# RELATIONSHIP BETWEEN POLLUTION LEVELS AND POVERTY: REGIONS OF ANTOFAGASTA, VALPARAISO AND BIOBIO, CHILE

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## ABSTRACT

The regions of Antofagasta, Valparaíso and Biobío present a series of environmental problems. Inhabitants perceive that air pollution, water pollution and rubbish contamination contribute to the deterioration of the quality of life in their territories. Based on air pollution information obtained from monitoring stations of the National Air Quality Information System (SINCA), meteorological information obtained from the Meteorological Directorate of Chile, and socioeconomic information on income poverty level, multidimensional poverty level, and energy poverty level, a data panel was constructed with information from 2017 to 2021 with daily information at the commune level. Three ordinary least squares regression models were estimated to determine the relationship between the socioeconomic variables (income poverty, multidimensional poverty and fuel poverty) and each of the pollutants studied. The results show that, in general, there is a positive and significant relationship between the level of income poverty, multidimensional poverty and fuel poverty. The main objective of this study was to investigate the possible relationship between pollution and the variables of income poverty, multidimensional poverty and fuel poverty, in order to build evidence that will allow the creation of environmental public policies in the future.

*Keywords: air pollution, energy poverty, environmental issues, multidimensional poverty, particulate matter, sulfur dioxide.*

## 1 INTRODUCTION

The 2019 National Environmental Survey [1], conducted by the Ministry of Environment of the Government of Chile, shows that the regions of Antofagasta, Valparaíso and Biobío present important similarities in terms of environmental degradation. Respondents consider that atmospheric pollution, water pollution or its restricted use for human consumption, and rubbish pollution contribute significantly to the deterioration of the quality of life in their territories. They also point out that, in their communes, the activities that have a major impact on air pollution are industries (mining industry, energy production, pulp mills, forestry industries, agro-industrial production, copper smelters, cement works, etc.), domestic heating (particularly in the Biobío region) and transportation networks (cars, buses, trucks, etc.).

The results of pollution in these three regions, empirically, derive from the negative externalities [2] of their industrial mining, agricultural and forestry poles [3], added to an explosive population growth in recent decades, as a consequence of a mobile labor market, increased services and a strong migratory flow [4], putting pressure on urban infrastructure, promoting economic growth without sustainable development, where pollution is one of the notorious effects that the territories and their communities must currently face.

Although Chile implemented an environmental policy in the mid-1980s [5], institutionalizing a government program under the creation of the National Environmental Commission in 1994, which in 2010 became the Ministry of the Environment [6], progress has tended to slow down because the neo-extractivist economic growth model [7–9] has intensified


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productive processes with high environmental impact, where many of the industrial areas have been located next to poor communities.

The object of study, the regions of Antofagasta (8 active conflicts), Valparaíso (16 active conflicts) and Biobío (2 active conflicts) are among the territorial spaces with the greatest environmental conflicts in Chile at present. According to the National Institute of Human Rights [10] during 2018, emissions and contamination of natural resources resulting from energy, mining, agro-industrial and forestry projects, represented 60% of the total number of conflicts [11, 12]. The territories involved present worrying figures of multidimensional poverty, insufficient public health services and a lax environmental policy regarding the exploitation of natural resources and emissions of polluting particles [13] to such an extent that some of these localities have become sacrifice zones, which have increased their inequality indicators [9, 14].

The Chilean State has made unsuccessful attempts to reduce environmental damage – to air, soil and biodiversity – throughout the country. Despite increased environmental regulation in the last decade – since the creation of the Ministry of Environment – better investment in technology and monitoring instruments, both the state and companies (particularly energy, mining and forestry companies) continue to fail to resolve pollution episodes in their multiple dimensions. Antofagasta, Valparaíso and Biobío have repeatedly presented critical episodes of air saturation as a result of the production process carried out in those areas. The instruments and measurements, in turn, have been imprecise in clarifying the toxicological damage to the population, which is added to other environmental disasters produced by fuel spills, chemical substances and waste from productive activities, damaging ecosystems and the sustainability of self-subsistence activities, thus widening the inequality in the assurance of environmental rights to the communities. It is paradoxical that the State itself is often the protagonist in the movement to ensure the human right to live in a pollution-free environment. Both the National Petroleum Company (ENAP) and the National Copper Corporation (CODELCO) are responsible for particulate emissions in the regions studied, which complicates the State's role as guarantor of the protection of the right to live in pollution-free territories.

