in the series and their timing. Fig. 1 briefly describes the methodology used in this study to detect breaks in the time series of product prices.

[1] Several approaches exist to address the issue of heteroscedasticity. One such method involves utilizing the Huber/White/sandwich estimator to calculate the variance-covariance matrix of the estimators. This estimator is robust in the presence of heteroskedastic errors and offers distinct advantages, such as providing consistent estimation of the variance when the underlying model is misspecified. Alternatively, alternative standard error adjustments can be explored, including clustered standard errors or heteroscedasticity-autocorrelation-consistent (HAC) standard errors. These approaches serve as extensions to heteroskedasticity-consistent standard errors and provide additional techniques for handling complex data structures. It is important to note that the results presented in this study are not significantly influenced by the choice between these alternative methods.

Weekly price data were used from December 1, 2017, to February 10, 2021. The number of breaks in each series is endogenously determined as well as the moment of time in which breaks occur, and estimation results are shown in Table 2 through 9: each table shows least squares result for the first stage together with structural break results identified in the second stage.

For the data collection, we searched for some of the most popular brands of the products sold in Amazon® in the Web Site CamelCamelCamel, classified them as low, medium, or high price; and retrieved data such as maximum, minimum, and average prices, and price vs time plots (for the relevant periods of time). To retrieve the values of the S&P 500 index, we used those given by Google (INDEXSP: INX).

In selecting the brands and products for our analysis, we considered multiple criteria to ensure a comprehensive representation of price dynamics and consumption changes during the pandemic's early weeks. Firstly, we focused on the availability of historical price data, which allowed us to capture the price fluctuations over time. Secondly, we considered the relevance of the chosen products to household consumption. Specifically, we aimed to include well-known and widely consumed brands within each product category. This selection criterion enabled us to examine how changes in consumption patterns influenced the pricing of these popular and frequently purchased items. Additionally, we classified the products as low, medium, or high-priced by comparing their price points to the overall price distribution within each category. This approach provided insights into the different price segments and their sensitivity to changes in consumer behavior and purchasing power during the early stages of the pandemic. By employing these criteria, we sought to provide a detailed understanding of the significance of the selected products and their impact on consumption patterns during the initial weeks of the pandemic.

With the plots, we proceeded to approximate raw data with the Software GeoGebra®: the plot was placed in the axes and scaled accordingly (the y-axis units coinciding with the price units); then, with a slider, a vertical line (of the form $x = a$, where a was the slider-a parameter which varied between 0 and the value corresponding to the last value and had a step that corresponded to approximately one (1) week in the scale) was set to move gradually (one step every two-three seconds) and a point was inserted where the line intercepted de plot each time, as shown in Fig. 2.

For the supremum and Wald tests to find the structural points of brake, we used Stata and computed the p-values for the nonstandard limiting distributions following the method developed by (Hansen, 1997).

To overcome the well-known problem of evaluating the presence of possible structural breaks at the beginning or the end of the time series we implemented the trimming strategy suggested by (Andrews, 2003).

4. Data, results, and discussion

4.1. Data

Following the methodology outlined in Section 3, an estimation of the unprocessed data on product prices from December 2017 to February 2021 was obtained, presented in Table 1.

Within the table displaying the descriptive statistics for each price series, the mean values are presented for three distinct time periods: pre-pandemic, the initial three months of the pandemic, and the entire duration of the pandemic. It is crucial to acknowledge that these descriptive statistics serve the purpose of characterizing the behavior of the series at different temporal points, rather than being directly utilized in the empirical analysis. Hence, the selection of the pre-pandemic period, three months of the pandemic, and the complete pandemic period is arbitrarily determined.

In the empirical analysis conducted in this study, a contrasting approach is undertaken. In the presence of a potential structural change

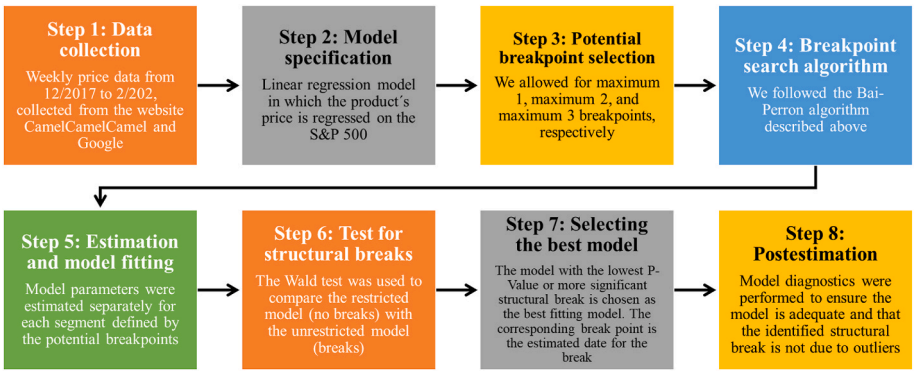

Fig. 1. Main steps of the methodology.

