RELATIONSHIP BETWEEN POLLUTION LEVELS AND SOCIOECONOMIC VARIABLES: CONDITIONS IN NINE REGIONAL MUNICIPALITIES IN VALPARAÍSO, CHILE

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ABSTRACT

Air pollution, which generates negative effects on people's health, is linked to 23% of deaths worldwide. Among the main air pollutants are particulate matter (PM_{10} and $PM_{2.5}$), which causes cardiovascular and respiratory diseases, affecting the whole community living in a sector exposed to emissions; and sulphur dioxide (SO_2), which can cause severe effects even with short exposures. Based on air pollution data obtained from National Air Quality Information System (SINCA) monitoring stations, meteorological information from the Meteorological Directorate of Chile, and socioeconomic information on income poverty level, multidimensional poverty level, unemployment, schooling, overcrowding and health, we constructed a data panel containing daily information at the community level, from 2016 to 2019. Using three ordinary least squares (OLS) regression models, we studied the relationship between socioeconomic variables and each of the pollutants. Our results show that, in general, there is a positive and significant relationship between the level of multidimensional poverty of a population and the totality of regional pollution levels; as well as a negative and significant relationship between unemployment and the different pollution levels. Finally, there is a negative and significant relationship between the level of citizen's education and pollution. The main objective of this study was to investigate the possible relationships between socio-economic variables and pollution, in order to generate evidence to aid implementation of environmental public policies.

Keywords: air pollution, particulate matter, sulphur dioxide, socioeconomic variables, poverty level, health risk, environmental monitoring.

1 INTRODUCTION

According to Chile's 2019 National Environmental Survey [1], carried out by the Ministry of the Environment, the main problem affecting the country's population is air pollution, as per 32.8% of those surveyed. The results indicated that 48% of those surveyed say they live in a municipality with fair to very bad air, and that in recent years, the country has stagnated (64%) or regressed (23.5%) with respect to its environmental situation. Also, respondents indicated that in their communities, the activities having a major impact on air pollution are: industries (energy production, pulp mills, copper smelters, cement plants) and land transportation (cars, buses and trucks), with 60% and 50% of the responses, respectively.

Although Chile has an environmental policy that has been implemented since the mid-1980s [2], by institutionalizing a governmental program through creation of the National Environmental Commission in 1994 (which in 2010 became the Ministry of the Environment [3]), progress tended to slow down because of the country's neo-extractivist economic growth model [4]–[6] and has intensified high-impact productive processes with a high environmental impact, as many industrial zones are located next to poor communities. Our object of study, the region of Valparaíso, is one of the territorial spaces with the greatest environmental conflicts.

The National Institute of Human Rights (INDH) [7] of Chile reports that there are currently 21 environmental conflicts in Chile, resulting from energy, mining and agro-industrial projects, where emissions and contamination of natural resources represent 60% of

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the total number of conflicts [8], [9]. The territories of Concón, Nogales, El Melón, Puchancaví-Quintero and Petorca-La Ligua present worrying figures of multidimensional poverty, insufficient public health services and a lax environmental policy regarding the exploitation of natural resources and emission of polluting particles, to such an extent that some of these localities constitute “sacrifice zones”, which increased their inequality indicators [6], [9].

The state has made unsuccessful attempts to reduce environmental damage to air, soil and biodiversity, in the Valparaíso region. Despite increased environmental regulation in the last decade (since the creation of the Ministry of the Environment), plus better investment in technology and monitoring instruments, both the state and companies continue to fail to resolve episodes of air pollution. From 2011 to now, sacrifice zones such as Puchuncaví-Quintero have had critical episodes of air saturation, as a result of sulphur particles, as well as other metals present in the productive process of the industrial park, creating high pollutant loads. The instruments and measurements have been inaccurate in clarifying toxicological damage to the population, in addition to other environmental disasters which were caused by oil spills, contaminating the flora and fauna in Quintero Bay. The paradox is that the episodes of contamination in localities within the Valparaíso region are the responsibility of state companies, which have produced long-term harmful effects on the region’s population. Both the National Petroleum Company (ENAP) and the National Copper Corporation (CODELCO) play a major role in the emission of polluting particles, which complicates the State’s role as a guarantor of protection for the right to live in pollution-free territories.

