Impacts of the COVID-19 pandemic on Colombian exports using time series models

Impactos de la pandemia del COVID-19 en las exportaciones colombianas usando modelos de series temporales

Impactos da pandemia de COVID-19 nas exportações colombianas usando modelos de séries temporais

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Abstract

The objective of this article is to show the effects of the COVID-19 pandemic on Colombia's exports between 2008 and 2020, based on a time series projection analysis. For this purpose, the statistical models of exponential smoothing were estimated, obtaining as a result adjusted values and forecasts to calculate the error difference indicator between these and the real one for each model as a response variable for a multiple regression model whose results indicated differentiated short-term impacts of decrease in exports mainly in textile products, toys, furniture, leather and footwear.

Key words: Time series, Forecasting models, Exports.

Resumen

El objetivo de este artículo es mostrar los efectos producidos por la pandemia del COVID-19 en las exportaciones de Colombia entre 2008 y 2020, a partir de un análisis de proyección de las series de tiempo. Para ello, se estimaron los modelos estadísticos de suavización exponencial, obteniendo como resultado valores ajustados y pronósticos para calcular el indicador de diferencia de error entre éstos y el real por cada modelo como variable respuesta para un modelo de regresión múltiple, cuyos resultados indicaron impactos diferenciados de corto plazo de disminución de exportaciones, principalmente en productos textiles, juguetes, muebles, pieles y calzado.

Palabras clave: Series de tiempo, Modelos de pronósticos, Exportaciones.

Resumo

O objetivo deste documento é mostrar os efeitos da pandemia da COVID-19 sobre as exportações da Colômbia entre 2008 e 2020, com base em uma análise de projeção de séries temporais. Para este efeito, foram estimados modelos estatísticos de suavização exponencial, obtendo-se como resultado valores ajustados e previsões para calcular o indicador de diferença de erro entre estes e o real para cada modelo como uma variável de resposta para um modelo de regressão múltipla cujos resultados indicavam impactos diferenciados a curto

prazo da diminuição das exportações principalmente em produtos têxteis, brinquedos, mobiliário, couro e calçado.

Palavras-chave: Séries cronológicas, Modelos de previsão, Exportações.

Código JEL: C23, C51, N10, N16

Introduction

The evaluation of the impact of the health emergency conditions caused by the COVID-19 pandemic, which emerged in 2020, has generated a vast amount of research. These studies not only focus on analyzing the detriment, for example, in economic matters but also on formulating strategies to overcome the crisis. The effects on the normal course of time series have been measured by authors such as Panzone et al. (2021), who found strong negative impacts on some businesses like restaurants, and positive impacts on others like supermarkets, which benefited from increased sales due to the trend towards consumption of essential products. However, the decline in sales both locally and internationally is a consequence of the confinement measures decreed by governments to prevent massive contagions of the COVID-19 virus, as well as the limitation of product and people flows in airports (Nakamura & Managi, 2020; Ibn-Mohammed et al., 2020). Restrictive measures such as flight cancellations and quarantines severely affected sectors such as aeronautics and tourism, among others.

In Colombia, Decree 417 of March 17, 2020 (Government of Colombia, 2020) prohibited the circulation of passengers and goods, thus all sectors, except the primary sector (supply of essential food and medicines), saw their local and international sales reduced. Similarly, air transport was totally suspended from March 25 to September 21, 2020, when a gradual opening of its main international flight lines began (Ministry of Transport, 2020; Hosteltur, 2020). In addition, the Ministry of Commerce, Industry, and Tourism (2020), with Decree 457 of 2020, generated a set of exceptions that allowed the opening of some sectors such as chemicals, disinfection products, cleaning, emergencies, construction when its continuity was fundamental to avoid collapse risks, among others. On the other hand, exception 25

opened the commercialization, import, and export of materials for public services, as well as for mineral inputs (MinCIT, 2020, p. 9).

The apparel sector, not belonging to the primary sector, was not among the exceptions and affected all links at different levels of the textile and apparel transformation chains. As a survival strategy, some manufacturers resorted to the production of face masks and garments for health personnel; others innovated in the production of objects with more durable materials, environmentally friendly, to mitigate the economic crises of unemployment, in addition to reducing damage from the high pollution associated with waste from non-recyclable materials (Ardusso et al., 2021).

In studies involving economic impacts of Covid-19, it is recommended to use traditional methods, showing partial evidence to establish patterns, and analyze the differences presented between a projection and the actual data, as has been explored in another recent research (Chicaíza, García & Urrea-Ríos, 2021; Ahmad et al., 2020). Another approach is to analyze propensity score matching for developing some change due to the intervention (Svabova & Durica, 2017), resorting to the use of logistic regression model techniques, or also through the estimation of time series models (Hanke & Wichern, 2010).

One way to evaluate the effects is with a model called "counterfactual," which establishes the premise: What would have happened to sales if they had continued without a pandemic? This is similar to what was established by authors Svabova and Durica (2017), Cerqua and Letta (2020) or Panzone et al., (2021). This suggests that if the data had followed the normal trajectory without intervention, as predicted, there would have been a difference with respect to the actual trajectory. It is here where the impact caused can be visualized, as proposed in this research. The objective of this research focuses on determining the impact on the change in export sales in the set of Colombian tariffs. To achieve this, counterfactual theory was employed, which consists of estimating robust time series models to make forecasts, which allowed identifying the differences between the predicted values and the actual export values recorded between April and August 2020, specifically for the tariff chapters classified in Colombia.

Historical data on exports by subheading of tariff chapters were taken from January 2008 to August 2020, which allowed representing the behaviors and periodic patterns of the time series and also forecasting future values, showing the difference or estimation error with the Mean Percentage Error (MPE) indicator. The lowest value of the error indicator allows for the selection of the best model with the best prediction trajectory without a pandemic and thus, add it to the aforementioned difference with the real data (with pandemic), which quantifies the MPE impact and the Root Mean Square Error (RMSE). After estimating these MPE differences, they are assumed as the response variable of an estimated regression model to facilitate the analysis of the effects by tariff section, indicating the nature of the impact.

