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Research paper

Assessing the effects of covid-19 pandemic and lockdown measures on air quality in the city of talca, chile

Evaluación de los efectos de la pandemia de covid-19 y las medidas de confinamiento sobre la calidad del aire en la ciudad de talca, chile

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ABSTRACT

The COVID-19 pandemic led to the implementation of several quarantines in Chile, which meant a decrease in transportation flow and lower production levels in some companies. It also led to more people using wood burning at home for heating. This study aimed to determine the effect of the pandemic on air quality in Chile. The methodology consists of a regression analysis using ordinary least squares, where the effects of temperature, quarantine, and pandemic periods on daily emissions of PM2.5, PM10, CO2, and O3 were analyzed. The results show that for the dependent variables PM10, CO2, and O3, the variables minimum, average temperature, and pandemic were significant and inversely related to said pollutants. For PM2.5, the above is not true for the case of the pandemic, which positively affects PM2.5. The variable quarantine was not significant in all models. Finally, it was concluded that the COVID-19 pandemic has resulted in a change in air quality in the city of Talca, mainly due to the greater use of wood burning for heating; there was a high impact of the pandemic on these emissions, producing an increase in critical episodes of MP2.5 and MP10. Also, impacts were observed in O3 and CO2.

KEYWORDS */ COVID-19 / Quarantine / Energy Uses / Wood Burning / Pollution / Air Quality*

RESUMEN

La pandemia de COVID-19 llevó a la implementación de varias cuarentenas en Chile, lo que significó una disminución en el flujo de transporte y menores niveles de producción en algunas empresas. También llevó a que más personas usaran leña quemada en casa para calentarse. Este estudio tuvo como objetivo determinar el efecto de la pandemia en la calidad del aire en Chile. La metodología consiste en un análisis de regresión utilizando mínimos cuadrados ordinarios, donde se analizaron los efectos de los periodos de temperatura, cuarentena y pandemia sobre las emisiones diarias de PM2.5, PM10, CO2 y O3. Los resultados muestran que para las variables dependientes PM10, CO2 y O3, las variables mínimo, temperatura promedio y pandemia fueron significativas e inversamente relacionadas con dichos contaminantes. En el caso de las PM2.5, lo anterior no es cierto para el caso de la pandemia, que afecta positivamente a las PM2.5. La variable cuarentena no fue significativa en todos los modelos. Finalmente, se concluyó que la pandemia del COVID-19 ha provocado un cambio en la calidad del aire en la ciudad de Talca, principalmente por el mayor uso de la leña para calefacción; hubo un alto impacto de la pandemia en estas emisiones, produciendo un aumento en los episodios críticos de MP2.5 y MP10. Además, se observaron impactos en O3 y CO2.

PALABRAS CLAVE / COVID-19 / Cuarentena / Usos de energía / Quema de leña / Contaminación / Calidad del aire

INTRODUCTION

A study of global mortality and pollution levels estimated that about 9 million people die from the pollution of different sources each year (Burkart et al., 2022), with economic losses of over US$4 trillion (Fuller et al., 2022), the deaths are greater than those provoked by COVID-19, which are about 6.7 million globally (World Health Organization, 2023; Wu et al., 2022). According to the UN Environmental Programme (2017), In Chile, air pollution is a major issue, and it costs the health sector at least 670 million dollars, resulting in 127,000 emergency health consultations and over 4,000 deaths (UN Environmental Programme, 2017). The COVID-19 pandemic had a significant impact on air quality not only in Chile but across the world.