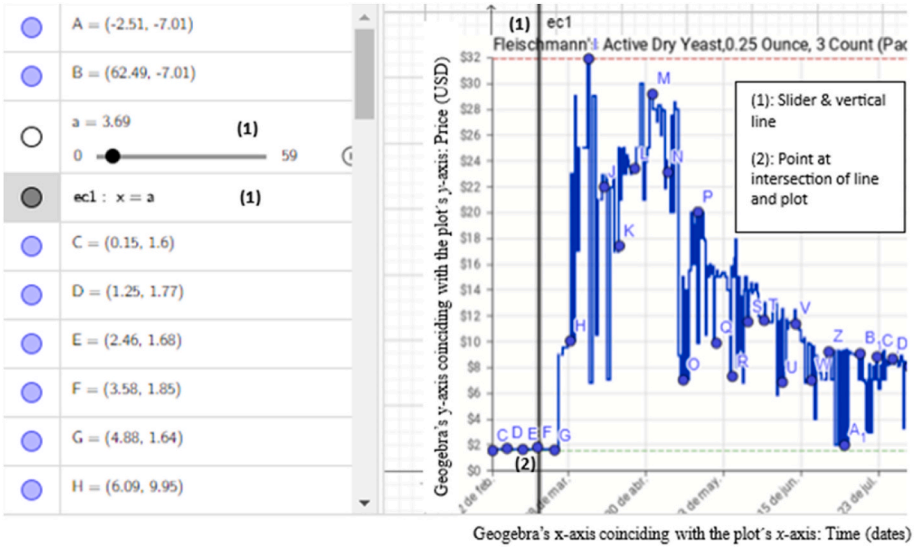

Fig. 2. Illustration of the procedure for the raw data extraction.

Table 1
Descriptive statistics for the prices of the products between December 2017 and February 2021.

	Hand sanitizer-low price	Hand sanitizer-medium price	Soap- high price	Soap-low price	Soap-Medium price	Baking Yeast-medium price	Baking Yeast-high price	Baking Yeast-low price	S&P 500
Mean	24,8	20,6	33,9	17,5	13,1	6,5	6,9	4,7	2980,1
Mean-prior to pandemic [a]	16,2	13,9	14,3	32,5	12,5	5,1	4,0	5,2	2858,9
Mean-first three months of Pandemic	70,2	36,7	26,7	36,0	16,1	17,5	12,1	16,9	2776,7
Mean-Pandemic	45,7	36,9	25,4	37,5	14,6	10,0	6,6	11,0	3273,5
Count	154	154	154	154	154	153	153	150	154
% Variation	545%	626%	174%	437%	376%	2214%	725%	38326%	170%
Maximum	70,9	49,6	41,9	40,4	26,8	31,4	25,2	25,2	3926,6
Max Date	March 13, 2020	October 30, 2020	September 25, 2020	March 27, 2020	March 06, 2020	March 20, 2020	April 24, 2020	April 09, 2020	February 10, 2021
Minimum	13	7,91942885	24,1592465	9,26178047	7,12625189	1,42	3,47192195	0,0657635	2304,92
Min Date	December 19, 2020	February 02, 2020	March 01, 2020	January 10, 2021	November 03, 2020	February 05, 2020	July 20, 2020	September 27, 2020	March 20, 2020

[a] 03/13/2020 (Presidential Document/Executive Office, 2020).

in a price series, an endogenous determination is made through the utilization of a statistical model specifically designed for capturing such changes. Nevertheless, the inclusion of descriptive statistics aims to visually illustrate the mean behavior of the price series before and during the pandemic, thereby providing the reader with insightful observations. Notably, the division of the pandemic period into two distinct sub-periods underscores the fact that during the initial three months, characterized by considerable uncertainty, retail market buyers exhibited less rational behavior, gradually transitioning towards a more rational approach as the pandemic progressed and its implications became more apparent.