This study’s main objective is to identify the relationships between socio-economic variables and pollution, in order to establish evidence for the implementation of environmental public policies in these territories. We tried to answer the following question: Is there a positive relationship between poverty and pollution? This research is divided into the following parts: Sections 2 and 3 contain the data and the methodology used, Section 4 presents the empirical results, and Section 5 is for the conclusions obtained from our research.

2 DATA

This paper uses different data sources. First, the pollution data panel obtained from the National Air Quality Information System (SINCA) website between January 2016 and June 2020. It was constructed with daily concentrations ($\mu g/m^3$) of PM_{10}, $PM_{2.5}$ and SO_2 from monitoring stations in the Valparaíso region that had information available for the period studied (totalling 25 monitoring stations from nine municipalities, corresponding to an area of 2369 km^2). Table 1 shows a list by municipality, with the names of the stations.

The location of the 25 monitoring stations is shown in Fig. 1.

Second, we used a meteorological data panel obtained from the Meteorological Directorate of Chile (MeteoChile). Daily data on temperature (°C), humidity (%), wind speed (degrees/knots) and rainfall (mm) were used. Thirdly, we obtained our socioeconomic data from the National Socio-economic Characterization Survey (CASEN). In particular, we used the population’s years of schooling as an indicator of education; their unemployment rate as a labour indicator; for housing we constructed an indicator representing the percentage of people living with some degree of overcrowding in the community; and for health we constructed an indicator representing the percentage of people subscribing to a private health regime. Income poverty and multidimensional poverty correspond to the percentages of people living in these conditions.

We were able to respond to the set of research questions by merging the aforementioned databases, resulting in a panel of 8572 records for PM_{10}, as well as 9661 records for $PM_{2.5}$ and 16,579 records for SO_2. The descriptive statistics by pollutant are shown in Table 2.

Table 1: Monitoring stations with pollutants measured.

Municipalities	Stations	PM_{10}	$PM_{2.5}$	SO_2
Catemu	Catemu			X
	Romeral			X
	Santa Margarita			X
Concón	Colmo			X
	Concón	X	X	X
	Concón MMA		X	
	Junta de Vecinos			X
	Las Gaviotas			X
Panquehue	Lo Campo			X
Puchuncaví	La Greda	X	X	X
	Puchuncaví	X	X	X
	Los Maitenes	X	X	X
	Campiche			X
	Ventanas	X	X	X
Quillota	Cuerpo de Bomberos	X	X	X
	La Palma	X	X	X
	San Pedro	X	X	X
Quilpué	Quilpué	X	X	
Quintero	Quintero	X	X	X
	Centro Quintero	X	X	X
	Loncura	X	X	X
	Sur	X		X
	Valle Alegre	X		X
Valparaíso	Valparaíso		X	
Viña del Mar	Viña del Mar	X	X	

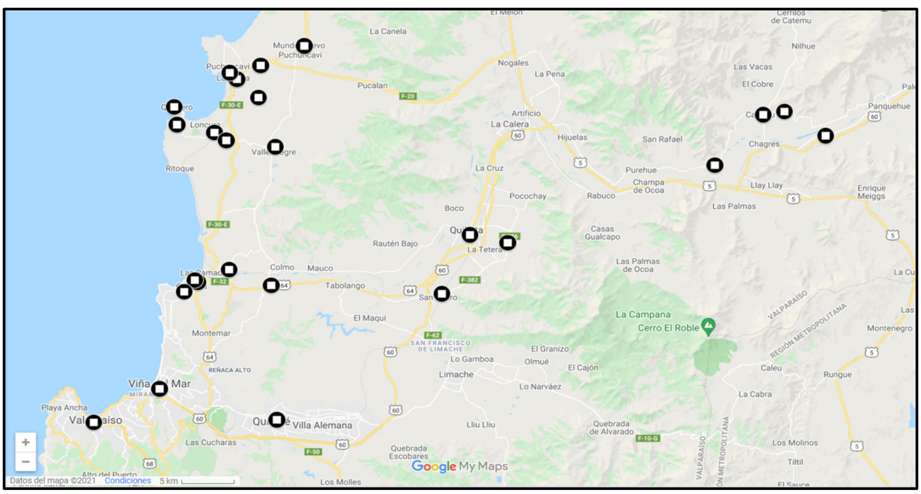

Figure 1: Location of the 25 environmental monitoring stations.