The global lockdowns and travel restrictions implemented to reduce the spread of COVID-19 resulted in a significant reduction in emissions from transportation and industry, leading to a significant improvement in air quality in many cities worldwide (Wang et al., 2022). For instance, in India, the lockdown resulted in an average reduction of 33% of particulate matter 2.5 (PM2.5) levels in major cities like Delhi, Mumbai, and Kolkata. Similarly, in China, the lockdown resulted in an average reduction of 40% in NO2 levels in February 2020 compared to the same period in 2019 (Niu et al., 2022). Studies have also reported significant reductions in nitrogen dioxide (NO2) levels in major cities in Europe (Ramacher et al., 2022), the United States (Dahu et al., 2023), and the Asia-Pacific region (M. Jakovljevic et al., 2020). A multi-city study in Spain found that the lockdown reduced the atmospheric levels of NO2 in all cities analyzed except for the city of Santander (Briz-Redón et al., 2021). Air quality in the metropolitan area of Santiago, Chile, showed that population quarantine and confinement reduced some air pollutants; PM2.5 decreased by 11% and particulate matter 10 (PM10) by 5.2% (F. et al., 2020). In general, studies show that meteorological changes, together with periods of quarantine have impacted the level and concentration of NO2 and PM between 60% and 31% in 34 countries (Kaied et al., 2021). The improvements in air quality were not uniform across the globe (Soriano et al., 2020). In some regions, air quality worsened during the pandemic (Kganyago & Shikwambana, 2020; Mbandi, 2020; Ranabhat et al., 2021). In addition, in some regions, the reopening of industries and transportation as the pandemic receded led to a rebound in air pollution levels (Chattu et al., 2021).

The sources of pollution may vary according to transportation and industrial emissions (Martinez-Soto et al., 2021). The main atmospheric pollutants that are hazardous to human health in Chile are inhalable particulate matter (PM10, PM2.5, and PM1) and gaseous chemical compounds, such as nitrogen dioxide, ozone, sulfur dioxide, and carbon monoxide. Factors such as industrial development, the number of automobiles, the use of fossil fuels, and the use of firewood for heating all contribute to the concentration of pollutants (Frostad et al., 2022). A study has shown that firewood for heating and cooking food accounted for 94% of PM2.5 emissions in central and south of Chile (Huneeus et al., 2020).

Several environmental-related studies in the region examined the perception and environmental behavior of users of firewood for heating. People consider the main air pollutant in the Maule is coming from wood-burning (65.4 %), and they are willing to pay to reduce pollution (Adams et al., 1993; A. Cerda et al., 2007; A.A. Cerda & Garcia, 2010; A.A Cerda & García, 2010; A. A. Cerda et al., 2010; L. Y. García & A. A. Cerda, 2021; García et al., 2021). The use of firewood to heat homes during the winter is a crucial factor in determining the air quality of a region, as it inevitably leads to an increase in respiratory health problems due to the smoke emitted from chimneys when people use wet firewood increasing pollution by particular maters, like PM2.5, and PM10 (MB Jakovljevic et al., 2013).

In March 2020, the arrival of COVID-19 in Chile, as in several countries worldwide, caused important changes in people's way of life, including energy use. The routines of individuals and families, as well as existing companies in the country, suffered modifications due to the restrictions associated with the COVID-19 pandemic. This situation modifies the energy demand and carbon dioxide (CO2) emissions, among other pollutants (Le Quéré et al., 2020). Additionally, government policies associated with controlling the COVID-19 pandemic, especially forced confinement, keep many people at home, during work, and leisure hours, which, in many cases, increases the use of energy for heating, electricity, oil, and wood burning (Leidy Y García & Arcadio A Cerda, 2021; García et al., 2021; Langille, 2021). Some policies implemented by the governments have generated impacts on the level of emissions of CO2 and particular materials, such as PM2.5, and PM10, changing the air quality and level of respiratory problems in the population (Martinez-Soto et al., 2021; Morales-Solís et al., 2021; Sánchez-López et al., 2022). For instance, in Chile, part of the population of the country stayed in their homes; therefore, this generated a reduction in transport use because of businesses and school closures, which decreased the concentration of MP10 and MP2.5 (Morales-Solís et al., 2021). By May 2020, a study by the National Chamber of Commerce (CNC) mentioned that 59% of the companies were working under 30% of their capacity, whereas 30% was at 0% (National Confederation of Commerce and Goods, 2020). Finally, the Chilean economy experienced a 6% decrease in the gross domestic product by 2020.