With this data, Price (or S&P500 Index) vs. Time plots were created

to visualize any relationship between the prices and the S&P500 index; specifically, structural breaks. Fig. 3 shows aggregate graphs (see Fig. 4).

4.2. Results

In this section, we provide an overview of the findings for each product, including the results of robust least squares regressions (where the price is the dependent variable) and the Price and S&P500 Index VS Time plots depicting the structural points of change (refer to Tables 2 and 3, and Fig. 3). We assume that each time series contains only one structural break, as per the conventional information criteria and due to the relatively short duration of the time series under analysis (see Table 5) (see Table 6) (see Table 7) (see Table 8) (see Table 9) (see Table 4).

4.2.1. Hand sanitizers

The Price and S&P500 Index VS Time plots of hand sanitizer reveal that before the COVID-19 pandemic, prices exhibited a certain degree of variation but maintained a real relationship with the S&P500 index, as evidenced by the similarities in plot shapes during specific periods (e.g., around April 2018, October 2018, or October 2019) in the first graph. However, with the onset of the pandemic, this relationship was significantly altered, as demonstrated by the estimated break date(s): around March. During this period, the S&P500 index declined sharply, while the prices of hand sanitizers experienced a sudden and substantial increase (more than four times their pre-pandemic average). In the subsequent months, prices gradually decreased for both hand sanitizer types, although not uniformly. While the prices of the first type have returned to pre-pandemic levels, the prices of the second type remain considerably higher.