Table 2: Descriptive statistics by pollutant.

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
PM_{10}	8,572	36.81	14.52	1	141
$PM_{2.5}$	9,661	15.18	7.06	1	84
SO_2	16,579	17.37	17.43	0.03	178.64

3 METHODOLOGY

Three ordinary least squares (OLS) regression models were designed to study the relationship between several air pollution (PM_{10}, $PM_{2.5}$ and SO_2) and socioeconomic variables. The first OLS model (1) seeks to explain the effect of socioeconomic variables on pollution more explicitly:

$$y_{it} = \beta_o + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 W_{it} + \beta_4 R_{it} + \beta_5 Z_i + \beta_6 D_i + \epsilon_{it}. \quad (1)$$

Here, y_{it} represents the daily concentrations of particulate matter (PM_{10}, $PM_{2.5}$) and sulphur dioxide (SO_2), measured in weight/volume (µg/m^3) expressed logarithmically, while the subscript *it* corresponds to both the municipality and the day, respectively. The explanatory variables considered are meteorological data and socio-economic variables. Among the meteorological data considered were: *T* representing temperature (°C), *H* representing humidity (%), *W* representing wind speed (degrees/knots), and *R* representing total rainfall (mm). Among the socio-economic variables considered, *Z* represents the income poverty level and *D* indicates the unemployment rate. Estimates include a fixed effect by year and month, thus controlling for all time-varying differences. Results are given by type of pollutant.

In the second model (2), income poverty's explanatory variable was replaced by the multidimensional poverty variable, leaving the model as follows:

$$y_{it} = \beta_o + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 W_{it} + \beta_4 R_{it} + \beta_5 M_i + \beta_6 D_i + \epsilon_{it}, \quad (2)$$

where *M* represents the multidimensional poverty indicator. Estimates include the temporal controls mentioned above. Results are presented by type of pollutant.

In the third model (3), the aim was to delve deeper into the aspects of multidimensional poverty that are related to pollution. To this end, the explanatory variable multidimensional poverty is replaced by three variables that are used to construct this indicator: health, education and housing; thus, model (3) is as follows:

$$Y_{it} = \beta_o + \beta_1 T_{it} + \beta_2 H_{it} + \beta_3 W_{it} + \beta_4 R_{it} + \beta_5 H + \beta_6 S_i + \beta_7 O_i + \beta_8 D_i + \epsilon_{it}. \quad (3)$$

Here, *H* is an indicator of the percentage of the population using the private health system, *S* represents the level of schooling and *O* the level of household overcrowding. As in previous estimations, fixed effects of year and month are included to control for all types of seasonality. Results are presented by type of pollutant.

4 RESULTS

The results of the first estimated model (1) show the relationship between climatic and socio-economic variables with the level of pollution: Table 3 shows that meteorological variables are related to the different pollutants. In particular, precipitation, humidity and temperature have a significant and negative relationship with PM_{10}, $PM_{2.5}$ and SO_2; while wind speed shows a negative and significant relationship with particulate matter $PM_{2.5}$ and sulphur dioxide (see columns 3, 4, 5 and 6); yet a positive and significant relationship with particulate matter PM_{10} in the model with controls (column 2).

Table 3: Summary eqn (1) – OLS.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	SO_2	SO_2
Water	–0.0271***	–0.0241***	–0.0177***	–0.023***	–0.0051***	–0.0069***
	(–0.214)	(–0.190)	(–0.139)	(–0.184)	(–0.0237)	(–0.0323)
Humidity	–0.0112***	–0.0136***	0.00102	–0.0012**	–0.011***	–0.0107***
	(–0.195)	(–0.237)	(0.0186)	(–0.0225)	(–0.163)	(–0.159)
Temperature	–0.0111***	–0.0467***	–0.0511***	–0.046***	–0.0179***	–0.00447
	(–0.0790)	(–0.334)	(–0.337)	(–0.301)	(–0.0857)	(–0.0214)
Wind speed	0.000578	0.0091***	–0.0208***	–0.005**	–0.058***	–0.049***
	(0.00303)	(0.0478)	(–0.101)	(–0.0242)	(–0.136)	(–0.116)
I. Poverty	0.726***	0.508**	–1.070***	–1.687***	2.627***	2.996***
	(0.0352)	(0.0246)	(–0.0590)	(–0.0930)	(0.169)	(0.193)
Unemployed	–9.385***	–10.15***	–0.357	4.136***	6.598***	8.622***
	(–0.154)	(–0.167)	(–0.00499)	(0.0579)	(0.115)	(0.150)
Observations	8572	8572	9661	9661	16,579	16,579
R-squared	0.110	0.175	0.164	0.259	0.071	0.096
Fixed eff. month	No	Yes	No	Yes	No	Yes
Fixed eff. year	No	Yes	No	Yes	No	Yes