The research problem is derived from the need to determine how the pandemic has affected air quality indicators. The hypothesis is that there is a negative relationship between the COVID-19 pandemic and air quality in the city of Talca, where the greater moving restrictions generate higher pollution levels. This study aimed to determine the effect of the pandemic on air quality in Chile by a regression analysis using ordinary least squares, where the effects of temperature, quarantine, and pandemic periods on daily emissions of PM10, PM2.5, CO2, and O3

Material and methods

Location

This research concentrates on the city of Talca, the capital of the Maule Region, Chile, which is in the depression intermedia, a valley that extends through much of the continental territory of Chile and is in the space that develops between the Coastal and Andes Mountains. Talca has a Mediterranean climate and typically has four seasons, but two very defined seasons: a dry and a rainy/cold season. The average annual temperature is 13°C, with cold winters and frequent rain, fog, and frost. Summers are dry and hot, with maximum temperatures exceeding 32°C. The methodology for measuring contaminants is called Beta attenuation, which consists of determining how opaque the contaminated filter becomes to a standardized pollution so that the greater the environmental contamination, the greater the presence of these in the filter and consequently the less "transparency" of said filter before said pollution.

Data

The data used were the daily emissions of particulate matter PM2.5 and PM10, along with the daily temperature between January 2018 and August 2022. The data were obtained from the National Air Quality Information System (SINCA) from the air monitoring stations at La Florida. Continuous monitoring of PM10, PM2.5, CO2, and O3 ambient concentrations is conducted to estimate 24-hour moving averages. The data is updated every hour. The calculation of the 24-hour moving average is based on a minimum of 75% of the available data, which equates to a minimum of 18 hourly average.

Data pertinent to the quarantine periods were obtained from the COVID-19 Data Table led by the Ministry of Science, Technology, Knowledge, and Innovation, where epidemiological data from the Ministry of Health and other sources were obtained from the provisions of Law No. 19628. The period covered as a pandemic is from the detection of the first case of COVID-19 on March 1, 2020, until August 31, 2022.

Model

Based on the literature (A.A Cerda & García, 2010), a regression model was estimated, using the ordinary least squares method (OLS). Estimations were done with Stata. For the analysis it was established that air quality is related to a measure of particulate matter emissions ($PM_{2.5}$ and PM_{10}), which is called the Air Quality Index(ICA); and will be studied according to four variables with daily data (t). The first two correspond to the minimum (T_{Mt}) and average temperatures ($Tavg_t$), respectively, whereas the remaining are dummy variables that allow us to assess the effect of the pandemic (P_t) and quarantine periods (Q_t) in the ICA (1). Where P_t=1 if there are pandemic and cero if not. Similarly, P_t =1 with pandemic period and 0 otherwise.

$$ICA_t = f\left[T_{M_t}, Tavg_t, P_t, Q_t\right] \quad + \varepsilon \tag{1}$$

Equations (2) and (3) are the estimated final models:

$$PM2.5_t = \beta_0 + \beta_1 T_{Min_t} + \beta_2 T_{avg_t} + \beta_3 P_t + \beta_4 Q_t + \varepsilon \tag{2}$$

$$PM10_t = \beta_0 + \beta_1 T_{Min_t} + \beta_2 T_{avg_t} + \beta_3 P_t + \beta_4 Q_t + \varepsilon \tag{3}$$

The ICA is related to emissions of particulate matter; in this case, we considered PM2.5 and PM10. We included four independent variables: two related to temperature, and two dummy variables related to the pandemic. These were minimum temperature (T_{Min}), average temperature (T_{avg}), a dummy variable that allows us to assess the effect of the pandemic (*P*) and other to assess quarantine periods (*Q*) in the *ICA* (1).