This document is structured in five sections, including the introduction. The second section presents applied studies differentiating by thematic and methodological axes. The third section describes the adopted methodological approach to then discuss and analyze the findings in the fourth section. Finally, the main conclusions and limitations of the study are indicated.

Literature review

This section is subdivided into three subsections to present related literature. The first reviews applied works on the general topic, namely, sectoral impacts, where studies on the relationship between the pandemic and its economic impact are presented. Secondly, several documents that evaluate and compare the performance of techniques in forecasting time series for highly disaggregated data are addressed. The last subsection deals with the theoretical foundation of the models used in this specific analysis.

Economic Impact of the Health Emergency (Applied studies of the impact of the health emergency in business and export contexts)

A debate originating in the context of the Covid-19 crisis, at different levels, is associated with state intervention and its consequences on productivity. Although the business fabric has generally suffered the onslaught of the situation, micro, small, and medium-sized enterprises (MSMEs), that plays a key role in supply chains, have seen decreases in their sales, having less access to inputs, globally, even in the production of prepared meals (Nordhagen et al., 2021). In addition, the population's purchasing habits through digital

channels and the response capacity of many companies to virtual orders were two factors that added to the situation, which generated a decrease in the normal sales volume, weakening industries such as those in Saudi Arabia, with plant closures and staff layoffs during the pandemic (Tanveer et al., 2020). Other studies show deeper effects in the entertainment industry, such as the case of cinemas and restaurants, affected by longer closures due to social distancing measures, due to their nature of high risk of contagion by agglomerations (Kim, 2021; Song et al., 2021).

Along these lines, there are studies on the impact of factors associated with state policies in some economic sectors. Time series statistical models have been applied to the sales variable, for example, to compare the projected versus the actual. Some results show how restaurants and fast-food businesses decreased in the United Kingdom, unlike supermarkets which exhibited increases in their income during the 2020 pandemic (Cerqua & Letta, 2020; Panzone et al., 2021).

The entire word was witnessed the effects of the pandemic in 2020, both due to the particular conditions of health impact, as well as economic and social difficulties; as the way the health crisis also affected world trade and economy is unprecedented (Ibn-Mohammed et al., 2020), translated into decreased income, led to non-payment to suppliers and credits, contract termination and increased unemployment, especially in companies with little liquidity or lack of support strategies in the face of crises (Félix et al., 2020; Silvieira & Philippi, 2020). The service sectors, as well as the textile sector, commerce, faced significant decreases in their income, coupled with barriers to access to credit, which results in a high risk of insolvency (ECLAC, 2020a). In addition, due to the Covid-19 situation, world trade decreased by 17.7 % compared to May 2019, generating a generalized reduction, with greater impact on exports from various countries, among others, for example, the United States. However, China noticed a reduction below the world average, due to the control and reopening of its economy in a relatively quick time. For its part, Latin America and the Caribbean suffered greater impact (ECLAC, 2020a), generating an almost complete paralysis of informal jobs during the pandemic, which worsened income generation and has increased poverty (ECLAC, 2021).

The evidence regarding the effect on trade balances is overwhelming given that countries with traditional deficits throughout history have a high probability of worsening their negative indicators if they do not take appropriate measures; coupled with other economies that do not have opportunities to forge the changes required to face the negative implications of the crisis. Thus, according to ECLAC (2020b), the contraction of the dynamics of world trade, mainly in the United States, China and Europe, presents a strong negative impact in Latin America and the Caribbean through trade, both in volume and price, and more representative in raw materials, because important productive sectors of the region are circumscribed to global value chains driven by the United States and China, taking into account the fall in remittances from these economies. Faced with the new economic scenario in the region and with the reduction in prices, the impact on exports has been presented at approximately 15 %, reducing prices by 8.8 % and contracting volume by 6 %.

The recent pandemic has significantly affected international trade worldwide, which has led several studies to examine the evolution of its effects at various points in time. In the Ecuadorian case, Jumbo et al. (2020) show that, during the first four months of 2020, foreign sales experienced a marked decrease in their exports, which affected the country's economy, a situation that was later reversed due to the increase in the price of oil and the growth of mining exports. Hayakawa & Mukunoki (2021) determined the impact of the pandemic on world trade from January to August 2019 and 2020, finding significantly negative effects on both exporting and importing countries' trade, although the negative effects on importing countries tended to decrease after July 2020. Meanwhile, Rose et al. (2021) used a computable general equilibrium model to analyze the transmission of economic shocks through international trade, indicating negative impacts on U.S. GDP due to international trade linkages, with variations across regions; interestingly, China managed to increase its exports following mandatory closures in other regions, while the U.S. economy demonstrated relative isolation from trade linkages with the rest of the world. For his part, Kerr (2021) highlighted the unprecedented pressure of the pandemic on food supply chains and the possible repercussions on international trade and long-term cooperation, with increasingly isolationist governments. Finally, Dong & Truong (2022) showed how exports from a developing country like Vietnam were severely affected by the decline in trading partners in aggregate, with significant variations across subsectors and the positive role of government

response and economic support in mitigating impacts. These studies underscore the complex nature of the pandemic's impact on international trade and the challenges it poses.

Now, Bonet-Morón et al. (2020), evaluated the regional and sectoral economic impact in Colombia, due to preventive isolation measures to prevent the spread of Covid-19. The authors resorted to an input-output model that allowed the estimation of the economic loss of isolation and consequent reduction of formal and informal jobs in different sectors of the country, the above is close to finding economic losses between $4.6 trillion and $59 trillion per month according to different isolation scenarios, and for the national GDP, they range between 0.5 % and 6.1 %. The most affected is the service area, highlighting a prevalence of activities in accommodation, tourism, food, real estate, and other administrative or educational services; in addition, the departments of Antioquia, Boyacá, San Andrés, Santander and Valle del Cauca present the greatest vulnerability.

Under this scenario, Latin America, and with this, Colombia, suffered important impacts because of export prevalence of essential products, which are the most sensitive to price reduction, added to the aftermath of the impact of the U.S. economy and the fall in oil prices; all of this significantly affected the trade balance in the pandemic scenario.

