The gendered effects of air pollution on labour supply

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Abstract

Air pollution affects workers ability to work by damaging their own health, but also by damaging the health of their dependents. This paper draws on 20 years of air pollution and employment data from Santiago, Chile, a highly polluted metropolis, particularly in fall and winter months. The paper finds that though air pollution does not reduce overall hours worked, it does so for women and particularly for women with children. A week with pollution at 100 µg/m3, common for Santiago, doubles the gender difference in working hours. It is hypothesised that children, unable to go to school, must stay home and cared for. Findings do not hold for elderly care, probably reflecting the fact that both sick and healthy dependent elderly are cared for at home and their main family caregiver is generally out of the labour force to begin with. These findings suggest that air pollution may contribute to gender inequality through the gendered-biased distribution of care responsibilities. Pollution brings to evidence gender inequalities in care and, given the gendered nature of care and the geographic distribution of pollution, contributes to enhance gender and geographic labour market inequalities. Environmental policy is a gender equality policy as well.

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1. Introduction

The environment and the world of work are tightly linked. Environmental degradation can, in the long term hurt jobs through two channels: reduction in the provision of ecosystem services which sustain jobs and a direct impact on individuals' health (ILO, 2018). Indoor and outdoor air pollution, as a form of environmental degradation can affect workers' right to work through own illness or, when the care of dependents relies on working individuals, through the illness of dependent others (e.g. children or the frail elderly).

This paper focuses on the effects of urban outdoor air pollution. It takes advantage of 20 years of daily outdoor air pollution and quarterly employment data from Santiago, Chile. Results show that pollution does not decrease overall labour supply, but that the null results on the aggregate hides a gender-biased effect: when air pollution rises, women – and women with children, in particular – are more likely to work fewer hours. The results hold for households with children but not for households with an elderly. This apparent discrepancy in how care for children and care for the elderly impact labour supply when air pollution increases, reflects carers' ability to combine paid work and care when caring for children and the elderly, respectively: as children go to school or are more likely to attend childcare when healthy, when they fall sick they need to be cared for by someone. As care for the healthy elderly relies mostly on women who do not work for pay, when the elderly falls sick it does not impact his or her carers' work for pay.

The following sections develop further the link between air pollution, labour supply and the care economy, describe the data sources and methods and discuss the results.

2. Air pollution, labour supply and care

Several contaminants produce urban outdoor air pollution.[1] The most commonly measured are Ozone (O3), Sulphur Dioxide (SO2), Carbon Monoxide (CO), Nitrogen Oxide (NO2) and the set of small airborne particle depending on their size, PM10 and PM2.5. Each contaminant is associated to different health hazards including, but not exclusive to, respiratory problems which may be transient or bring about long-term health deterioration (Muñoz, 1991). Air in polluted urban areas can also contain heavy metals like lead, which are especially dangerous to children's cognitive and physical development.[2]

Air pollution is the fourth leading fatal health risk worldwide. The World Bank (2016) estimates that the 5.5 million premature deaths associated to air pollution in 2013 led to 225 billion USD in income losses. These costs only consider lost income due to premature deaths, but air pollution also reduces labour supply and productivity as a result of lost working days, which the OECD (2016b) estimates at 1.2 billion USD. Air pollution increases health expenses. Illness-related costs that do not result in

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[1] To facilitate exposure, in the remaining of the paper, urban outdoor air pollution is referred to as "air pollution" or "pollution".

[2] Lead is another powerful urban outdoor pollutant which can adversely affect the nervous system, kidney function, the immune system, reproductive and developmental systems and the cardiovascular system. Children are particularly sensitive to lead accumulation in the blood and bones, leading to cognitive deficiencies and behavioural problems (EPA, 2017). Lead pollution in Chile is considered low as a result of the introduction of lead-free gasoline in 1993 and its abolishment in 2001. By 1998 lead levels in infants had decreased considerably (O'Ryan and Larraguibel, 2000).

mortality – morbidity costs – amount to around 10% of mortality costs in the case of air pollution (OECD, 2014a), resulting in over 100 billion USD in Europe (WHO and OECD, 2015). In California, hospital-related expenses that result from air pollution resulted in 193 million USD over the 2005-2007 period (Romley, Hackbarth, and Goldman, 2010).

