A tale of two cities: air pollution exposure, social inequalities, and perinatal health in Madrid.

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Research topic and theoretical focus

Perinatal health is tightly related to the maternal environment. This simple statement implies a plethora of factors that are going to influence the health outcomes of the newborn and the subsequent health status and overall wellbeing of the individual. The relation between the perinatal health outcomes and other health and social determinants in life can be explained through the cumulative advantage process, coined by Merton (Merton, 1968) and then applied from a social stratification perspective, and measured through perinatal health indicators.

An adverse perinatal outcome might be related to a household with more sources of deprivation. Low birth weight (LBW) and preterm birth (PTB) are conditioned by a series of determinants (genes, lifestyle, educational level, access to health care) that depend on the parental socioeconomic status (Currie & Moretti, 2003). These socioeconomic conditions tend to mediate birth outcomes, with lower maternal resources constituting an individual stressor that can lead to LBW, and PTB, among others (Kramer et al., 2000).

The Spanish context is no exception, with a high prevalence of LBW among the OECD countries (OECD 2014), related to the growing postponement of maternity and the increased use of assisted reproduction techniques (Luque Fernández, 2008), and a larger proportion of births to unmarried mothers (Castro-Martín, 2010).

In addition to the impact of individual stressors, there are also several contextual stressors that influence the health of newborns. These include in utero exposure to environmental pollution. Profound maternal physiological changes take place during pregnancy (Ciliberto et al., 2008), increasing the susceptibility to the risks of inhaled pollutants(Almetwally et al., 2020) for both the mother and the foetus, as most of these pollutants cross the placenta by simple diffusion (Hackley et al., 2007). As a result, foetuses, still going through decisive stages of development, can end up being small for gestational age (SGA) (Hannam et al., 2014), experience intrauterine growth restriction, PTB (Liu et al., 2003), LBW (Bell et al., 2007), and even a higher incidence of mortality (Chay & Greenstone, 1999).

Despite the relevance of the physiological alterations caused by pollution, socioeconomic factors tend to mediate the process of damage. The already mentioned psychosocial stressors that traditionally affect to a greater extent lower SES (like material deprivation, work uncertainty or migratory status) tend to cluster with a (greater) exposure to environmental pollution (Currie, 2013; Mathiarasan & Hüls, 2021), a phenomenon described as environmental injustice by the United States Environmental Protection Agency (US EPA 2015). Both exposures are ubiquitous during pregnancy and are individually related to adverse pregnancy outcomes, with a potential synergetic or additive effect that can outweigh the individual impact of each factor (Currie & Hyson, 1999; Padula et al., 2020). These concurring challenges has been referred to as a "double jeopardy" (Parker et al., 1988) and can be the explanation underlying differences in perinatal outcomes for babies being born in similarly impoverished or polluted environments.

At the same time, due to a process of accumulation of disadvantage that can magnify small differences over time, being born in poor health may correlate with poorer lifetime health and disadvantage in several dimensions of life (Diprete & Eirich, 2006). LBW and PTB correlates with infant morbidity and mortality, with worse health later in life (Johnson et al., 2011), higher incidence of several conditions (Barker, 1995), impairment of cognitive development, and worse educational and employment attainment (Bilgin et al., 2018; Boardman et al., 2002; Juárez et al., 2014), acting as a mechanism for intergenerational transmission of education and economic status (Currie, 2009, 2013).

Based on the above theoretical framing, the purpose of the present paper is to study this phenomenon in the context of Madrid. The Spanish capital is the most polluted city of the country, with levels that go above the limits stablished by referent institutions like the European Union and the WHO (Izquierdo et al., 2020; Khomenko et al., 2021b, 2021a). It is also a city with a socio-spatial segregation that physically stratifies the population and possibly conditions the access to cleaner environments and health services. An analysis is going to be conducted for the year 2019, the most recent data available for the whole compilation of datasets, but excluding the years of the pandemic, as the exceptional characteristics of these years need to be studied on their own. The purpose is to answer two main questions: Are socioeconomically disadvantaged mothers more likely to live in a district with poor air quality? And second, is the effect of being exposed to air pollution during pregnancy the same for all babies or does it vary depending on the SES of the mother?