Applied time series studies

In the specialized academic literature, there are multiple applications in the estimation and forecasting of high-frequency time series, both for foreign trade data and for other types of economic variables. The range of applications includes modeling exercises ranging from Holt-Winters (HW) filters, Box-Jenkins (BJ), Engle-Granger (EG), the autoregressive integrated moving average (ARIMA) and seasonal (SARIMA) model, vector autoregressions (VAR) and vector error correction models (VECM), special cases of ARMA models (ARAR algorithms), to artificial neural networks (ANN) and their Bayesian variants (BANN).

Statistical models for data with a longitudinal nature, have been developed with increasing precision in the forecasting of temporal variables such as sales (Higuita et al., 2018); among these types of models, the Autoregressive Integrated Moving Average Model (ARIMA) is a classic model used to predict by the information of the past of the same time series. In the

specific field of international merchandise flows, Kargbo (2007) shows the applicability and better performance when combining techniques, making use of five different econometric tools, finding better behavior for those of the ARIMA and EG type; a similar result in terms of fit is reported by Ghauri et al. (2020), while for Emang et al. (2010) the seasonal ARIMA reported better forecasts when compared to an ARAR and HW in their data. This SARIMA model also showed adequate performance in terms of explained variability and prediction power in the work developed by Paul et al. (2013). In the case of Mladenović et al. (2016), different from the previous ones, they show that the HW filter performs better in long-term forecasts when compared to ARIMA.

Some forecasting techniques such as ANNs have shown better performance in forecasts by capturing dynamic, non-linear and seasonal behaviors, better than in Holt Winters and Box Jenkins models (Co & Boosarawongse, 2007), and in the case of BANNs when compared to the ARIMA model (Urrutia et al., 2019). On the other hand, statistical learning techniques have been compared with regression modeling, or to establish an association between different social and economic variables with deaths in Elgar, Stefaniak & Wohl (2020). In this sense, the use of forecasting procedures based on optimization has gained great importance for their precision (Schumacher & Breitung, 2008).

Experience has shown that some statistical models are very efficient for studying the effects of certain variables on others. In Mexico, Gutiérrez-Cruz (2017) investigates the implicit relationship between private and public investment, and spending for the period 1980-2015. Under this premise, a time series analysis was used using an ADL model, whose explanatory factors were private investment, primary public expenditure and GDP. The results showed that, both for the short and long term, the total net effect of primary public expenditure and GDP on private investment was positive and of considerable magnitude; now, just as the fall in private investment as a proportion of GDP can be partly explained by the fall in different types of public spending, it is possible to resort to these techniques to demonstrate the impact of the health crisis on the fall in exports.

Mladenović, Lepojević & Janković-Milić (2016) explore the forecast of export trends in the Republic of Serbia from January to December 2015. For the analysis of time series, they resort to the HW and ARIMA methods and provide an insight into the forecasts of export

trends for a period of 12 months, evidencing the practical use of time series analysis methods in forecasting macroeconomic variables such as exports.

In the economic field, de Meira-DeOliveira and Cyrino-Oliveira (2018) resort to combined Bootstrap aggregation methods (Bagging) to analyze the electricity sector, with the purpose of obtaining more accurate demand forecasts; in this sense, they perform a comparative analysis using monthly electricity consumption time series from different countries and evidence that the methodological proposal contributes to a substantial improvement in the accuracy of forecasts of end-use energy services demand in both developed and developing countries.

The application of statistical methods with autoregressive terms and moving averages has been considered for more than half a century, however, these are based on some analytical processes based on probability distributions, or algorithmic on numerical optimization methods, which has gained greater development and increasingly diverse models (De Gooijer & Hyndman, 2006), as done by Li & Li (2023), who formulate a hybrid model with optimization to forecast the performance of a daily air quality index.

Accurate and unbiased estimation of time series data produced by these systems cannot always be achieved using well-known linear techniques, reason that leads to the increase of the applicability of the support vector machines or deep learning algorithms (Sapankevych & Sankar, 2009), in order to optimize forecasts. Finally, there is a limited history of performance of these models when applied to complex and highly non-linear data and the results show that the SARIMA model is the only statistical method capable of outperforming, although without statistical difference, machine learning algorithms (Sabino, Alves & Batista, 2019), but this depends on the distribution of the data, variability, and trajectory.

Theoretical foundation of the techniques used

A time series is a realization or sample function of a stochastic process, which occurs randomly over a period of time. In this case, quantitative random variables are considered, with a longitudinal nature. The realization of the variable Z(t) occurs in a set of temporal values of a vector w, which present components that characterize them, such as: trend,

seasonality, autocorrelation, randomness and stationarity (Dozie et al., 2020). These aspects are considered in the classical theory of time series estimation, from which the roots for estimations based on error indicator optimization, or data learning techniques arise (Arango-Marín et al., 2013).

Exponential Smoothing

This method provides a moving average with an exponential weight of all previously observed values (Hanke & Wichern, 2010), but with an optimization over this weight. The simple exponential smoothing model uses the averages of past values of the time series, so that it is associated with a decreasing sequential series, establishing more importance of the most recent observation until finding that the oldest data will be the one with the least weight; a technique that demonstrates adequate results (Domínguez-Hurtado & Soto-Valero, 2020).

Holt's smoothing method performs a double exponential smoothing, has been used for time series that present variation and trend. This method requires the specification of alpha and beta smoothing constants, one for the value of the series (intercept) and another for the trend. This technique is often used for time series with increasing trend and seasonality. In the case of the additive model, the level, growth rate and seasonal pattern are optimized by minimizing the sum of squares of the error and are projected to forecast time series values (Hanke & Wichern, 2010).