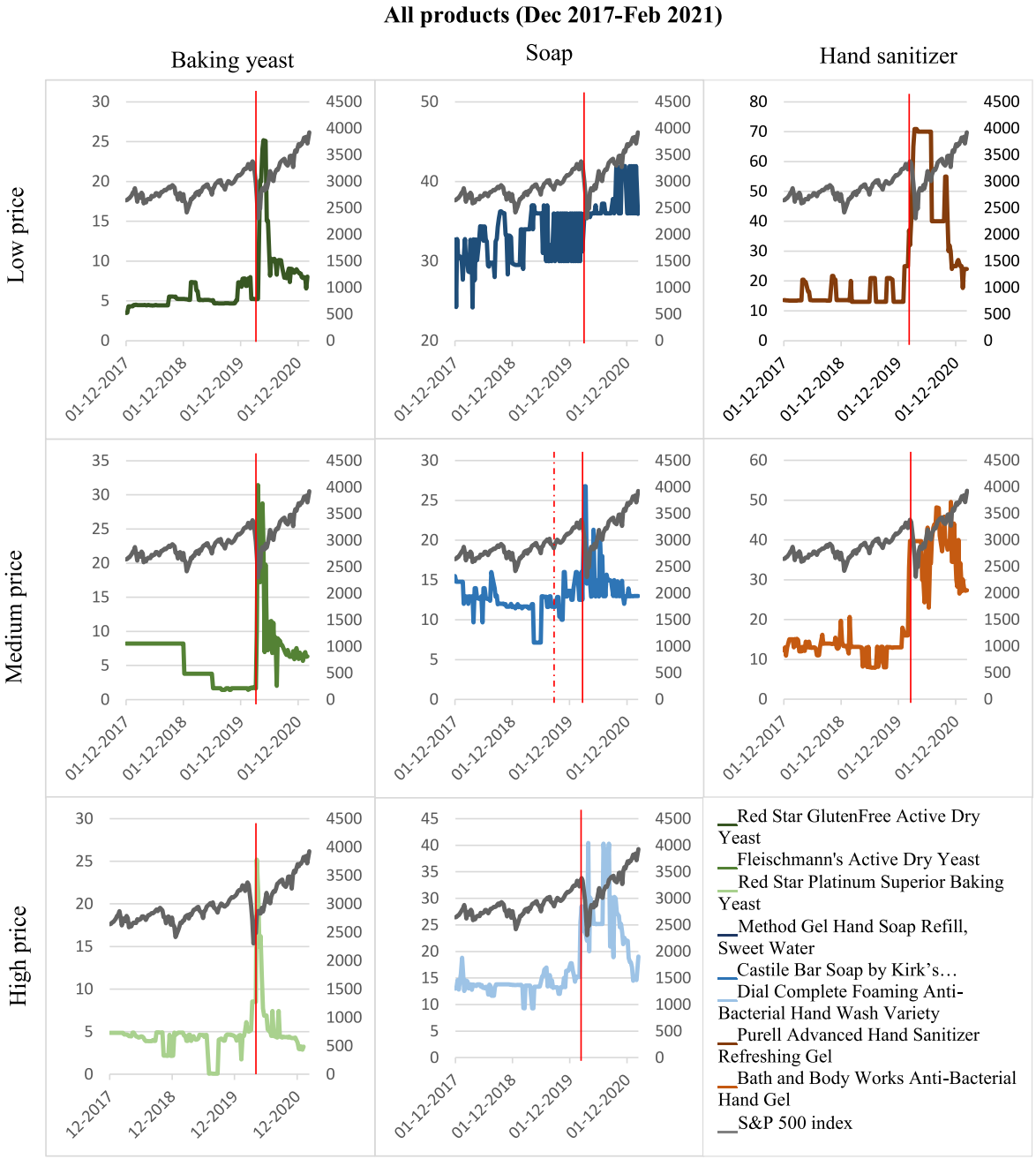

Fig. 3. Aggregate Graph. The left vertical axes correspond to the prices (in USD) of the different products, and the right ones to the S&P500 index. The lines represent the break dates; the dashed ones represent the calculated ones (if applicable).

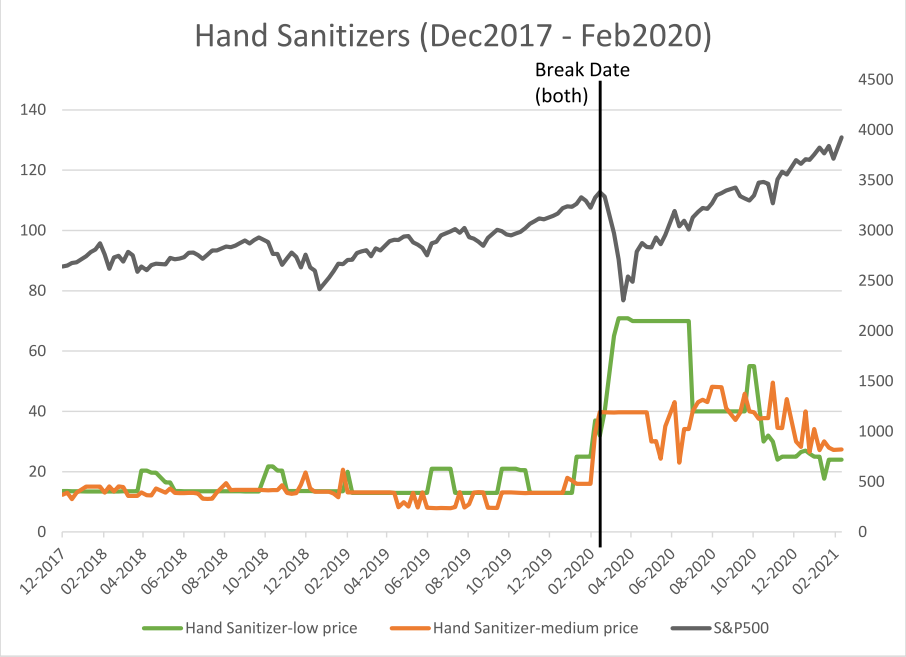

Fig. 4. Hand sanitizers analysis.

Table 2
Results for "purell", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "Purell"		
Variable	Coefficient	Robust Standard Error
S&P 500	0.94**	0.39
Constant	−0.31	0.12
Structural Break Identification		
Test	Statistic	P-value
Wald	467.74	0.00
Estimated break date	February 7, 2020	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

Table 3
Results for "bath & body works", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "B&BWorks"		
Variable	Coefficient	Robust Standard Error
S&P 500	0.19***	0.02
Constant	−0.37	0.08
Structural Break Identification		
Test	Statistic	P-value
Wald	528.76	0.00
Estimated break date	February 7, 2020	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

Table 4
Results for "method", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "Method"		
Variable	Coefficient	Robust Standard Error
S&P 500	0.62***	0.08
Constant	1.54	0.24
Structural Break Identification		
Test	Statistic	P-value
Wald	123.12	0.00
Estimated break date	March 6, 2020	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

Table 5
Results for "dial", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "Dial"		
Variable	Coefficient	Robust Standard Error
S&P 500	0.76***	0.17
Constant	0.51	0.50
Structural Break Identification		
Test	Statistic	P-value
Wald	123.12	0.00
Estimated break date	February 7, 2020	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

The consistent positive and statistically significant coefficient of the S&P 500 for all hand sanitizers indicates a positive price correlation between these products and the S&P 500 during the sample period. This relationship is visually evident in the corresponding graphs. Such findings suggest that the prices of hand sanitizers tend to rise during periods of economic growth and decline during economic downturns, as the S&P 500 index generally exhibits procyclical behavior.