1. Data and methods

For assessing the exposure to air pollution, data was obtained from The Integrated Air Quality System of the Madrid City Council, that provides hourly data for a wide range of pollutants in the capital. It is composed by 24 stations spread through the 21 districts of the city (Portal de datos abiertos del Ayuntamiento de Madrid). For this study, pollutants are selected according to the volume of evidence pointing to a detrimental effect on perinatal health, their incidence in urban pollution and the existence of regulatory agency guidelines setting safe concentration limits. These pollutants are nitrogen dioxide (NO_2), particulate matter 2.5 ($PM_{2.5}$) and particulate matter 10 (PM_{10}).

The Childbirth Statistics Bulletin (Boletín Estadístico del Parto) provided by the National Statistics Office (Instituto Nacional de Estadística) covers all singleton births whose mothers resided in Madrid for the period studied. This individual birth registration data provides information about the birth and the newborn. Linked to each individual birth, there is data on the mother such as her age, as well as socioeconomic characteristics (nationality, education, employment status/occupation), that constitute the covariates or individual independent variables. The level of disaggregation of the data for Madrid is available at the district level. The perinatal health indictors used are low birth weight (LBW) and preterm birth (PTB), operationalized through a dichotomic variables.

At the aggregate level, two indicators are studied to understand the overall sociodemographic characteristics of the districts: the average annual net income of households and the aggregated educational level for the year 2019, both obtained from the National Statistics Office.

First, it is necessary to examine the composition of the city at an aggregated level through descriptive analysis of the variables of interest, to assess pollution levels by district and determine whether its distribution is unequal, and the socioeconomical composition of the districts more affected by it. Then, adverse perinatal outcomes, measured by LBW and PTB, will be included in a regression model for the year 2019, to identify how pollution and is correlated to adverse perinatal outcomes, and to identify the independent and interactive effect of the SES.

2. Expected findings

A preliminary descriptive analysis of the data was performed, to detect patterns in the distribution of the interest variables. The aggregated socioeconomic indicators for the districts of Madrid reveal a repetitive pattern, with the districts located at the south and between the M-30 and M-40 highways having lower average net incomes and less university degrees of the overall population, as it is show in Image 1. Then, the aggregate maternal characteristics are compared with the results for the socioeconomic indicators, to assess if the pattern on the distribution of the less advantage districts is consistent in the target population.

Table 1. Aggregate socioeconomic indicators for Madrid

	Aggregate SES variables			Aggregate SES maternal variables		Perinatal health indicators	
District	**Average annual net income of households**	**% Population over 25 y.o. with a university degree**	**% Mothers with a university degree**	**% Mothers born in Spain**	**% Mothers employed**	**Prevalence of LBW**	**Prevalence of PTB**
Chamartín	69.558	50,35	86,23	79,20	84,01	5,39	4,61
Moncloa-Aravaca	62.482	44,09	79,83	76,77	77,50	3,72	4,49
Salamanca	60.435	49,59	84,64	73,46	77,78	5,98	5,91
Retiro	57.027	44,28	83,54	79,41	81,64	5,73	4.81
Chamberí	56.073	50,43	85,70	77,18	81,93	6,06	5,97
Fuencarral-El Pardo	54.493	36,47	76,24	78,13	80,51	5,99	5,17
Hortaleza	53.836	33,24	72,26	75,15	80,30	5,14	4,01
Barajas	51.108	31,88	74,33	75,13	78,93	3,60	3,77
Arganzuela	45.262	37,43	77,81	76,40	81,96	6,52	5,52
Ciudad Lineal	40.948	26,14	53,14	55,71	69,61	6,46	5,58
Tetuán	39.332	31,41	53,00	53,74	69,25	6,86	6,11
San Blas - Canillejas	38.560	19,98	43,38	59,00	66,46	6,40	5,17
Centro	38.171	42,16	65,64	55,65	64,97	6,00	5,93
Moratalaz	37.951	20,74	49,82	64,97	69,11	7,91	5,75
Vicálvaro	35.510	16,51	40,55	61,69	66,98	6,40	5,52
Villa de Vallecas	34.168	17,46	46,94	72,86	68,55	6,74	5,12
Latina	33.237	16,24	36,79	48,72	61,46	5,98	5,43
Carabanchel	31.190	14,2	31,82	44,47	57,23	6,55	6,14
Villaverde	29.873	9,64	21,99	43,22	52,36	7,23	6,82
Usera	29.061	10,31	21,07	41,52	51,29	5,09	5,46
Puente de Vallecas	27.975	9,86	19,63	46,17	51,30	7,59	6,28
Madrid	**43.393**	**28,43**	**57,35**	**63.74**	**70.15**	**6.21**	**5.42**