Based on the literature (A.A Cerda & García, 2010), a regression model was estimated, using the ordinary least squares method (OLS). Estimations were done with Stata. For the analysis it was established that air quality is a measure of particulate matter emissions, which is called the Air Quality Index (*ICA*); and will be studied according to four variables with daily data (t). The first two correspond to the minimum (T_{Mt}) and average temperatures (T_{avgt}), respectively, whereas the remaining are dummy variables that allow us to assess the effect of the pandemic (P_t) and quarantine periods (Q_t) in the *ICA* (1). Where P_t=1 if there are pandemic and cero if not. Similarly, P_t =1 with pandemic period and 0 otherwise.

$$ICA_t = f\left[T_{M_t}, Tavg_t, P_t, Q_t\right] \quad + \varepsilon \tag{1}$$

Equations (2) and (3) are the estimated final models:

$$PM2.5_t = \beta_0 + \beta_1 T_{Min_t} + \beta_2 T_{avg_t} + \beta_3 P_t + \beta_4 Q_t + \varepsilon \tag{2}$$

$$PM10_t = \beta_0 + \beta_1 T_{Min_t} + \beta_2 T_{avg_t} + \beta_3 P_t + \beta_4 Q_t + \varepsilon \tag{3}$$

The ICA is related to emissions of particulate matter; in this case, we considered $PM_{2.5}$ and PM_1 . We also estimate the above model for CO_2 and O_3. We included four independent variables: two related to temperature, and two dummy variables related to the pandemic. These were minimum temperature (T_{Min}), average temperature (T_{avg}), a dummy variable that allows us to assess the effect of the pandemic (*P*) and other to assess quarantine periods (*Q*) in the ICA (1).

Results

Antecedents

Table I presents the reference limits for emergency levels of the Primary Quality Standard for PM2.5 and PM10. These limits trigger emergency pollution control measures, which include promoting responsible and efficient wood heating practices, enforcing restrictions on visible smoke emissions from homes during specified hours, and prohibiting the operation of wood or coal boilers, among other actions.

Table I. Category Limits of Emergency Levels of the Quality Standard for $pm_{2.5}$ and pm_{10}

Category	Daily concentration $PM_{2,5}$ µm/m3	Daily concentration PM_{10} µm/m3
Good	Entre 0 y 79	Entre 0 y 194
Alerta	Entre 80 y 109	Entre 195 y 239
Pre-emergency	Entre 110 y 169	Entre 240 y 329
Environmental Emergency	170 o superior	330 o superior

Source: Ministry of Environment.

Table II shows the number of annual critical episodes of PM2.5, in Talca. We can observe that the number of episodes in 2020, with confinement, is quite like the average number of critical episodes for 2017-2022 (Ministerio del Medio Ambiente, 2022).

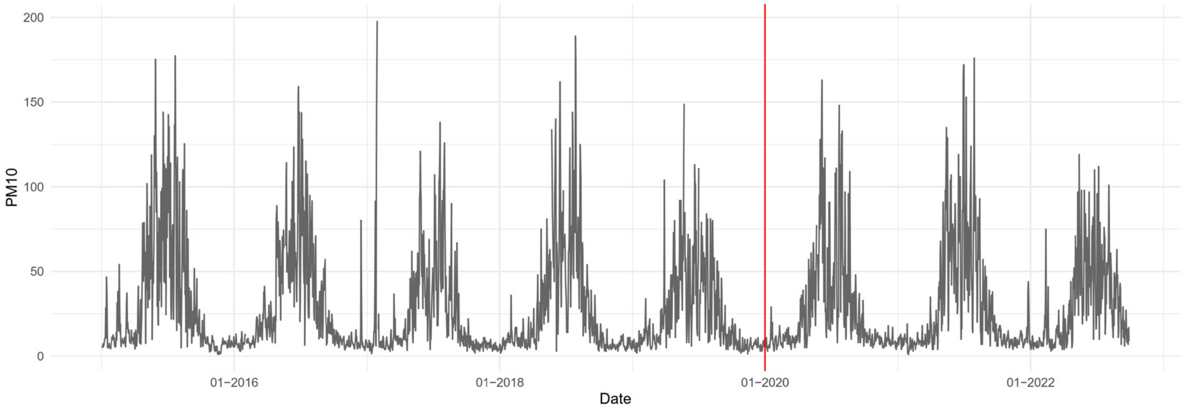
Table II. Annual Critical Episodes Of $PM_{2.5}$ in Talca

Year	Number of critical episodes
2016	49
2017	27
2018	59
2019	33
2020	42
2021	61
2022	30
Average	43

Source: Author's elaboration based on reports of the evolution of critical episodes for MP2.5 of the Ministry of Environment between 2016 and 2022.