However, it is important to note that while this positive correlation holds for the entire sample period, the graphs clearly depict an inverted correlation during the times of the pandemic. This divergence is attributed to the sharp increase in demand for hand sanitizers amidst the pandemic, despite the economic contraction. Individuals' heightened

Table 6
Results for "kirks", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "Kirks"		
Variable	Coefficient	Robust Standard Error
S&P 500	0.13**	0.06
Constant	0.91	0.17
Structural Break Identification		
Test	Statistic	P-value
Wald	42.29	0.00
Estimated break date	October 25, 2019	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

Table 7
Results for "fleischmanns", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "Fleischmann's"		
Variable	Coefficient	Robust Standard Error
S&P 500	−0.36***	0.13
Constant	0.17	0.04
Structural Break Identification		
Test	Statistic	P-value
Wald	139.44	0.00
Estimated break date	March 13, 2020	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

Table 8
Results for "red star GlutenFree", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "RS GlutenFree"		
Variable	Coefficient	Robust Standard Error
S&P 500	0.23***	0.06
Constant	0.11	0.22
Structural Break Identification		
Test	Statistic	P-value
Wald	98.13	0.00
Estimated break date	November 15, 2019	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

Table 9
Results for "red star platinum", December 1, 2017–February 10, 2021.

Robust Least Squares Regression Results. Dependent variable is "RS Platinum"		
Variable	Coefficient	Robust Standard Error
S&P 500	−0.12***	0.04
Constant	0.82	0.15
Structural Break Identification		
Test	Statistic	P-value
Wald	27.35	0.00
Estimated break date	October 11, 2019	

*Indicates significance at the 10% level.
**Indicates significance at the 5% level.
***Indicates significance at the 1% level.

concerns about contagion lead to a surge in the demand for hand sanitizers, even during a period of economic decline.

One notable distinction between the two hand sanitizers is that the price surge occurred more abruptly for the second type. In contrast, the other type experienced a slight decline in mid-February before prices increased. Additionally, an intriguing characteristic of the higher-priced hand sanitizer is the presence of peaks in prices around mid-December each year, which may be attributed to the popularity of Bath&Body-Works® products as Christmas gifts. Furthermore, the highest price was observed in December 2020, reaching more than six times the lowest price recorded.

4.2.2. Soaps

The soap price graphs exhibit a behavior similar to that of the hand sanitizers. They experience a sharp increase during the initial weeks of the pandemic (February–March), reaching prices that are twice as high as before the pandemic, although the change is less drastic. This can be attributed to the fact that both are in the same category in CNN-Business (2020) and are used for the same purpose of disinfecting hands. After stabilizing, all prices remain higher than those before the pandemic, although the prices of the medium-range soap are comparable.

The association between the S&P 500 and the price of soaps exhibits a resemblance to that observed between the S&P 500 and hand sanitizers. In the regression analysis, the corresponding coefficient demonstrates a positive and statistically significant relationship, indicating that, on average, the two variables move in tandem. However, akin to hand sanitizers, this positive correlation undergoes a transformation during the pandemic period. While the S&P 500 experiences a significant decline, the price of soaps sharply increases as individuals prioritize reducing the likelihood of contagion. This phenomenon further reinforces the presence of a structural break, indicating a departure from the usual positive correlation observed in normal circumstances.

Interestingly, two soap brands, "Method" and "Dial," show estimated structural breaks around February and March 2020, coinciding with the beginning of the pandemic's spread in the US. However, the break date for the other soap brand, "Kirks," is in the last quarter of 2020. Price increases in this brand may have occurred before the virus hit the US, when news about the virus in China began to appear, indicating the importance of expectations in price formation mechanisms. "Kirks" is a costly soap brand, and therefore the pricing process may be more responsive to expectations than the other two soap brands.