Aside from the effects of premature deaths and health care expenses, air pollution affects labour supply through two channels: workers' own health deterioration and dependent caregiving (Aragon, Miranda, and Oliva, 2016). When pollution levels reach critical levels, workers may be ill and call in sick. In New Delhi, the city with the worst outdoor air pollution level (WHO, 2016), for example, 5-10 per cent of staff report called in sick due to respiratory or breathing problems following the critical pollution episodes in 2016 (ASSOCHAM, 2016). The direct effects of critical pollution episodes on labour supply are not limited to the immediate health risks: they persist in the medium term as well (Kim, Manley, and Radoias, 2017).

A second channel by which air pollution impacts is indirect and operates through dependents (Aragon, Miranda, and Oliva, 2016). Children and the elderly are particularly sensitive to the health effects of pollution. When pollution is high, but not critical, workers may still be healthy enough to work, but children and the elderly may fall sick. If care for sick children and dependents relies on working adults, they will likely have to skip work to take care of their dependent children or elderly. This is the case, for example, when children cannot go to school as a result of illness.

An additional channel, not explored in this paper, is the reduction in natural assets caused by air pollution affecting the availability of work. Airborne pollutants, for example, affect plant growth and agricultural productivity (Unsworth and Ormrod, 1982).

The distribution of care work is gendered-biased, with the bulk of care work falling on women in unpaid arrangements, with some variation across countries (OECD, 2014b). If the distribution of care for sick children and the elderly relies on one group of workers, e.g. women, the effects of air pollution on labour supply will fall disproportionately on this group.

Importantly, this indirect effect of air pollution on labour supply only affects individuals who combine paid work and care. Informal family caregivers who care for children or the elderly on a full-time basis are not in paid work, so air pollution will not affect their position in the labour market though it will further limit their possibility to enter the labour market. These indirect effects will only apply in cases in which the carer combines paid work and care, that is, when the standard care arrangement cannot be met when the child or elderly is sick. In countries where childcare, schooling and elderly care is shared between the family and institutions (e.g. nurseries, day care centres), the impact on the labour supply will be the strongest (Heymann, Penrose, and Earle, 2006). The 2002 Community Care and Health Act in Scotland offered free formal personal care to the elderly, increasing the working hours of their family caregivers by an average of 0.4 hours per week, as a result of a reduction in informal care provided (Hollingsworth et al., 2017).

Chile provides an interesting case study for this hypothesis. From age 3 to 5, 75.3 per cent of children spend their days in pre-primary school. From age 5 onwards, the majority go to school (OECD, 2016a). If children fall sick, they have to stay home. If the child's parents work, one of them will have to stay home. It is usually the mother, even in countries with greater levels of gender equality (Eriksson and Nermo, 2010). If the household hires a full-time housemaid, working parents need not stay home and

the housemaid will care for the child. By contrast, few, if any, options exist in Chile to support the care of the frail elderly. Almost 90 per cent of them stay in their home under the care of a non-working family member (Palacios, 2017).[3] Given the unavailability of institutional care options for the frail elderly, their falling sick may not impact labour supply since the majority of elderly family caregivers are out of the labour force.

Santiago, Chile's capital endures high levels of air pollution during the fall and winter months. Annual average pollution levels systematically exceed annual WHO guidelines for Particulate Matter-10 (PM-10) on all the city's monitoring stations.[4] Roughly 7 million people live in Santiago, in an area of 15,400 km2. During the 1990s, Santiago was among the most polluted cities in the world (O'Ryan and Larraguibel, 2000) and, even though summer months have relatively low pollution levels, Santiago still ranks among the most polluted cities in the world (WHO, 2016).[5] Pollution levels are not equally distributed throughout the city, with concentration of particulate matter and other pollutants (with the exception of Ozone) more common in the southern parts of the city. Pollution levels are not equally distributed throughout the year, with high levels of pollution more common in the fall and winter months.

This paper takes advantage of a continuous quarterly measurement of employment and daily measurement of pollutants in Santiago for 20 years. It draws on the temporal and geographical variation to explore the gendered and care-related impact of air pollution on labour supply.