ARIMA model

It is an autoregressive integrated moving average model, which is estimated on the time series Yt, where, in addition, the same series are considered as covariates, with autoregressive terms as components of lagged dependence by p lags (Colorado, 2020). For its estimation, it is usual to start from the identification of the degree of autocorrelation of the time series with itself, followed by the identification of trend and possible seasonality and stationarity of the time series (Panzone et al., 2021); with respect to this, it is then possible to estimate a model that allows adjusting and forecasting future values of the time series (Miller et al., 2017). Equation [1] describes a general equation that represents these models of the autoregressive integrated and moving average model:

$$Y_t = \delta + a_t - \theta_1 a_{t-1} - \cdots - \theta_q a_{t-q} + \emptyset_1 Y_{t-1} + \cdots . \emptyset_p Y_{t-p} \qquad [1]$$

Dynamic model

This model is estimated from the Ordinary Least Squares (OLS) theory, where a response variable is proposed, which in this case is the exported value, and covariates related to temporal behavior: time, seasonality, lags of the time series, as highlighted in Equation [2]. It has been used in various applications, in some cases it is called a dynamic econometric model, due to the temporal nature of the covariates used, in other cases it is also called a regression model in time series. One of the objectives is to estimate the association between variables, however, they are also used to adjust and forecast time series values, in the short term as a recommendation, one of the usual equations to represent this type of models is such as regression models in time series.

$$Y_t = \beta_0 + \beta_1 x_{t1} + \beta_2 x_{t2} \ldots e_t \qquad [2]$$

Materials and methods

Seventy-two time series on Colombian monthly exports were used, estimating four statistical models in the R program. A partition was established for each of the series, in two parts; the first from January 2008 to March 2020, to estimate the models with historical data; the second, from April to August 2020, with which the MPE and RMSE of fit and forecast between the adjusted and real values are found. Given that the MPE started from the difference between the adjusted value minus the real one, it takes negative values when the real series, on average, is greater than the adjustment, and positive otherwise. If it is positive throughout the range of the forecasted period, it means that the forecast is higher than the real, which reflects an impact on the decrease in sales, an effect that is detrimental to the sector.

The time series data are the monthly export values for all tariffs classified in Colombia. The following statistical models are estimated to allow adjusting values and predicting them monthly: Holt Winters exponential smoothing, ARIMA model, dynamic model based on least squares, dynamic model with autoregressive residuals, comparing their adjustment

capabilities with error indicators as has been done in other works (Kırbaş et al., 2020). In this work, error difference indicators are also used such as: MPE (Mean Percentage Error) and RMSE (Root Mean Square Error), with which averages are calculated in adjustments and forecasts in exports for each tariff chapter and model.

To determine a possible impact on exports, with historical and adjusted data, the MPE and RMSE were calculated, specifying that a model was chosen as the best possible to forecast for having low values of MPE and RMSE, since the real data do not show what was expected. When the real values are lower than projected with the best model, the average percentage error MPE will be negative, and negative in the opposite case. The methodological strategy in this work took two possible levels of MPE as exploratory thresholds, for having medium and low scale, 15 % and 5 %, finding quantities of time series that exceed both thresholds. Additionally, an analysis of the behavior of the MPE differences of forecasts of all estimated models for all export time series was performed, based on a cross-sectional regression model, with MPE being the response variable, which allowed inferring whether these differences are influenced by the type of model used, or the commercial sector, which facilitated the impact analysis.

Error indicators

MPE: Mean Percentage Error, defined as the mean of the estimated errors between the adjusted values minus the real ones, over the real values of the time series, as expressed in Equation [3].

$$MP = \frac{1}{N}\sum_{t=1}^{N}\left(\frac{\hat{y}_t - y_t}{y_t}\right) \qquad\qquad [3]$$

Thus, when the real value is below the forecasted value, the MPE takes a positive value, as other higher values were expected, this reflects a detriment in sales, and if the average with respect to N (evaluated periods) is positive, in the forecasts, it indicates a deterioration in sales, which would be the last period where the COVID-19 pandemic occurs.

RMSE: Root Mean Square Error, defined as the root of the average of the sum of the differences between the adjusted values minus the real ones squared, as observed in Equation [4].

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(y_t - \hat{y}_t)^2}$$

[4]

Where N corresponds to the number of periods of the export time series, y_t as well as represents the estimated values of exports, in each model respectively.

The error indicators are estimated both for the values that are adjusted with the real data, and for the data that are estimated for future values, or forecasts. This can facilitate choosing the best models by finding lower values of the MPE and RMSE indicators. The counterfactual hypothesis indicates that the series should follow a projected course according to the best model, however, if the real values occur in a much lower way than the adjusted values, there is an impact, in which case a positive value of the MPE is found, or impact of decrease in exports due to the pandemic.

Results and analysis

We employed the seventy-two series of tariff chapters were effectively estimated, revealing that approximately 14 % (10 series) of the estimated models exhibited a Mean Percentage Error (MPE) difference greater than 15 %, indicating decreases in exports or impacts. Furthermore, approximately 34 % demonstrated export reduction impact exceeding 5 % of the difference relative to the adjustment. While initial observations suggest primarily manufacturing sectors such as textiles, toys, paper, and leather were affected, cereals also exhibited a reduction effect in exports during certain months, despite food products playing a privileged role within governmental strategies for the country's supply. This may be related to the decrease in purchases from their second destination market (Ecuador), leading them to opt for other international markets (Directorate of National Taxes and Customs-DIAN, 2020). Lastly, other aspects should not be overlooked, such as restrictions and issues that have hindered rice production in recent years, including restrictions in the sowing process or increased costs of inputs and intermediary processes (Ministry of Agriculture, 2020; Sectorial, 2020).

The analysis begins by estimating MPE values by model and section. Positive average MPE values indicate a detrimental impact on sales, as they would show that actual sales occur below the predicted value in the averaged time period.

The impact description that follows first presents the analysis of specific time series on carpet and textile material exports, as well as exports of toys and recreation-sports articles. Subsequently, the effects on MPE indicators for all 72 tariff sections are shown, which also allow for the construction of a time series model that determines the sectors with the worst economic detriment consequences and whether the time series models used also have an impact on the MPE.

Description of impacts

The following cases indicate particular situations of some of the time series found with impacts. Table 1 shows values of MPE, averages of the adjusted data for each model, and the predicted data.

Firstly, for the time series of carpets and textile materials, as seen in Table 1, although its natural logarithm shows a decreasing trend, it is also found that from March 2020, its exports fall much more than expected. With the dynamic and dynamic plus Arima error models, the percentage adjustment error is 2 %, while for the adjustment it was 20.3% with the dynamic linear model, showing that the predicted value is generally higher, and that there was a detriment in sales, i.e., an impact of decrease in sales.