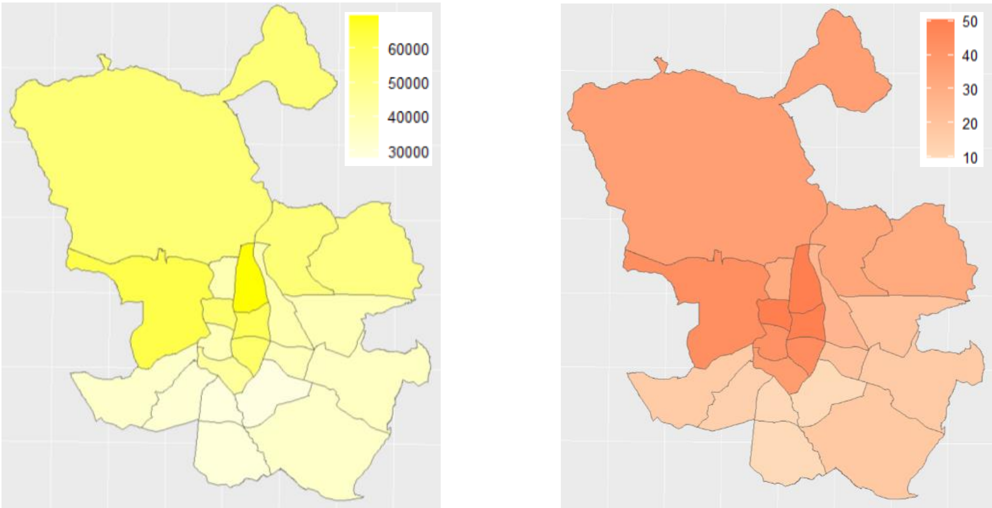

Image 1. Average annual net income of households (a) and percentage of college graduates over 25 years old (b) by district in Madrid, according to the National Statistics Institute (2019)

The pattern of socioeconomic segregation keeps being present in the maternal population, with lower educational attainment and employment status in the districts of the south and outside the main highway, as shown in Image 2. A preliminary descriptive analysis is also performed for the perinatal health indicators, with the calculation of the aggregate value for the prevalence of LBW and PTB by district, as represented in Image 3.

From the visualization of these maps, we can see that a line crosses the city in a northwest-southeast direction, south of which there is greater spatial segregation, with neighbourhoods at greater risk of vulnerability.