3. Data and methods

This paper merges air pollution and labour market data for the urban area of Santiago, Chile and then regresses hours worked per week on air quality, gender and household composition and other controls.[6]

The Sistema de Información Nacional de Calidad del Aire (SINCA) provides daily measures for several air pollutants measured in eight monitoring stations distributed across the city in Santiago (monitoring stations also exist for other Chilean cities). Today, measures include Ozone (O3), Sulphur Dioxide (SO2), Carbon Monoxide (CO), Nitrogen Oxide (NO2) and particulate matter density (PM10 and PM-2.5). The series of measurement for Santiago for PM10, SO2, O3 and CO dates back to 1997 in the majority of the stations.

The discussion in this study draws mostly on PM10, which has the longest data series. The correlation between the measured pollutants, with the exception of O3, is relatively high (see Figure 1 and Appendices A and B for all the measures gathered from the Pudahuel monitoring station; correlations

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[3] Palacios (2017) notes that around 90% of the dependent elderly in Chile have a family member as the main caregiver. Only a minority rely on institutional care (e.g. nursing homes) or are able to pay nurses or housemaids to this effect.
[4] WHO guidelines (2006) suggest annual air pollution averages of 20 µg/m3. In 2014, one of the years with the lowest air pollution levels observed in the period under study, Santiago's monitoring stations averaged between 50 µg/m3 (Las Condes) and 69 µg/m3 (El Bosque) over the course of the year.
[5] The WHO's Outdoor Air Pollution Database (2016) ranks Santiago 12th in PM2.5 concentration (over a total of 576 cities) and 119th in PM10 concentration (over a total of 1099 cities).
[6] Though restricted to Santiago, results are likely to hold for other Chilean cities with pollution levels observed since 1997 in Santiago (e.g. Concepción, Coyhaique, Temuco and Osorno, among others in WHO, 2016) and to other Latin American cities with pollution levels and similar care regimes (for a discussion on care regimes in Chile and Latin America, see Martínez Franzoni (2008).

for other pollutants are similar in other stations).

The results shown in the paper and its conclusions are robust to different specifications. They remain largely unaffected by the choice of pollutant as an independent variable: they hold for PM2.5, NO2 and CO but do not hold for SO2 (inverse estimates) or O, (non-significant but estimates in the same direction as those for PM10) (See Appendix). The results remain if the analysis is restricted to the 2007-2016 period or if the analysis is restricted to the June months and include educational attainment as a control. Results also remain largely unaffected if regressions use discrete measures of pollution associated to the implementation of mitigation measures (Regular, Alerta, Pre-emergencia or Emergencia levels).

The Encuesta Nacional de Ocupación y Desocupación del Gran Santiago (EOD) samples around 2 500 individuals every March, June, September and December to measure the labour force participation, employment rate and hours worked of the population in Santiago for a specific reference week in each quarter. The sample is stratified into eight strata. Each strata is geographically determined, linked to the administrative boundaries of municipalities. The EOD provides continued labour force statistics since 1957. The survey collects information on the labour force and employment status, hours worked, age and gender for all household members. The information in the survey allows identifying the number of children in the home (individuals aged 14 or younger) and the number of dependent elderly in the home (individuals aged 60 or older who are neither the head of the household nor the spouse). Up until 2008, income is only available in the March and June surveys; it is used to test for the robustness of the results. Educational attainment is only available in the June surveys and is not used in the study due to the strong reduction in sample sized entailed.

This study merges the data from the SINCA and the EOD. The study uses data from seven SINCA monitoring stations (Cerrillos, El Bosque, Independencia, La Florida, Las Condes, Parque O'Higgins and Pudahuel) to match each of the strata in the EOD, as per Table 1. The data from the Puente Alto and Quilicura stations are not used due to their shorter series of data. For strata not represented by any particular monitoring station (e.g. Strata 1 and 4), the average of the closest monitoring stations is used.