Table 1

Error indicators: MPE and RMSE for the time series of textile materials and carpets

|	FITTED		FORECASTS	
	MPE	RMSE	MPE	RMSE
Holtwinters	-49,80%	6,7	26,50%	1,055
ARIMA	56,30%	2,81	45,30%	1,461
Dyn	1,90%	0,64	20,30%	0,98
dyn+ari	1,60%	0,6	13,50%	0,827

Source: authors.

Despite finding noticeable decrease effects in all forecast MPE, the trend of this Time series has been decreasing since approximately 2019, i.e., its exports are seen to decrease, as expressed in Figure 1. This is further confirmed by analyzing the average export sale in 2019,

which was 66 thousand USD, while the average was 20 thousand USD between April and June 2020.

Figure 1

Real values vs forecasted of time series textile materials and carpets.
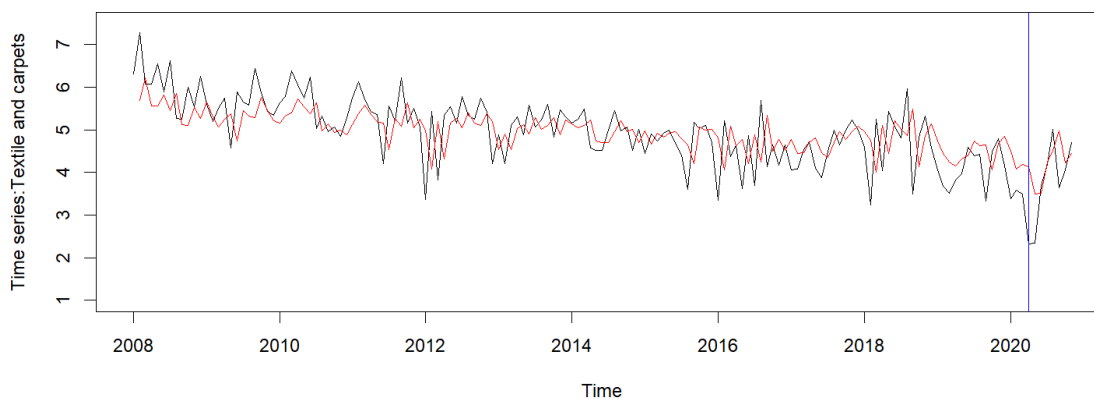
Source: authors. Continuing with another example of impacts, the results of the toys, sports articles, and accessories sector, as seen in Table 2 and Figure 2, presented a large decreasing trend and a very low hit in May 2020, with 116.2 thousand USD, and 309.99 in June 2020, dropping from an average sale in 2019 of approximately 1858 to these quantities.

Table 2

Time series of toys, articles for recreational sport parts and accessories
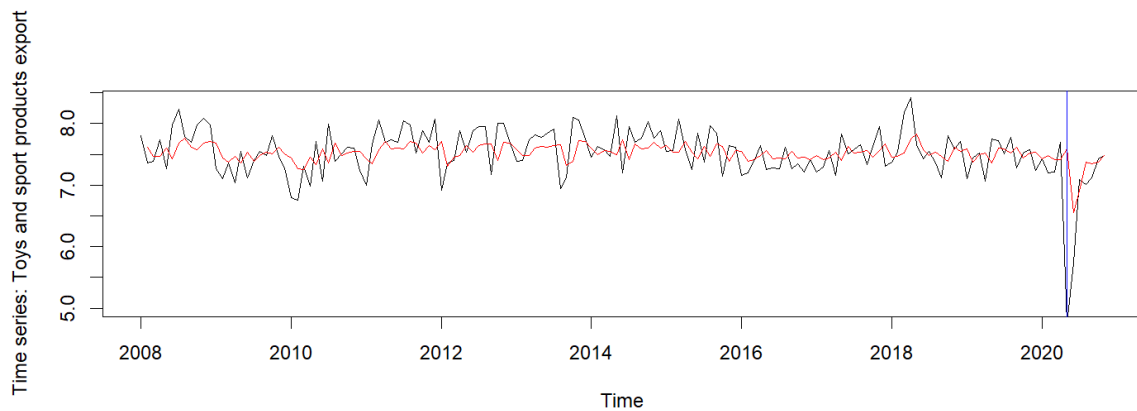
	FITTED		FORECASTS	
	MPE	RMSE	MPE	RMSE
Holtwinters	-50,10 %	10,22	17,00 %	1,39
ARIMA	5,40 %	1,62	20,40 %	1,53
Dyn	0,10 %	0,28	21,80 %	1,58
dyn+ari	0,10 %	0,27	20,80 %	1,54

Source: authors.

Figure 2

Real values and forecasted in time series of toys, articles for recreational sport parts and accessories.
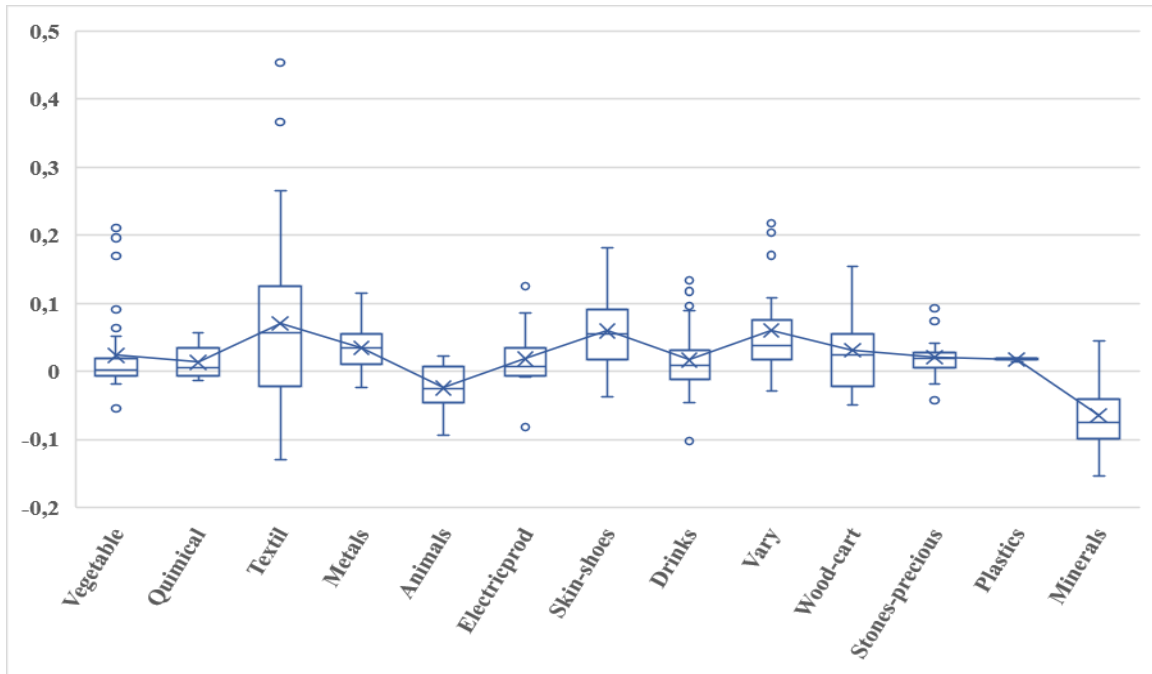