Robust standard errors (SE) in parentheses below numerical values. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

In the case of socio-economic variables, our main focus of interest in this study, income poverty, showed a positive and significant relationship with PM_{10} and SO_2, while for $PM_{2.5}$ it is negative and significant. As for the unemployment variable, results show there is a negative and significant relationship for PM_{10} concentrations (columns 1 and 2). This could be because lower economic activity generates lower concentrations of pollutants. On the contrary, the relationship was positive and significant between unemployment and pollutants $PM_{2.5}$ and SO_2 (columns 4, 5 and 6). This relationship may be due to factors unrelated to economic activity.

Results of the second estimated model (2) are similar to those obtained in the previous section for the climate variables, as seen in Table 4. A negative and significant relationship is shown for most of the climate variables and the various pollutant emissions (see columns 1–6). For the socio-economic variables, the results indicate there is a positive and significant relationship between multidimensional poverty and the concentrations of all pollutants. On the contrary, the unemployment variable shows a negative and significant relationship with each pollutant, which we believe can be explained by the relationship between economic activity and pollution, as in the previous case.

Table 5 has results of the third estimated model (3), where it can be seen that the relationship between the meteorological variables and the different pollutants is similar to what was obtained previously. A negative and significant relationship is evident for all climate variables and the various pollutant emissions (columns 1–6).

As pertains to the elements in relation to multidimensional poverty, our results showed that schooling has a negative and significant relationship with all pollutants, except the uncontrolled model that explains PM_{10} (columns 2–6 in Table 5). Overcrowding also brings

Table 4: Summary eqn (2) – OLS.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	SO_2	SO_2
Water	–0.0256***	–0.0229***	–0.0167***	–0.0217***	–0.004***	–0.0068***
	(–0.202)	(–0.181)	(–0.131)	(–0.171)	(–0.0204)	(–0.0317)
Humidity	–0.0124***	–0.0146***	0.000107	–0.0029***	–0.011***	–0.0113***
	(–0.216)	(–0.255)	(0.00196)	(–0.0521)	(–0.165)	(–0.168)
Temperature	–0.0101***	–0.0459***	–0.0501***	–0.0438***	–0.017***	–0.00404
	(–0.0724)	(–0.328)	(–0.330)	(–0.289)	(–0.0803)	(–0.0193)
Wind_speed	–0.0075***	0.00237	–0.0256***	–0.0136***	–0.060***	–0.0487***
	(–0.0393)	(0.0124)	(–0.124)	(–0.0662)	(–0.142)	(–0.115)
M. Poverty	0.930***	0.818***	0.405***	0.811***	2.851***	3.602***
	(0.103)	(0.0910)	(0.0455)	(0.0911)	(0.180)	(0.228)
Unemployment	–12.20***	–12.20***	–3.473***	–1.441*	–3.451***	–3.102***
	(–0.200)	(–0.200)	(–0.0486)	(–0.0202)	(–0.0601)	(–0.0541)
Observations	8572	8572	9661	9661	16,579	16,579
R-squared	0.115	0.178	0.162	0.256	0.077	0.104
Fixed eff. month	No	Yes	No	Yes	No	Yes
Fixed eff. year	No	Yes	No	Yes	No	Yes