Table 1: Matching strata in the employment survey with air pollution monitoring stations

Strata	Municipalities in the strata	SINCA Monitoring station
1	Ñuñoa, La Reina, Macul, Peñalolén	La Florida, Las Condes
2	San Miguel, La Cisterna, San Joaquín, La Granja, San Ramón, Pedro Aguirre Cerda, Lo Espejo	El Bosque
3	El Bosque, La Pintana, San Bernardo	El Bosque
4	Maipú, Cerrillos, Pudahuel, Lo Prado, Cerro Navia	Pudahuel, Cerrillos
5	Recoleta, Independencia, Conchalí, Renca, Quilicura, Huechuraba	Independencia
6	Providencia, Vitacura, Las Condes, Lo Barnechea	Las Condes
7	Santiago, Estación Central, Quinta Normal	Parque O'Higgins
8	La Florida, Puente Alto	La Florida

Note: Strata are the primary sampling units in the Encuesta de Ocupación y Desocupación del Gran Santiago. Each strata comprises of between two and seven municipalities.

The employment data refers to one specific week in each quarter (i.e. reference week). For example, for the March, 2016 survey, the EOD asked the sample about their employment status between March 6, 2016 and March 12, 2016. The average pollution level from the week prior to the reference week is

taken as the relevant air pollution metric as there is a lag between the air pollution level and the associated health deterioration.[7] This strategy matches that of other similar studies, notably Aragon et al. (2016).

Of the 80 quarterly employment surveys carried out between 1997 and 2016, nine are excluded. Eight are excluded because of the unavailability of the specific reference week of the survey (1997Q2, 1997Q4, 1999Q3, 1999Q4, 2001Q4, 2006Q2, 2006Q3, 2006Q4). The 1997Q1 survey is excluded because it precedes the public availability of the pollution trend data, which begins in April 1997. A total of 71 employment surveys is used, which total 787 969 surveyed individuals, of which 255 683 worked in the respective reference week.

To estimate the effect of air pollution on labour supply, models regress the total number of hours worked by worker i in strata s in the reference week w on the corresponding strata's average pollution level (P) in the preceding week *(w-1)*. Given the strong socioeconomic segregation in Santiago (Sabatini et al., 2009; Rodríguez and Arriagada, 2004), the model includes fixed effects for the sample strata (A). To account for seasonal and structural changes in hours worked, the model includes fixed effects for the survey quarter (Q) and the year (Y). Simply put, in estimating the relationship between pollution, gender and childcare demands, the models estimate

$$H_{w,s,i} = \beta_1 P_{s,w-1} + \beta_2 F_i + \beta_3 C_{i,w} + \beta_4 F_i \cdot P_{s,w-1} + \beta_5 F_i \cdot P_{s,w-1} \cdot C_{i,w} + \beta_6 P_{s,w-1} \cdot C_{i,w}$$
$$+ \beta_7 F_i \cdot C_{i,w} + \sum_{a=1}^{7} \alpha_a A_a + \sum_{q=1}^{4} \rho_q Q_q + \sum_{y=1}^{20} \varphi_y Y_y + \varepsilon_{w,s,i}$$

which can be factored so that one set of coefficients measures the relationship between pollution and care for women and for men:

$$H_{w,s,i} = (\beta_1 P_{s,w-1} + \beta_3 C_{i,w} + \beta_6 P_{s,w-1} \cdot C_{i,w}) + F_i(\beta_2 + \beta_4 P_{s,w-1} + \beta_7 C_{i,w} + \beta_5 P_{s,w-1} \cdot C_{i,w}) + \sum_{a=1}^{7} \alpha_a A_a + \sum_{q=1}^{4} \rho_q Q_q + \sum_{y=1}^{20} \varphi_y Y_y + \varepsilon_{w,s,i}$$

A similar model evaluates the relationship with an elderly in the home. Models also test the effect by age and economic activity of the worker.[8] To check whether childcare is the main driver of the relationship, an additional model controls for whether the household includes a non-working adult who could, potentially care for the sick child or elder when they fall sick.

Sample weights are used as appropriate.

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[7] As discussed further below, the results shown here remain if the maximum pollution level associated to the reference week is used, or the number of environmental alert episodes (*Alerta ambiental)* during the reference week is used. An *Alerta ambiental* calls for specific policy measures if PM_{10} is above 195 µg/m³. Further measures are enacted if PM_{10} surpasses 240 µg/m³ (*Pre-emergencia ambiental*). Another set of measures are enacted if PM_{10} passes above 340 µg/m³ (*Emergencia ambiental)*.