Figure 1 shows the daily record of PM10 in µg/m3(micrograms per normal cubic meter) in the city of Talca, University of Talca Station, from January 1, 2015, to September 30, 2022. It follows that the average emission of PM10 of the pre-pandemic period (taken from January 1, 2015, to December 31, 2019) was 42.42 µg/m3, according to validated records, with a minimum of 3 and a maximum of 210.6, while during the pandemic (taken from January 1, 2020, to September 30, 2022), it is shown that the average emission of PM10 is 38.96 µg/m3, with a minimum of 4 and a maximum of 158 (Chilean Ministry of Environment, 2022).

Figure 1. Average daily emissions of PM10, 01/01/2015 - 30/09/2022 at La Florida.



Source: Own elaboration based on data on PM10 emissions from La Florida Monitoring Center. Data from the Air Quality Information System (SIMCA), Ministry of Environment. The red line marks the pre- and post-pandemic periods.

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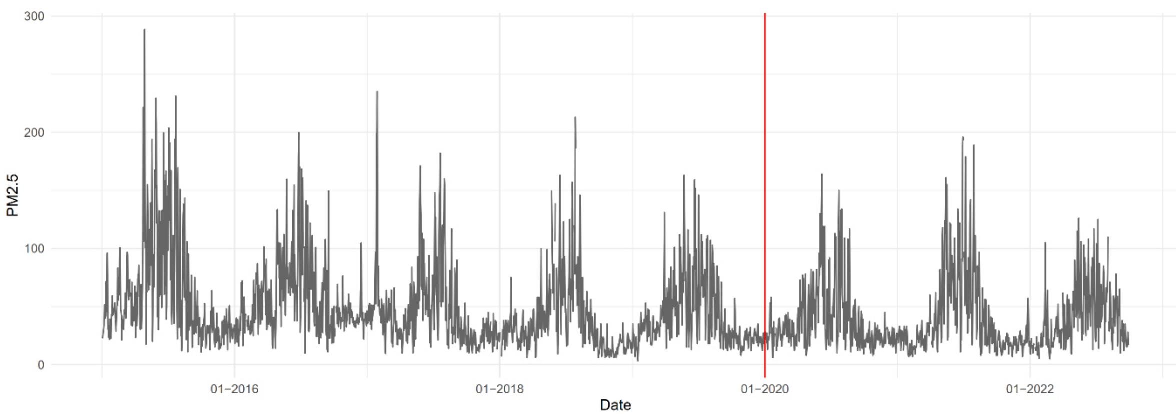
Figure 2 shows the average daily emission of PM2.5 in the pre-pandemic period (January 1, 2015, to December 31, 2019) is 17.83 µg/m3, with a minimum of 1 and a maximum of 161.3. During the pandemic (January 1, 2020, to September 30, 2022), the average PM2.5 was 16.96 µg/m3, with a minimum of 1 and a maximum of 127 (Ministerio del Medio Ambiente, 2021).

Figure 2. Average daily emissions $PM_{2.5}$, 01/01/2015 - 30/09/2022 at La Florida.



Source: Own elaboration based on data on PM10 emissions from La Florida Monitoring Center. Data from the Air Quality Information System (SIMCA), Ministry of Environment. The red line marks the pre- and post-pandemic periods.

When comparing the pre-pandemic and pandemic periods, it follows that there was a change in both emissions of particulate matter, with aerodynamic diameters less than or equal to 10 micrometers and 2.5 micrometers. However, it can be noted that the change in the PM_{10} had a greater decrease than that of the $PM_{2.5}$, passing its average from 42.42 to 38.96 µg/m3, and going from a maximum of 210.6 to 158 µg/m3.

The pandemic period was marked by the implementation of mandatory quarantine, which meant the obligation to remain at home for a certain period (Carvalho et al., 2021). These quarantines caused a change in the routine of the country, reducing transportation uses and the closure or reducing production in some companies, but also brought with it an increase in wood heating due to people staying at home, which contributes to the increase in fine particulate matter in some cases. The cities belonging to the south and south centers of the country were the most affected owing to the high consumption of this type of energy for heating (Morales-Solis et al., 2021).