The main objective of this study is to identify the relationship between socioeconomic variables and pollution in order to establish evidence for the implementation of environmental public policies in the territories. Socioeconomic variables, such as income poverty, multidimensional poverty and energy poverty, are considered. The last variable seems to be of paramount importance. It is an articulating concept in today's global energy policy, seeking to guarantee equitable access to quality energy services for human populations without exception and to direct efforts toward a just energy transition that consolidates a decarbonized economy [15, 16]. Looking at the household without omitting relevant energy conditions at the territorial scale, are issues that in this study are complementary in the three regions studied.

The rest of the paper is organized as follows. Section 2 presents the data collection and methodology. Section 3 presents the results and, finally, the conclusions are highlighted in Section 4.

## 2 MATERIALS AND METHODS

### 2.1 Data

The data used in this study were obtained from various sources. Firstly, pollution data obtained from the National Air Quality Information System (SINCA) website between

Table 1: Monitoring stations by region.

| Region | Commune | Monitoring Station |
|---|---|---|
| Antofagasta | Tocopilla | Tres Marias, Super Site, Gobernación, Bomberos |
| | Antofagasta | Antofagasta |
| | Calama | Nueva Chiuchiu, Hospital, El Cobre, Colegio Pedro Vergara, Club Deportivo 23 de marzo, Estación Centro |
| Valparaíso | Valparaíso | Valparaíso |
| | Viña del Mar | Viña del Mar |
| | Concón | Junta de Vecinos, Concón, Las Gaviotas, Colmo |
| | Quillota | San Pedro, La Palma, Cuerpo de Bomberos |
| | Catemu | Romeral, Catemu, Santa Margarita |
| | Panquehue | Lo Campo |
| | Quintero | Valle Alegre, Sur, Loncura, Centro Quintero, Quintero |
| | Puchuncaví | Los Maitenes, La Greda, Ventanas, Puchuncaví |
| Biobío | Curanilahue | Balneario Curanilahue |
| | Nacimiento | Club de empleados, Lautaro, Entre Ríos |
| | Los Angeles | Los Angeles Oriente, 21 de Mayo |
| | Laja | Laja |
| | Coronel | Cerro Merquín, Coronel Norte, Calabozo |
| | Hualqui | Hualqui |
| | Chiguayante | Punteras |
| | Hualpen | Bocatoma, ENAP Price, JUNJI |
| | Talcahuano | Indura, Inpesca, Nueva Libertad, Consultorio San Vicente |
| | Concepcion | Kingston College |
| | Tome | Liceo Polivalente |

January 2017 and December 2021 were downloaded. Below, in Table 1, is a list by region, commune and names of the monitoring stations considered.

This allowed the formation of a data panel with daily concentrations (μg/m$^3$) of PM10, PM2.5 and $SO_2$ from monitoring stations in the regions of Antofagasta, Valparaíso and Biobío. The monitoring stations considered in this study are those that had information available for the period studied. A total of 54 monitoring stations were used, covering an area of approximately 52,928 km$^2$.

Subsequently, meteorological data were downloaded from the Meteorological Directorate of Chile (MeteoChile), which allowed the formation of a data panel with temperature (degrees Celsius, °C), humidity (percentage) and waterfall (mm) on a daily basis. Finally, poverty data were obtained from the National Socioeconomic Characterization Survey (Encuesta de Caracterización Socioeconómica Nacional [CASEN]). In particular, data on unemployment, income poverty, multidimensional poverty and energy poverty were used to construct an indicator that represents the percentage of people in the commune in this condition. For the calculation of fuel poverty, the Low Income-High Cost method [17] was used. The household income level is reduced by the amount spent on electricity by the family, thus obtaining an adjusted income that was compared to the poverty line. In this way, the percentage level of energy poverty per commune was obtained.

The splicing of the aforementioned databases makes it possible to answer the research questions posed. As a result, a panel of 34,462 records for PM10, 32,190 records for PM2.5 and 36,383 records for $SO_2$ was obtained.

The location of the 54 monitoring stations is shown in the following map (Fig. 1) for each of the regions.

The descriptive statistics by pollutant are shown in Table 2.