[8] Models testing for children as defined by different age groups do not substantially change the results. Models that add the age of the youngest child in the home as a control does not affect the results either.

4. Results

Figure 1 shows the daily pollution in the Pudahuel monitoring station, located in the south-west of Santiago. As noted earlier, PM10 concentration peaks in the fall and winter months and rarely pass above 100 µg/m3 ¬in the spring and summer months. Pre-emergencies, critical episodes above 240 µg/m3 tended to be more common in the late 1990s compared to the 2010s, and emergencies (declared when PM10 passes above 330 µg/m3) rarely happened in after 2007.

Figure 1: PM$_{10}$ concentration in Santiago, Chile, 1997-2016
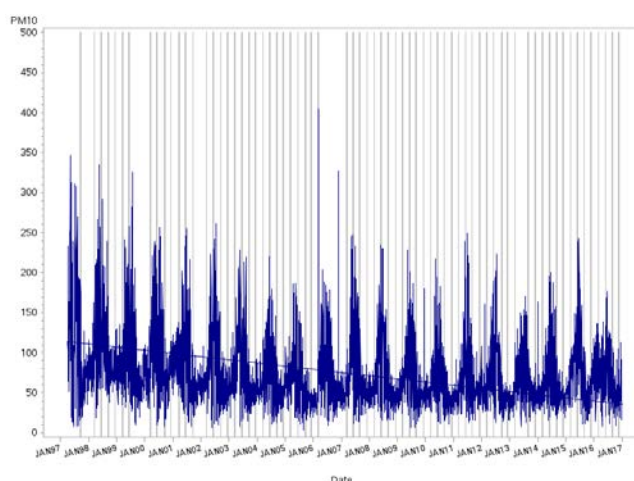
Note: Shaded area corresponds to the week prior to the employment survey reference week.
Source: Sistema de Información Nacional de Calidad del Aire, Estación Pudahuel.

Figure 2: Geographical distribution of PM$_{10}$ in Santiago, Chile, 2015
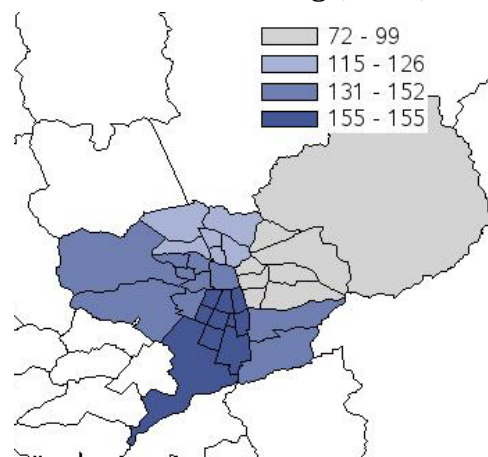
Note: Data for the reference week of June, 2015. Municipalities are grouped by their corresponding strata in the employment survey. Municipalities in white are not covered in the employment survey.
Source: Sistema de Información Nacional de Calidad del Aire.

Pollution in Santiago is not equally distributed within the city owing to the geography, ventilation conditions, and the distribution of industrial and transport activity. Southern and western municipalities tend to experience higher pollution levels (with the exception of O$_3$) (Figure 2).

Since 1997, the employment rate in Santiago has followed the macroeconomic conditions and the expected seasonal variation. Employment fell as a result of the consequences of the Asian financial crisis in the late 1990s, the global recession in the late 2000s and the fall in commodity prices in the 2010s. Male and female employment are sensitive to these fluctuations, but female employment remains, for the majority of the period under study, below 50 per cent (Figure 3). Hours worked are calculated among those that are employed. Despite some seasonal variation, they have tended downwards, to an average of 44 hours per week, with women working fewer hours, on average, than men (Figure 4).

Figure 3: Employment in Santiago, Chile, 1997-2016
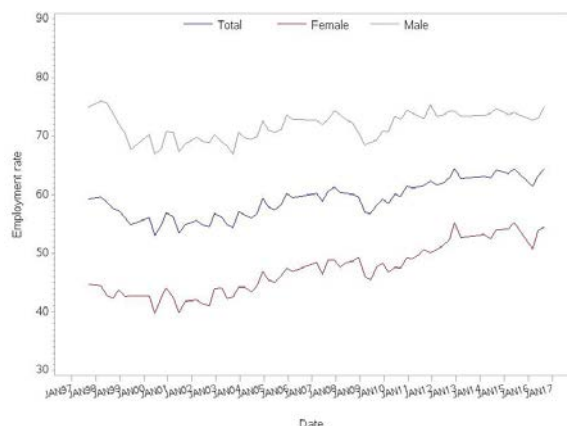
Source: Encuesta de Ocupación y Desocupación del Gran Santiago.