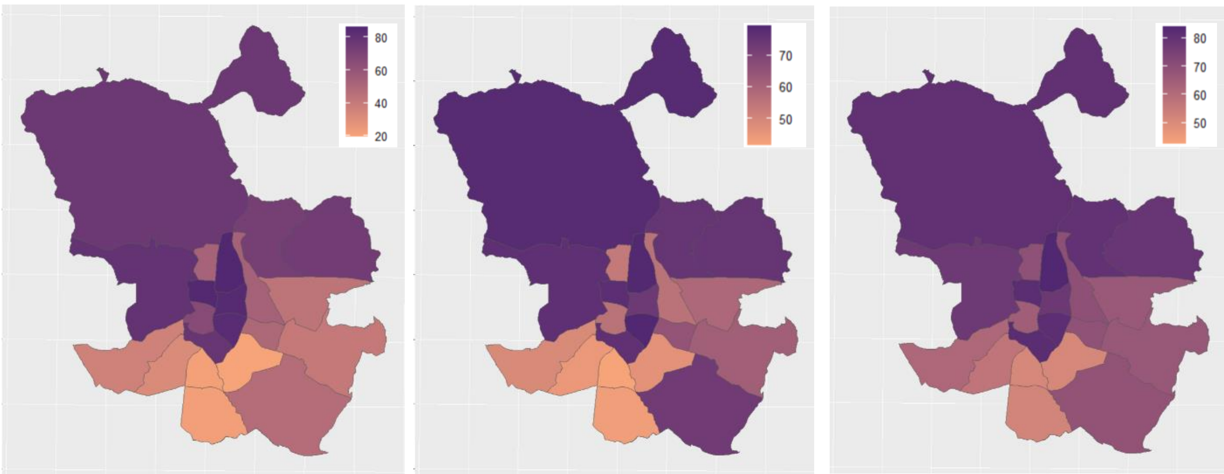

Image 2. Percentage of mothers with a university degree (a); percentage of mothers born in Spain (b); and percentage of mothers with employment (c) by district in Madrid, from the Childbirth Statistics Bulletin *(2019).*

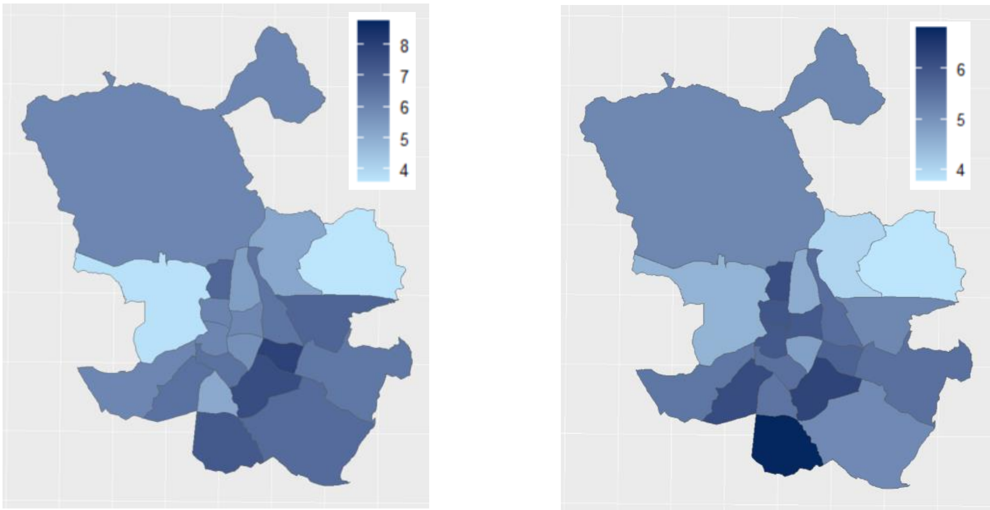

Image 3. Prevalence of LBW (a); prevalence of PTB (b) by district in Madrid, from the Childbirth Statistics Bulletin *(2019).*

The next step will be using the geographic location of pollution sensors to assign pollution levels to each district. This will allow further multivariate analysis to be performed at the individual level and try to measure the influence of air pollution and socioeconomic factors on perinatal health. It is expected that higher pollution levels and lower SES will correlate with worse perinatal outcomes. The comprehensive quantitative analysis seeks to understand the interactions between these factors, focusing on the spatial distribution and potential interactions.

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