Talca entered quarantine for the first time on January 23, 2021, with 415 active cases. The city ended its first quarantine on February 21, but on March 18, it was again mandated. There are a series of periods in which the population was confined: January 23, 2021, February 21, 2021, March 18, 2021, April 28, 2021, and June 5 to June 23. The city has a total of 91 days. During this period of constant quarantines, from January 23 to June 23, the average $PM_{2.5,}$ according to records validated by the Ministry of the Environment, was 18.54 ug/m3(36).

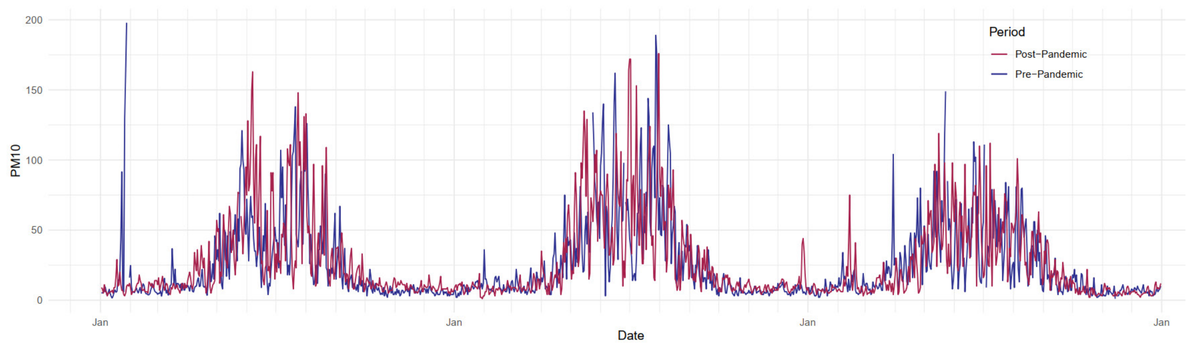
Data description

The descriptive analysis of the data showed that during the pandemic, there were higher emissions of PM, considering the number of critical episodes, by $MP_{2.5,}$ which increased by 18 during the pandemic period, while those by MP_{10} increased by five episodes. Between May and September, the highest levels of emissions were recorded, regardless of the observation period.

Daily Emission comparison between pre and pandemic periods

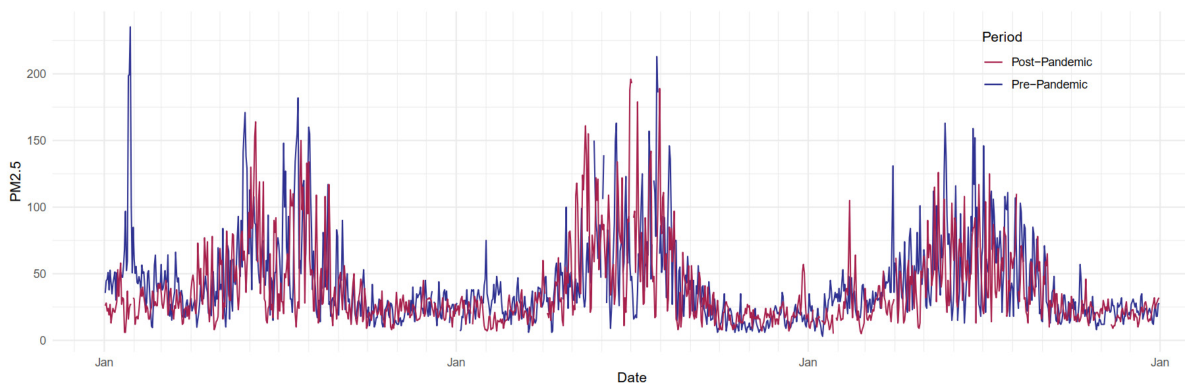
Fig. 3 and 4 show a daily comparison of PM_{10} and $PM_{2.5,}$ before the COVID-19 pandemic and during the pandemic, respectively. We can observe that the emission of $PM_{2.5}$ increased considerably, especially in 2021, during the months of July and August (Table III).