Figure 4: Hours worked per week in Santiago, Chile, 1997-2016
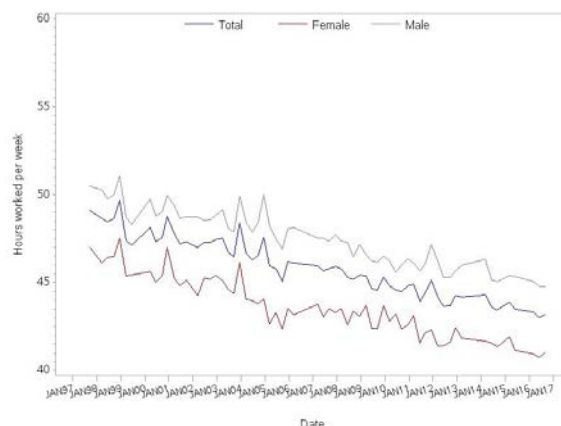
Source: Encuesta de Ocupación y Desocupación del Gran Santiago.

As expected by the socioeconomic segregation in Santiago, employment outcomes also vary geographically. Figure 5 and Figure 6 show the employment rate and hours worked in December, 2015. December is, in the absence of forest wildfires, a month with low pollution levels so any observed geographic variation will not be due to differences in pollution exposure. Employment rates are lower in the southern and western municipalities, but hours worked tend to be higher in those municipalities.

These results show that any analysis that estimates the relationship between labour supply and pollution needs to account for the structural, cyclical/seasonal and geographic variation observed in both air pollution and labour supply.

Figure 5: Employment by area in Santiago, Chile, 2015
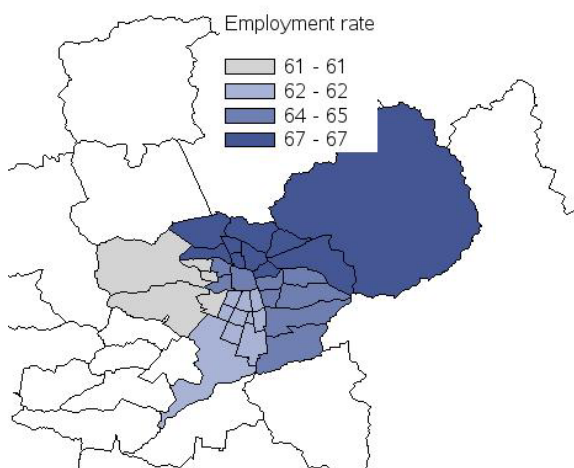
Note: Employment for the week of 29 November 2015 to 5 December 2015.
Source: Encuesta de Ocupación y Desocupación del Gran Santiago.

Figure 6: Hours worked per week by area in Santiago, Chile, 2015
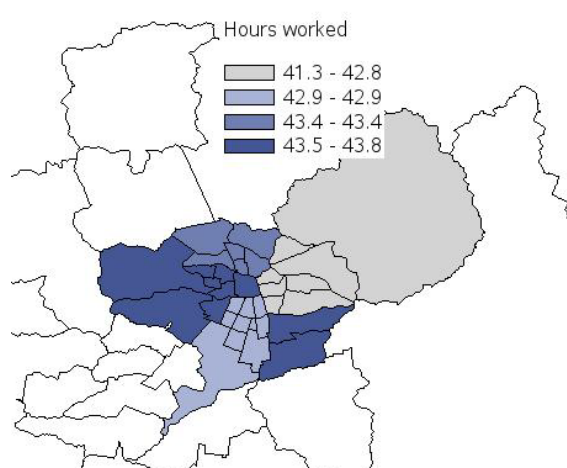
Note: Hours worked for the week of 29 November 2015 to 5 December 2015.
Source: Encuesta de Ocupación y Desocupación del Gran Santiago.