4.2.3. Baking yeast

Upon examining the graphs, it is apparent that the prices of baking yeast begin to rise slightly later than those of other products (such as soaps and hand sanitizers), but reach their peaks several weeks later (in mid-April), which is consistent with the findings of CNN-Business (2020). These products exhibit the most drastic changes, with increases (compared to their lowest prices) of 725%, 2214%, and 38326% (a high rise of more than 38 times) for low, medium, and high-priced yeast, respectively. After a few months, prices began to decrease, approaching pre-pandemic levels. Structural breaks in yeast prices do not precisely coincide with the onset of the pandemic. Although price behavior is distinct during the pandemic compared to the pre-pandemic period, there is no compelling reason to believe that a structural break in the price formation process should have occurred at the beginning of the Covid-19 pandemic. One reason that can explain why yeast prices were not as affected by the pandemic arises from the fact that yeast is used in the production of baked goods such as bread, cakes, and other bakery items that are not as sensitive to changes in economic conditions as other goods, given their daily consumption nature.

The relationship between the S&P 500 and baking yeast differs from the associations observed between the S&P 500 and soaps or hand sanitizers. Notably, for two out of the three baking yeast brands, the coefficient corresponding to the S&P 500 exhibits a negative and statistically significant relationship. This suggests that, on average, the price of baking yeast tends to decrease during periods of economic

expansion. One possible explanation for this finding is that baking yeast is commonly used in the production of various consumer goods that households consider to be inferior goods. Consequently, as income levels rise during economic growth, households may shift their consumption patterns away from baking yeast-based products.

However, there is an exception to this pattern, specifically with gluten-free baking yeast. In the case of gluten-free baking yeast, the average correlation with the S&P 500 is positive. This indicates that households perceive gluten-free baking yeast as a normal good, with its price increasing in tandem with rising incomes. This observed behavior could be attributed to households' inclination to consume a greater quantity of gluten-free goods as their overall income levels increase.

Conducting formal tests for structural breaks serves a valuable purpose in substantiating the notion that the pandemic's impact on various products and brands was heterogeneous. By employing an endogenous approach to determine the break dates, we observe that product prices did not respond uniformly; instead, their reactions occurred at distinct points during the initial weeks following the global pandemic declaration.

The statistical significance of the S&P coefficient in most regressions indicates that most product prices behaved as expected during normal economic conditions, exhibiting an increase when the economy expanded. However, it is noteworthy that a singular product, namely non-gluten-free yeast, displayed a negative coefficient for the S&P 500. This peculiar finding may imply that consumers perceive this product as an inferior good, particularly in the present era where there is a prevailing preference for gluten-free products.

In conclusion, our methodological approach sheds light on the nuanced effects of the pandemic on product prices and provides insights into consumer preferences and market behavior amidst these unprecedented circumstances.

4.3. Discussion

In general, several results are noteworthy. First, all prices in the sample are significantly related to the S&P 500 Index, indicating that the index serves as a good indicator of the general state of the economy. However, while the prices of hand sanitizers (Purell), soap (Dial, Method, Bath & Body Works), and disinfectants (Kirk's) exhibit a positive correlation with the S&P 500 Index, baking yeasts (Fleischmann's, Red Star GlutenFree, Red Star Platinum) show a negative correlation with the index.

Second, a single structural break was detected for each price time series. Although the number of breaks may be any non-negative integer less than the total number of observations in the time series, only one break was endogenously identified in all cases. This finding indicates that two regimes govern the price dynamics of each product in the sample. Different moments were determined for each break, but most coincided with the beginning of the Covid-19 pandemic. Specifically, the breaks for the prices of Purell, Bath & Body Works, and Dial occurred during the week of February 7, 2020, while the breaks for the prices of Method and Fleischmann's happened in early March (the weeks of March 6 and March 13, respectively). Interestingly, the other three breaks occurred before the beginning of the pandemic (late 2019). The breaks in the prices of two yeast brands occurred before the pandemic, which is not an unexpected finding since there is no apparent reason to assume that yeast prices should have changed dramatically due to the pandemic. The price of Kirks, a high-price soap brand, also experienced a break before the beginning of the pandemic's spread in the US. This result suggests that the process of soap price formation is different for high-price soaps Probably expectations occupy a more important role for "Kirks".