Source: authors.

The above shows some specific cases of the detriment in exports that reflects the difficulties experienced in different economic sectors during the pandemic. Below, grouped data will be presented, after the application of models and MPE and RMSE error indicators for the 72 export series that yielded results.

Impacts by export sectors

When grouping the tariff chapters into sectors, the data show low values especially for the minerals sector, as well as animals, where, for example, live animals are, and textiles, showing that their trade was not affected, reflecting an almost normal sales flow.

Figure 3

Boxplot for MPE vs tariff sector grouping.

Source: authors.

Results of the multiple regression model

After having the data grouped by broader sections, a multiple regression model was estimated where the response variable was the MPE difference, and among the covariates are the factors: the section (tariff grouping), and the type of model. The purpose of this empirical approach was to analyze the effects of the tariff section factor on the differences, determining those that had the greatest generalized impact, given that their effect on the MPE is significant as highlighted in Table 3.

Table 3

ANOVA for the model with response variable of MPE vs model and tariff grouping

	Sum Sq	Df	F value	Pr(>F)
Groupping	0,41813	13	7,6542	6,61E-13
Model	0,09956	3	7,8977	4,53E-05
Residuals	1,14296	272		

Source: authors.

In accordance with the above, the effects found from the estimation of the grouped tariff chapters, exposed in Table 4, confirm what was highlighted in the box and whisker diagram (Figure 3). Minerals and animals had a negative effect on the mean MPE value.

This could have been influenced by government efforts focused on prioritizing aid to the agro and food sector to maintain the supply of the basic basket, through the availability of loans with low interest rates, decrease in input costs, and support for small and medium producers to maintain the sector's competitiveness during the pandemic (Government of Colombia, 2020; Ministry of Agriculture, 2020). However, it can also be observed that, despite such economic facilities granted by the government, not all of the agro sector could be stabilized, as evidenced by the effects found in the vegetables and fats section. Continuing with the sectors with acceptable effects, in the minerals section, there was an almost permanent flow of exports during the pandemic. When contrasted with government actions, this behavior coincides with the fact that this economic line was also prioritized from the beginning of the national quarantine, through economic exceptions as well as the implementation of prevention strategies against COVID-19 contagion, allowing for early adaptation and avoiding the cessation of the sector's productive activities (Ministry of Mines and Energy, 2020; Planetgold, 2020; Patzy & Dammert, 2020).

In contrast to the above, it is observed that sectors focused on the production of textiles, various (toys, furniture, rubber) and skins-footwear did not fare as well in the face of the crisis caused by the pandemic, as the highest impacts are seen in terms of sales detriment. In this sense, since the issuance of Decrees 417 and 457 (end of March), the income of the Colombian manufacturing sector was completely restricted due to the total closure of workshops/factories as well as the national market (points of sale, stores, and shopping centers) (CCCA, 2020).

This discouraging and uncertain panorama was maintained until April 24, when the main manufacturing sectors (textiles, leather, wood derivatives, paper and cardboard, chemicals, metals, and electrical materials) were considered within the governmental exceptions through Decree 593 and were able to resume their productive activities under security protocols (Presidency of the Republic, 2020). However, although these exceptions focused on the commercial reactivation of the manufacturing sectors, they did not contemplate resuming

export activities for this industry, as was the case for the agro and mining sectors (Government of Colombia, 2020). This, added to the long confinement of the industry, ended up triggering a massive detriment of the Colombian manufacturing sector (-25.4% in the first quarter), leading to the collapse of sales, levels of employed personnel, and the general level of exports (ANDI, 2020; UMAC, 2020; Fedemaderas, 2020).

Table 4

*Estimated effects for tariff grouping over indicator MPE*

Coefficients:	Estimate	Std, Error	t value	Pr(>|t|)
GROUP-ANIMALS	-0,006689	0,013232	-0,506	0,613616
GROUP-ELECPR	0,036416	0,019848	1,835	0,067633
GROUP-DRINKS	0,034425	0,015933	2,161	0,031605
GROUP-CARTONWOOD	0,049291	0,019848	2,483	0,013616
GROUP-METAL	0,052323	0,014794	3,537	0,000476
GROUP-MINERAL	-0,046975	0,03308	-1,42	0,156739
GROUP-STONEMETAL	0,038574	0,017504	2,204	0,028385
GROUP-SKIN SHOES	0,077285	0,015933	4,85	2,08E-06
GROUP-PLASTICS	0,035437	0,03308	1,071	0,285013
GROUP-QUIMICS	0,031279	0,013232	2,364	0,018787
GROUP-TEXTILS	0,088391	0,011801	7,49	9,67E-13
GROUP-VARIOUS	0,078163	0,014794	5,283	2,60E-07
GROUP-VEGETALS	0,041398	0,011801	3,508	0,000528
Model-dyn	-0,035105	0,010804	-3,249	0,001302
Model-dyn+ari	-0,0381	0,010804	-3,527	0,000494
Model-Holtwinters	0,001031	0,010804	0,095	0,924059

Source: authors.