To finalise the descriptive analysis, Figure 7 shows the evolution of the number of dependent children per household in Santiago between 1997 and 2016. For the purposes of this study, a dependent child is one who is 14 years old or younger; a dependent elderly is a 60-year-old or older who lives in a household as a relative or non-relative (i.e. not the head of the household nor the spouse of the household head). The average number of dependent children in the household peaked at 0.98 in 1998Q3 and decreases progressively to reach 0.63 in 2016Q3.

The average number of dependent elderly in a household shows a slow but continuous increase from around 0.06 in 1998Q3 to almost 0.1 in 2016. This means that, assuming one dependent elderly per household, the share of households with dependent elderly passed from 1 out of every 20 to 1 out of every 10 in 20 years, a very rapid change in the need for care, as noted by Palacios (2017).

Figure 8 shows that household income has shown a general increase throughout the period (dark blue line) and that there are strong geographic inequalities in income distribution. While the median income for households in the stratum that includes the wealthy municipalities of Las Condes, Lo Barnechea and Vitacura fluctuate around 1 million CLP, the median household income for household in the stratum that includes the poorer municipalities of El Bosque, La Pintana and San Bernardo fluctuates around the 400 000 CLP mark. Strata comprising the other municipalities have median incomes between these two extremes.

Figure 7: Average number of dependent children and elderly per household in Santiago, Chile, 1997-2016

Figure 8: Median household income in Santiago, Chile, 1997-2016
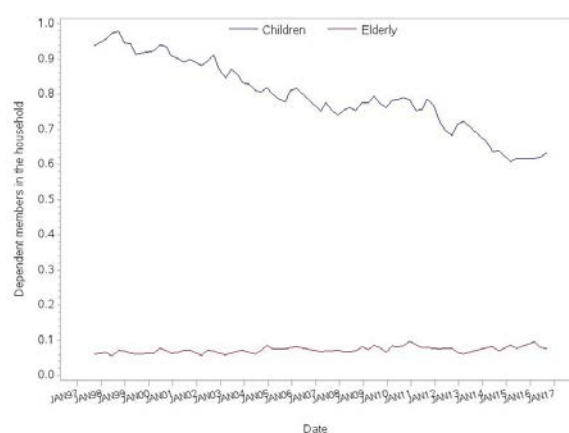
Note: Dependent children are household members aged 14 or younger. Dependent elderly are household members aged 60 or older who are relatives or non-relatives to the household head.
Source: Encuesta de Ocupación y Desocupación en el Gran Santiago.
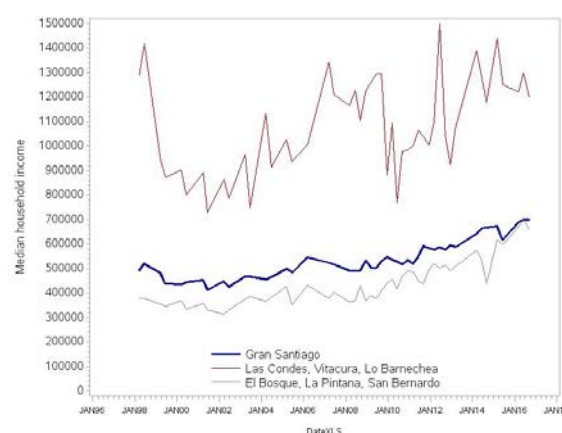
Note: Household income in 2016 Chilean Pesos. Sample trimmed at the 5th and 95th percentiles. The general median and the median for two of the eight strata in the sample are shown.
Source: Encuesta de Ocupación y Desocupación en el Gran Santiago.

Regression models shown in Table 2 estimate the relationship between air pollution and labour supply. After accounting for structural, cyclical and geographic variation through fixed effects, exposure to PM_{10} does not, on aggregate and for the whole labour market, reduce labour supply (Model 1). This aggregate relationship, masks differences by gender: when air pollution rises, women reduce their hours worked while men increase their hours worked: the coefficient for PM_{10} x Female is negative while the coefficient for PM_{10}, which corresponds to men, is positive (Model 2). For each 100 µg/m^3 increase in a week's PM_{10}, women reduce, on average, their work week in 2.6 hours while men increase theirs by

2 hours. These analyses speak to the general aggregate pattern, it is not clear whether men compensate for women's reduced working hours in the household (it is the spouse who works late when the children are sick and cared for by women) or in the workplace (it is the male colleague who works late when the female colleague goes home early or takes leave to care for her sick child). Given that employment rates for men are higher than women, men's smaller increase over a larger employed population compensates for women's larger reduction over a smaller employed population.