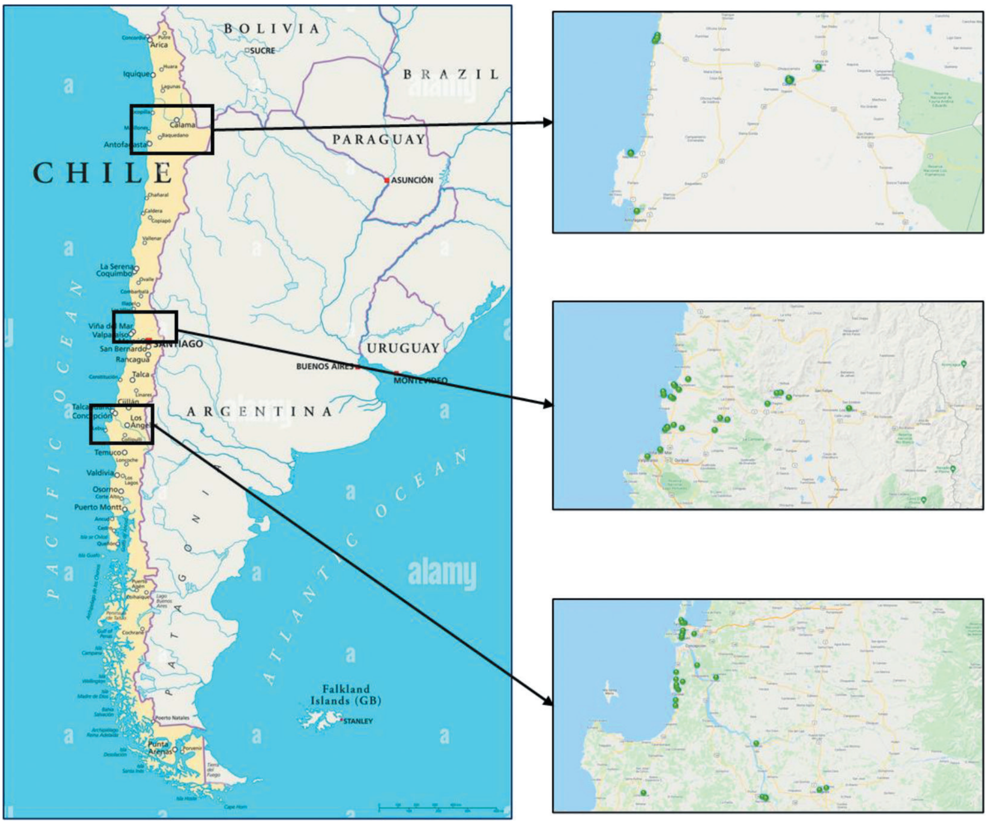


Figure 1: Location of the 54 monitoring stations [18, 19].

Table 2: Descriptive statistics by pollutant.

| Variables | Observations | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Particulate matter 10 | 34,575 | 36.71607 | 21.04791 | 0 | 874 |
| Particulate matter 2.5 | 32,266 | 17.19745 | 18.07546 | 0 | 529 |
| Sulfur dioxide | 36,522 | 4.695554 | 6.420443 | 0 | 77 |

## 2.2 Methodology

Three multiple linear regression models were estimated and, using the ordinary least squares (OLS), the estimators of $\hat{\beta}$ were obtained in order to study the relationship between pollution (PM10, PM2.5 and $SO_2$) and poverty [20]. The first model aims to explain the effect of income poverty on PM10, PM2.5 and $SO_2$ pollution, and is expressed as follows:

$$y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 R_{it} + \beta_4 Z_i + \beta_5 D_i + \in_{it} \tag{1}$$

where:

$y_{it}$: Logarithm of the daily concentrations of PM10, PM2.5 and $SO_2$, measured in (μg/m$^3$), for each commune *i* and for each day *t*.

$T_{it}$: Temperature measured in degrees Celsius (°C), for each commune and day.

$H_{it}$: Percentage of ambient humidity, for each commune and day.

$R_{it}$: Total rainfall (mm), for each commune and day.

$Z_i$: Income poverty level of commune *i*.

$D_i$: Unemployment rate of commune *i*.

Subsequently, a fixed effect per year and month is included, which allows for controlling for all types of seasonality. The results are presented for each type of pollutant.