Other affected sections are skins and footwear, metals, wood, but not Minerals or Animals and derivatives, sections that substantially improved their exports in the studied period. This methodology and its results for impact measurement can be confirmed in relation to subsequent results for the main export time series (Figures 4 and 5). Additionally, Figure 4 shows the exported values. It is observed that the time series of mineral fuels (secondary right axis) has always shown high levels of export, with little decrease in the pandemic, and those of coffee, animals, food did not have a significant fall in 2020, showing in fact, an improvement after 2020, especially coffee, live plants (and flowers) and edible fruits.

Figure 4

Trend figures in exportations with low affectations.
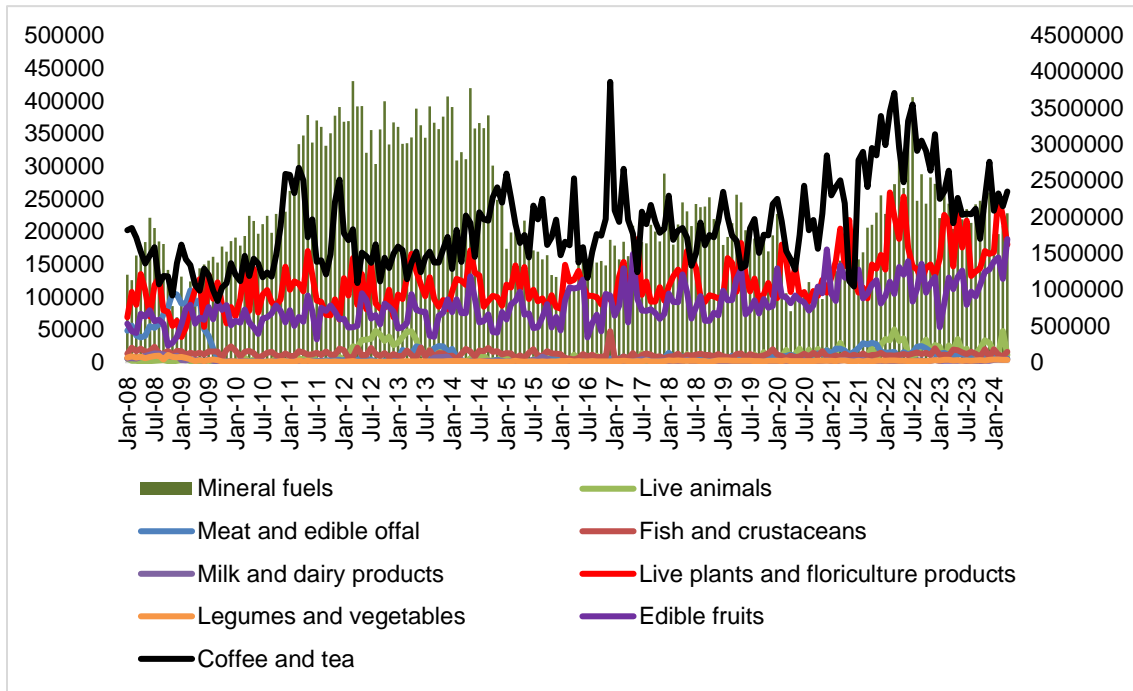
Source: authors. On the other hand, the series that were affected during the pandemic do reflect their fall in 2020, in addition to a considerable level loss, which, despite showing some recovery in 2021, in 2022 and 2023 have detriments in sales decreases.

Figure 5

Trend figures of exports with low levels and high affectation.
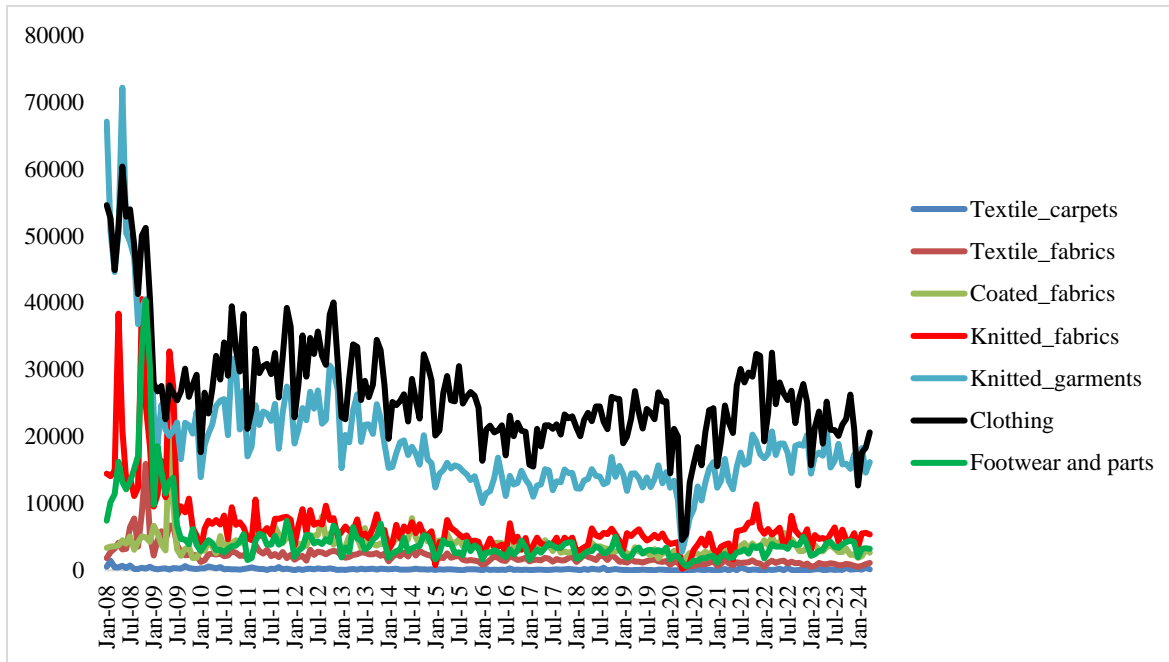
Source: authors.