Figure 3. Daily comparison of PM10 between pre-pandemic and pandemic emissions.



Source: Own elaboration based on data on PM10 emissions from La Florida Monitoring Center. Data from the Air Quality Information System (SIMCA), Ministry of Environment. Overlapped data considers the periods 2017-01-01 to 2019-12-31 and 2020-01-01 to 2022-12-31.

Figure 4. Daily comparison of $PM_{2.5}$ between pre-pandemic and pandemic emissions.



Source: Own elaboration based on data on PM2.5 emissions from La Florida Monitoring Center. Data from the Air Quality Information System (SIMCA), Ministry of Environment. Overlapped data considers the periods 2017-01-01 to 2019-12-31 and 2020-01-01 to 2022-12-31.

Table III. Statistical Summary

	$MP_{2.5}$	MP_{10}	CO2	Average Temperature	Minimum Temperature	Minimum Temperature Range
Pre-Pandemic	24.95 (28.22)	39.17 (29.67)	70.21 (59.88)	15.33 (5.8)	9.07 (4.5)	-3.84; 19.01
Post-Pandemic	30.24 (30.52)	40.47 (31.23)	73.51 (58.21)	14.1 (5.39)	8.22 (4.18)	-3.6; 17.3
Total	27.79 (29.59)	39.86 (30.52)	71.98 (58.99)	14.67 (5.62)	8.61 (4.35)	-3.84; 19.01

The averages for $MP_{2.5}$, MP_{10}, and CO are measured in µg/m^3. The temperatures are measured in Celsius degrees. The numbers in parentheses are the standard deviations. The pre-pandemic period in our data and models corresponds to 01/01/2018 to 31/12/2019. The post-pandemic period corresponds to 01/01/2020 to 31/08/2022.

Models estimates

With a sample size of 2068 observations per variable, between pre-pandemic and pandemic periods, the study was carried out with the Air Quality Index (ICA) considering two models:

The models presented in Eqs. 2 and 3 were estimated for PM_{10} and $PM_{2.5,}$ for the La Florida monitoring station. The results of these estimations are presented in Table IV.

Table IV. Econometric model results for $PM_{2.5}$ and PM_{10}, monitoring Station La Florida

Variable	La Florida monitoring station Model 1 (PM10) Coefficient (t-student)	 Model 2 (PM2.5) Coefficient (t-student)
Minimum Temperature (Tmin)	-0.6438*** (-2.60)	-2.3033*** (-8.10)
Average temperatura (Tavg)	-3.4166*** (-10.64)	1.8726*** (-8.53)
QUARANTINE (Q)	2.2667 (0.83)	1.2833 (0.53)
PANDEMIC (P)	-2.6067** (-2.11)	0.8162 (0.75)
Constant	80.0181*** (41.39)	74.6442*** (43.57)

Model 1.R^2 = 0.3506; F statistic =229.35; valor-p < 0.000; Model 2. R^2 = 0.4597; F statistic =360.75; ***p-value < 0.001;** p-value < 0.005; ***p-value < 0.01

Estimation of Models 1 and 2 for La Florida Station

When the minimum temperature increases one degree, emissions of coarse particulate matter decrease by 0.64 micrometers (μg/m3). As the average temperature rises by one degree, emissions decrease by 3.41 μg/m3. On the other hand, if you are in periods of pandemic compared to pre-pandemic, and the rest constant, there will be a decrease of 2.60 μg/m3 in PM_{10} emissions.

For the fine particulate matter $PM_{2.5.,}$ it was determined that the minimum temperature and average temperature are the only two significant variables, both of which have a negative relationship with $PM_{2.5.}$ emissions. When the minimum temperature increases one degree, emissions of fine particulate matter decrease by 2.30 micrometers (μg/m3). With an increase in the average temperature of one degree, emissions decrease by 1.87 μg/m3.