Robust standard errors (SE) in parentheses below numerical values. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5: Summary eqn (3) – OLS.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	SO_2	SO_2
Water	–0.025***	–0.0215***	–0.012***	–0.0163***	–0.006***	–0.008***
	(–0.193)	(–0.170)	(–0.0946)	(–0.129)	(–0.0262)	(–0.0380)
Humidity	–0.013***	–0.0154***	–0.004***	–0.0058***	–0.009***	–0.009***
	(–0.232)	(–0.270)	(–0.0649)	(–0.106)	(–0.136)	(–0.134)
Temperature	–0.010***	–0.0459***	–0.047***	–0.0449***	–0.018***	–0.00597*
	(–0.0688)	(–0.328)	(–0.311)	(–0.296)	(–0.0865)	(–0.0286)
Wind speed	–0.015***	–0.00601*	–0.065***	–0.0501***	–0.051***	–0.038***
	(–0.0807)	(–0.0314)	(–0.315)	(–0.244)	(–0.121)	(–0.0907)
Schooling	–0.0305	–0.162*	–0.494***	–0.514***	–0.160***	–0.235***
	(–0.0603)	(–0.320)	(–0.962)	(–1.002)	(–0.221)	(–0.323)
Overcrowding	–3.842***	–2.633***	–13.57***	–12.63***	–2.151***	–2.062***
	(–0.454)	(–0.311)	(–1.322)	(–1.229)	(–0.132)	(–0.127)
Health	–1.969***	–0.0636	–2.114***	–1.475***	–0.117	0.404
	(–0.407)	(–0.0131)	(–0.410)	(–0.286)	(–0.0146)	(0.0506)
Unemployment	–26.34***	–24.41***	–62.37***	–56.92***	1.408**	3.922***
	(–0.432)	(–0.401)	(–0.872)	(–0.796)	(0.0245)	(0.0683)
Observations	8572	8572	9661	9661	16,579	16,579
R-squared	0.118	0.181	0.240	0.316	0.086	0.114
Fixed eff. month	No	Yes	No	Yes	No	Yes
Fixed eff. year	No	Yes	No	Yes	No	Yes

Robust standard errors (SE) in parentheses below each value. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

a negative relationship that is significant for all pollutants (columns 1–6). Importantly, the health indicator showed there was a negative and significant relationship with $PM_{2.5}$. As for unemployment, the relationship takes on a negative and significant value for both pollutants, while for SO_2, the relationship is positive and significant.

5 CONCLUSIONS

Air pollution is one of the main problems affecting the human population worldwide. Although Chile has implemented an environmental policy since the mid-1980s, progress slowed down because of the economic growth model that has intensified production processes having high environmental impact, those that remain where many industrial areas have been, located next to poor communities. We focused on the Valparaiso region, a territorial space with the greatest environmental conflicts in Chile. We employed micro-level data about air pollution, meteorological indicators, and socio-economic variables to construct a panel of data with daily information at the municipality level, from 2017 to 2019. The main objective of this study is to identify the relationships between socio-economic variables and air pollution, in order to establish evidence for the implementation of improved environmental public policies in the Chilean territories.

Our results illustrate that the meteorological variables in all of the estimates made, relate in the same way to the different pollutants. In general, we show a negative and significant relationship between the climate variables and the various pollutant emissions.

In reference to socio-economic variables, we found that when we use income poverty, results showed a positive and significant relationship with PM_{10} and SO_2, while for $PM_{2.5}$ it is negative and significant. As for the unemployment variable, results showed there was a negative and significant relationship for PM_{10} concentrations (lower economic activity generates lower concentrations of pollutants),; while on the other hand, the relationship is positive and significant between unemployment and the pollutants $PM_{2.5}$ and SO_2 (perhaps due to factors unrelated to economic activity).

For multidimensional poverty, our results indicated a positive and significant relationship with the concentrations of all pollutants. On the contrary, the unemployment variable showed a negative and significant relationship with each pollutant, which can be explained by the relationship between economic activity and pollution, as in the previous case. In relating the elements to multidimensional poverty, in general the results demonstrated that schooling and overcrowding have a negative and significant relationship with all pollutants.

The health indicator showed us a negative and significant relationship with $PM_{2.5}$. As for unemployment, that relationship takes a negative and significant value for both pollutants; while for SO_2, the relationship is positive and significant.

Our study results are in line with our hypothesis, because we found there was a positive relationship between poverty and pollution. The relationship found between multidimensional poverty and the different pollutants is striking. This relationship is positive and significant at 1%. This will allow us to discuss the environmental and social inequalities that exist in the region productively. In considering future work, we recommend that this type of sampling and analysis be extended to other regions of the country, to see if similar results can be obtained. If so, investigation into the reasons for the negative relationship found between overcrowding and pollution is recommended.

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