Discussion of results

The research findings support one of the arguments found by Panzone et al. (2021), as among the most affected products are those that were not primary necessities; aspects that are generalized not only at the local level but for international needs, given the nature of the pandemic.

Moreover, the regional impacts found are similar to those described by Jumbo et al. (2020), who in Ecuador detect descriptively a temporary impact in the first months of 2020, which showed a generalized fall in income, however, the subsequent forecast may bring other scenarios, which deserves to be investigated in future work.

In light of other results such as those presented by Luque et al. (2021), food security was a significant concern, as the costs of inputs, raw materials, and transport increased greatly, therefore, these impacts could show other difficulties in subsequent years, aspects that deserve to be reviewed in greater depth later. Meanwhile, Stubbs et al. (2021) pointed out the importance of having economic strategies of liquidity or leverage, for greater financial security especially for sectors such as textiles, which show decreases in their sales at local and international levels and may need government relief such as low-interest loans. In this

sense, authors such as Sandoval & Sandoval (2022) or Sercan (2022) consider leverage and other financial strategies as solid support for business sectors in crisis, however, this must also be accompanied by adequate resource management that maintains their borrowing capacity in balance.

Impact assessments during or after pandemic lockdowns have occurred at many levels. This article presents evidence of the economic impact on some of the non-essential product sectors, contrary to those of food, which have managed to sustain themselves. However, other questions remain about what to do if other virus pandemics were to occur again? Or will the decrease in income affect non-primary production sectors for a longer time, further lowering their profitability?

Conclusions

The research findings reveal a significant impact on the decrease in exports, aligning with the hypothesis proposed in the counterfactual model. Initially, this model was applied to 97 time series, achieving convergence in 72 of them. Specifically, 9 series demonstrated a notable decrease in exports from April 2020 onwards. The primary hypothesis addressed was: What would have occurred if the pandemic had not materialized?

Based on these data, time series models were estimated to adjust export values. This process generated error indicators that facilitated the identification of the most accurate models. From these models, time series exhibiting significant decreases compared to initial forecasts were selected.

The findings of numerous affected series in our research both corroborate and, in some instances, diverge from previous studies. It is suggested that the majority of exports would have registered an increase, with percentage data ranging between 5 % and 40 %, had it not been for the pandemic. However, all growth projections are subject to errors, which can be even greater if they are predictions about possible trend changes made when the previous year's growth was negative. This discrepancy demonstrates a need for detailed analysis and the pursuit of support for many sectors, as the emergency implies both a supply and demand

economic shock; that is, it is affecting both producers and consumers (Cavallo & Powell, 2021).

Regarding specific affected products, a greater impact was observed in non-food items. Upon examining the groupings of tariff subheadings, it was detected that the textile sector, as well as others including toys, rubber, and furniture, along with leather and footwear, suffered the greatest effects in terms of exports during 2020. This was evidenced by decreases compared to projections from appropriate time series models.

Conversely, the sectors that registered a higher volume of exports were minerals, animals or their derivatives, chemical products, and food and beverages. These data underscore the complexity and scope of the pandemic's economic effects, offering a detailed perspective on how different sectors were affected in terms of exports during this critical period.

The present research has revealed significant findings that both align with and diverge from previous works in crucial areas, contributing to a deeper and more nuanced understanding of the pandemic's effects across various sectors.

The similarity with the arguments of Panzone et al. (2021) is evident in the identification of non-essential products as the most affected. This trend, not limited to a specific region, is reflected internationally, highlighting the universality of the challenges posed by the pandemic. This convergence points to the need for cohesive and well-articulated policies to address the complexity of the global impact.

On the other hand, the study has also shown similarities with the regional impacts described by Jumbo et al. (2020) in Ecuador. The correspondence in the fall of income during the first months of 2020 is a crucial aspect that deserves to be investigated in depth. However, it is essential to recognize that future scenarios are uncertain and could diverge from current expectations, underscoring the importance of continuous vigilance and evolving analysis.

Regarding food security, the results align with the concerns highlighted by Luque et al. (2021), related to increases in production costs. These trends could generate unforeseen difficulties in the future, requiring not only close monitoring but also flexible and long-term policy solutions.

Concurrently, the analysis coincides with the importance of economic strategies emphasized by Stubbs et al. (2021), especially in vulnerable sectors such as textiles. The need for financial support measures reflects a challenging economic reality that demands a coordinated and well-considered response from governments.

From a contemporary perspective and in line with emerging market needs, strategies focused on increasing business digitalization are highlighted. This trend towards reducing face-to-face channels not only represents an adaptation to the new normal but also offers a promising avenue for strengthening security in crucial activities such as order processing, both nationally and internationally. This transition to more robust and efficient digital channels, however, is a complex terrain that requires thorough analysis and deep exploration of new trends. Future research in this area, as noted by Ibn-Mohammeda et al. (2020) and Tanveer et al. (2020), will be fundamental to fully understanding and leveraging the opportunities and challenges inherent in this digital evolution. Innovation and collaboration between sectors may be key in building a solid and resilient digital infrastructure that supports sustainable business growth in the current global landscape.

Regarding the methodology used, the approach of mean percentage error difference indicators (MPE) allowed for establishing the differences between adjusted values with respect to real ones and analyzing the average relative differences with 95 % of the data (January 2008 to March 2020), to then forecast with the remainder. This approach is similar to that of Mejía (2021), who also examined fluctuations in exports over a time series. Through a different approach, simple differences over time could be analyzed. However, this methodology would be useful for projecting an estimated recovery time but has the limitation of subtracting some factors that influence projections, such as changes in trade policies or fluctuations in raw material prices. Nevertheless, the integration and contrast of these methodologies and findings reflect a complex and diverse understanding of the situation. The differences in results, methodologies, and underlying assumptions emphasize the importance of continued research, with the aim of providing a more solid basis for future policies and economic recovery strategies (Juliá Igual, et al 2022).

Finally, the research has shed light on a complex network of challenges and opportunities emerging from the pandemic. The interaction of these factors requires a multifaceted and

adaptive approach that considers both convergences and divergences with previous studies. Interdisciplinary collaboration and a future-oriented mindset will be fundamental in forging effective paths towards recovery and resilience in this unprecedented context.

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