The second model corresponds to a variation of the first one. The income poverty explanatory variable is replaced by the multidimensional poverty variable. The expression is as follows:

$$y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 R_{it} + \beta_4 M_i + \beta_5 D_i + \in_{it} \tag{2}$$

where $M_i$ represents multidimensional poverty in commune *i*. As in the previous estimation, year and month controls are included to control for all types of seasonality. Results are presented for each type of pollutant.

In the third model, the explanatory variable of multidimensional poverty is replaced by the fuel poverty indicator, leaving the model as follows:

$$y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 R_{it} + \beta_4 E_i + \beta_5 D_i + \in_{it} \tag{3}$$

where $E_i$ represents the percentage of fuel poverty in the commune *i*. As in the previous estimations, time fixed effects are included. The results are shown for each type of pollutant.

# 3 RESULTS

The results obtained from the first estimation model (eqn (1)) are shown in Table 3. It is possible to see that the meteorological variables are related to the different pollutants. Specifically, in the case of precipitation, a negative and significant relationship with the different pollutants can be seen. In the case of temperature, a negative and significant relationship with both types of particulate matter was found, while with $SO_2$, the correlation is positive and significant. Finally, in the case of ambient humidity, the relationship is negative and significant in the case of PM10, while for PM2.5 and $SO_2$, it is positive and significant.

In the particular case of the variable of interest, the results confirm the assumptions showing how income poverty is positively and significantly related to both types of particulate matter (PM10 and PM2.5) and $SO_2$. The unemployment variable shows a positive and significant relationship for PM2.5 and a negative and significant correlation for $SO_2$, the latter being closely linked to economic activity, as less pollution is generated when there is less

Table 3: Summary of results from eqn (1) – OLS.

| **Variables** | **PM10** | **PM2.5** | **$SO_2$** |
|---|---|---|---|
| Temperature | −0.702*** | −1.912*** | 0.187*** |
| | (0.0473) | (0.0407) | (0.0107) |
| Water | −0.623*** | −0.361*** | −0.0780*** |
| | (0.0201) | (0.0170) | (0.00843) |
| Humidity | −0.103*** | 0.0696*** | 0.0512*** |
| | −0.00492 | −0.00323 | −0.00153 |
| Income poverty | 0.0000327*** | 0.0000898*** | 0.00000944*** |
| | (0.00000416) | (0.00000439) | (0.000000974) |
| Unemployed | −0.00000527 | 0.0000474*** | −0.0000734*** |
| | (0.00000623) | (0.00000562) | (0.00000137) |
| Const. | 52.54*** | 26.43*** | 4.370*** |
| | (0.824) | (0.636) | (0.199) |
| Observations | 34,462 | 32,190 | 36,383 |
| R-squared | 0.035 | 0.218 | 0.082 |
| Fixed effect Month | Yes | Yes | Yes |
| Fixed effect Year | Yes | Yes | Yes |

Robust standard errors in parentheses.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

economic activity. The results corroborate that the economic growth model has intensified productive processes with a high environmental impact [7–9].

The results obtained from the second estimation model (eqn (2)) are similar to those obtained in the previous section and are shown in Table 4.

Precipitation shows a negative and significant relationship with the different pollutants. In the case of temperature, there is a negative and significant relationship with PM10 and PM2.5, while with $SO_2$, the correlation is positive and significant. Finally, in the case of ambient humidity, the relationship is negative and significant only in the case of PM10, while for PM2.5 and $SO_2$, it is positive and significant.

In the particular case of the variable of interest, the results confirm the assumptions showing how multidimensional poverty is positively and significantly related to all pollutants; these results confirm the relationship found by Herrera *et al.* [13]. In the case of unemployment, a positive and significant relationship is shown for PM10 and PM2.5 and a negative and significant correlation for $SO_2$, the latter being closely linked to economic activity, since less pollution is generated when there is less economic activity.

Finally, the results of the third estimated model (eqn (3)) are shown in Table 5. It can be seen that the relationship between the meteorological variables and the different pollutants is the same as in the previous estimations in terms of sign and significance, which confirms the need to generate efforts toward an energy transition [15, 16]. In relation to fuel poverty, the results show that there is a positive and significant relationship with all pollutants. As for unemployment, the relationship takes a negative and significant value for PM10 and $SO_2$, while for PM2.5, the relationship is positive and significant.