Third, although all the products in the sample exhibited a positive jump around the time of the structural break, the leap was particularly notable for hand sanitizers, soap, and disinfectants, as anticipated. For instance, the price of Purell, which was $13.00 at the beginning of 2020, surged to a historical peak of $70.91 during the week of March 13, 2020. Subsequently, the prices of these sanitizing products declined, but they remained at levels higher than those observed before the onset of the COVID-19 pandemic.

Fourth and finally, the findings of this study contribute to the existing literature on price fluctuations during crises or periods of high demand. Previous research has demonstrated that changes in supply and demand dynamics, consumer behavior, and market conditions play a crucial role in influencing price variations during such challenging times. This study builds upon this body of literature by explicitly examining the impact of the COVID-19 pandemic on product prices across different sectors and market niches. The results reveal significant price variations during the pandemic, with specific products experiencing notable increases or decreases in response to shifts in consumer demand and disruptions in the supply chain. These findings align with prior research emphasizing the sensitivity of prices to external shocks and the importance of understanding price dynamics during challenging periods. By establishing this connection, this study adds to the growing knowledge on price fluctuations during crises and high-demand situations, offering valuable insights that can inform decision-making processes and guide strategies for effectively managing price volatility in such circumstances.

5. Conclusion and further research

This study aimed to examine the impact of the COVID-19 pandemic on the prices of essential commodities in the United States, specifically hand sanitizers, soaps, disinfectants, and baking yeasts. The findings revealed significant correlations between the prices of these products and the S&P 500 index. Positive correlations were observed for sanitizing products, indicating an increase in prices, while negative correlations were found for baking yeasts, suggesting a decrease in prices. The analysis of price time series indicated a single structural break, with most breaks occurring at the beginning of the pandemic. Notably, the prices of sanitizing products experienced a particularly substantial increase around the time of this structural break.

The COVID-19 pandemic has significantly impacted supply chains across sectors, including the retail industry. The retail sector stands out with its unique challenges and characteristics. Notably, the direct influence of consumer demand on retail supply chains has necessitated rapid adjustments to meet evolving preferences. Store closures and restrictions on in-person shopping have fueled a surge in online shopping, placing greater pressure on e-commerce supply chains. Additionally, the diverse range of product categories and market niches within the retail sector presents specific challenges, such as managing perishable goods and navigating sourcing disruptions for durable goods. Understanding these distinctive aspects is crucial for developing tailored strategies to mitigate disruptions, enhance resilience, and effectively address evolving consumer demands.

Furthermore, the findings of this study have significant implications for supply chain management, consumer behavior, and market dynamics during periods of crisis. The observed price variations highlight the importance of agile and adaptive supply chain strategies to respond to shifts in consumer demand and disruptions in the supply chain. Supply chain managers can use these insights to enhance inventory management practices, establish robust supplier relationships, and develop contingency plans to ensure product availability and mitigate price fluctuations. Also, understanding consumer sentiment and preferences is crucial in driving price dynamics during crises, enabling businesses to anticipate and respond to changing demand patterns. This knowledge can inform pricing strategies and resource allocation optimization. Additionally, the study emphasizes the dynamic nature of market conditions during crises, emphasizing the need for businesses to monitor and adapt to remain competitive and resilient closely. Considering these broader implications, this study contributes valuable insights for practitioners and policymakers in navigating and mitigating the

impact of future crises on supply chain management, consumer behavior, and market dynamics.

To enhance our understanding of the topic, future research could expand the analysis beyond the United States and include other countries or regions to explore whether similar dynamics in essential goods' prices were observed during the pandemic. Additionally, investigating the influence of government policies on the prices of basic goods during this period would provide valuable insights. Another potential avenue for future research is to examine consumer behavior and demand for these essential goods during the pandemic, particularly regarding the observed price hikes. Finally, future research can delve deeper into sector-specific analyses and explore innovative approaches to strengthen supply chain capabilities in the face of future crises. This could involve examining the specific challenges and dynamics within different sectors and identifying strategies to enhance resilience and adaptability. These areas of future research can contribute to a more comprehensive understanding of the impact of the COVID-19 pandemic on essential goods' prices, supply chains, consumer behavior, and market dynamics, guiding the development of effective strategies to mitigate the impact of future crises and strengthen supply chain capabilities.

Declaration of competing interest

The authors declare they do not have any conflicts of interest.

Data availability

Data will be made available on request.

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