Estimation of Models 3 (CO2) and 4 (Ozone) for La Florida Station

For Ozone, the results showed that both minimum temperature and average temperature and quarantine are significant variables for the model, where minimum temperature, quarantine and pandemic have a negative relationship with O3, while average temperature has a positive relationship with it. When the minimum temperature increases one degree, O3 decreases by 0.28 parts per billion (ppb). When there is an increase of one degree in the average temperature, there will be an increase in Ozone of 0.62 ppb. On the other hand, if you are in quarantine periods, this will bring with it a decrease of 2.03 ppm.

Table V: Econometric model results for Co2 and ozone, monitoring center La Florida

Variable	La Florida monitoring station Model 3 (CO2) Coefficient (t-student)	 Model 4 (OZONE) Coefficient (t-student)
Minimum Temperature (Tmin)	-5.0896*** (-7.93)	--0.2863*** (-4-86)
Average temperatura (Tavg)	-2.0059*** (-4.04)	0.6254*** (13.74)
QUARANTINE (Q)	-1.9153 (-0.35)	-2.0345*** (-4.03)
PANDEMIC (P)	-3.2751 (-1.33)	-0.0765 (-0.34)
Constant	147.1234*** (38.05)	3.0697*** (8.64)

Model 5. R^2 = 0.3053; F statistic = 186.56; Model 6. R^2 = 0.2327; F statistic =128.48; valor-p < 0.000; ***p-value < 0.001; **p-value < 0.005; ***p-value < 0.01

DISCUSSION

Particulate matter and various chemical compounds can have significant impacts on both environmental quality and human health (Jin et al., 2022). Numerous studies have demonstrated that the burning of firewood for residential heating in the winter months can result in a reduction in air quality, which aligns with the results of our study when considering $PM_{2.5,}$ which is related positively with the variable pandemic (A. Cerda et al., 2010; A. A. Cerda et al., 2010). However, other research has suggested that air quality improvements occurred during the pandemic due to reductions in several human activities. (Dahu et al., 2023; Kaied et al., 2021); the same occurred in China, where $PM_{10,}$ $PM_{2.5,}$ $NO_{2,}$ and CO showed the largest reduction during the shutdown period of COVID-19 in 2020 (Niu et al., 2022). In our study, the variable pandemic was negatively related to $PM_{10,}$ CO_2 and O_3, generating a better quality of the air. This does not happen with $PM_{2.5.}$

This can be explained by the fact that PM emissions and concentrations have multiple sources, including climate, traffic, industry, commerce, and home heating, which can have a positive or negative impact on air quality (Wang et al., 2022). The latter stands out because heating by burning wood is highly used in the region, and when spending extended periods at home, the population uses it to a greater extent, generating more emissions of particulate matter. Reinforcing this point, new studies have concluded that the decrease in traffic emissions is offset by an increase in PM_{10} associated with domestic heating. Similar results were found in Italy, where certain air pollutants showed improvement during periods of the pandemic, unlike $PM_{10.}$ The analysis of some cities revealed that the national closure did not affect the reduction of the average concentration of $MP_{2.5}$ and PM_{10} in the pre-closure and that they were higher during 2020 compared to the same period in 2019 (Feiferyte Skiriene & Stasiskiene, 2021).. Additionally, climate change can affect energy consumption and emissions levels (Dirks et al., 2015; Grima et al., 2021).

Summarizing de models result, for the dependent variables $PM_{10,}$ $CO_{2,}$ and $O_{3,}$ the variables minimum, average temperature, and pandemic were significant and inversely related to said pollutants. For $PM_{2.5,}$ the above is not true for the case of the pandemic which affects positively $PM_{2.5,}$ worsening air quality measured by this indicator. The variable quarantine was not significant in all models.

CONCLUSIONS

The findings of this research reveal that the COVID-19 pandemic caused a shift in air quality within the city of Talca. While emissions of particulate matter typically increase between May and September each year due to the onset of autumn and winter and increased wood heating usage, the quarantine measures had a significant impact on these emissions (Grima et al., 2021). There was a marked increase in the frequency of critical episodes of both $PM_{2.5}$ and PM_{10} during the quarantine period, with $PM_{2.5}$ exhibiting a higher increase because the pandemic.

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