Table 4: Summary of results from eqn (2) – OLS.

| Variables | PM10 | PM2.5 | $SO_2$ |
|---|---|---|---|
| Temperature | –0.755*** | –1.902*** | 0.153*** |
| | (0.0459) | (0.0411) | (0.0115) |
| Water | –0.574*** | –0.317*** | –0.0364*** |
| | (0.0199) | (0.0176) | (0.00823) |
| Humidity | –0.124*** | 0.0799*** | 0.0311*** |
| | (0.00556) | (0.00446) | (0.00172) |
| Multi. poverty | 16.12*** | 6.690*** | 12.33*** |
| | (1.349) | (1.336) | (0.426) |
| Unemployed | 0.0000313*** | 0.000131*** | –0.0000717*** |
| | (0.000054) | (0.00000465) | (0.0000018) |
| Const. | 50.40*** | 23.47*** | 4.304*** |
| | (0.837) | (0.637) | (0.199) |
| Observations | 34,462 | 32,190 | 36,383 |
| R-squared | 0.036 | 0.196 | 0.096 |
| Fixed effect Month | Yes | Yes | Yes |
| Fixed effect Year | Yes | Yes | Yes |

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 5: Summary of results from eqn (3) – OLS.

| Variables | PM10 | PM2.5 | $SO_2$ |
|---|---|---|---|
| Temperature | –0.713*** | –1.920*** | 0.192*** |
| | (0.0473) | (0.0408) | (0.0107) |
| Water | –0.626*** | –0.365*** | –0.0712*** |
| | (0.0200) | (0.0172) | (0.00847) |
| Humidity | –0.110*** | 0.0673*** | 0.0527*** |
| | (0.00498) | (0.00321) | (0.00157) |
| Energy poverty | 0.0000409*** | 0.000083*** | 0.00000229*** |
| | (0.00000351) | (0.00000383) | (0.000000889) |
| Unemployed | –0.0000130** | 0.000045*** | -0.000000776*** |
| | (0.00000597) | (0.00000559) | (0.00000145) |
| Const. | 52.87*** | 26.87*** | 5.167*** |
| | (0.825) | (0.642) | (0.200) |
| Observations | 34,462 | 32,190 | 36,383 |
| R-squared | 0.037 | 0.219 | 0.078 |
| Fixed effect Month | Yes | Yes | Yes |
| Fixed effect Year | Yes | Yes | Yes |

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

## 4 CONCLUSIONS

Air pollution is one of the main problems affecting the population. Despite the existence of an environmental policy in Chile since the mid-1980s, progress has slowed down as a result of the economic growth model that has generated a high environmental impact and many of the industrial areas have been located next to poor communities. The work focused on three regions of the country that have important similarities in terms of environmental degradation: Antofagasta, Valparaíso and Biobío. Air pollution data were used: fine particulate matter (PM2.5), coarse particulate matter (PM10) and sulfur dioxide ($SO_2$), meteorological indicators and socioeconomic variables, from 2017 to 2021. A total of 54 monitoring stations from the three different regions covering an area of approximately 52,928 km² were used. The purpose of the study was to determine the relationship between pollution and socioeconomic variables, in particular income poverty, multidimensional poverty and energy poverty, in order to generate evidence for environmental decision making.

In relation to the variable of interest, the results show a positive and significant correlation between income poverty and the different pollutants. For multidimensional poverty, the results corroborate a previously obtained relationship, showing a positive and significant relationship with the concentration of all pollutants. Finally, in the case of energy poverty, and like the two previous estimates, the results again show a positive and significant correlation with all pollutants. Finally, the unemployment variable is negative and significant for sulfur dioxide, while for fine particulate matter, there is a positive and significant correlation, and finally, in the case of coarse particulate matter, the results are mixed.

The results are in line with the working hypothesis, as the null hypothesis that there is no relationship between poverty and pollution is rejected. The relationship found for income poverty, multidimensional poverty and energy poverty is positive and significant at 1%, for each type of pollutant. Finally, this allows for the issue of environmental and social inequalities that exist in the country to be put on the table.

This work is an exploratory and empirical study whose main limitation is the lack of information from monitoring stations to characterize the entire territory, and secondly, the lack of information on other pollutants that would enrich the analysis and conclusions of the work. As for future work, it is recommended that this study be extended to the whole country to see if similar results can be obtained, and it is recommended that an econometric technique be used to measure the causality between the variables studied.

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