A week characterised by recurrent episodes of *Alerta ambiental* (set at 195 µg/m^3) is expected to reduce women's participation by the equivalent of half a day worth of work. These coefficients are important in magnitude. They compare to the 2.0 average difference in hours worked per week between men and women when PM$_{10}$ concentration is nil (Female coefficient). A week with pollution at 100 µg/m^3 doubles the gender difference in working hours.

Such levels of pollution are not uncommon. Of the 1068 weeks with PM$_{10}$ measurements considered in this study, the weekly average surpassed 100 µg/m^3 on 213 weeks in the El Bosque monitoring station, 193 weeks in the Parque O'Higgins monitoring station, 192 weeks in the Pudahuel monitoring station and 189 weeks in the La Florida monitoring station. The Las Condes monitoring station, situated on the north-east side of the city which hosts the majority of the upper-income population, only averaged pollution levels above or equal to 100 µg/m^3 on 20 weeks.

Model 2 also suggests that the impact of air pollution on working hours does not differ by age (PM$_{10}$ x Age coefficient). Air pollution impacts workers in the construction sector more heavily, in all likelihood because of their higher exposure to urban outdoor air pollution.

Table 2:   The relationship between hours worked, air pollution, gender and care in Santiago, Chile (Models 1-2)

	Model 1	Model 2	
PM_{10}	0.0017	0.0195	***
	(0.0021)	(0.0043)	
x Female		-0.0259	***
		(0.0025)	
x Age		-0.0001	
		(0.0001)	
x Agriculture and Mining		-0.0114	
		(0.0107)	
x Manufacturing		-0.0052	
		(0.0033)	
x Construction		-0.0242	***
		(0.0043)	
Female		-2.0167	***
		(0.1813)	
Age		0.0618	***
		(0.0064)	
Agriculture and Mining		1.6833	*
		(0.7392)	
Manufacturing		0.6568	**
		(0.2498)	
Construction		1.2886	***
		(0.3154)	
N	255418	255418	
R-squared	0.0123	0.0300	
Year, quarter, area fixed effects	YES	YES	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.
Source: Own calculation based on the Encuesta de Ocupación y Desocupación en el Gran Santiago and the Sistema de Información Nacional de Calidad del Aire.

Most of the gender-related difference in hours worked is driven by childcare (Model 3, Table 3). The coefficient associated to PM_{10} x Female interaction is halved (from -0.259 to -0.0124, it remains significant at the $p<0.05$ level). The coefficient associated to the gender-children-PM_{10} interaction absorbs most of this difference. For each child in the home, women are expected to see their weekly hours worked reduced, on average, by 1.6 hours when PM_{10} increases by 100 µg/m³.

These results do not hold for care for the elderly (Model 4). This may largely be the result of the fact that elderly are cared for at home in Chile, so when they fall sick there is not necessarily a change in the care arrangement: it is still a family relative who does not work for pay in parallel to the elderly care responsibility doing the care (Palacios, 2017).

These results suggest that when children fall sick they are not able to go to school and must be cared for at home, as found in the literature (Park et al., 2002; Currie et al., 2009). If no other care arrangement

exists, it is largely women who reduce their working hours.[9]

Model 5 confirms the idea that the gendered effect of air pollution on air supply is driven, to a large extent, by childcare. The effect of air pollution on women with children is largely nil for working women who have another non-working adult in the home who could, potentially care for the sick child. For women with no non-working adults, a 100 µg/m^3 increase in PM_{10} concentration is associated to an average 3.4 fewer hours worked for a woman with one child and 5.7 fewer hours worked for a woman with two children. Women with no children are also expected to see a small reduction in their working hours (at 1.1 hours per week, on average). The effect observed on women with no children could be the result of air pollution's direct effect on women's health.

The general pattern observed for PM_{10} holds for other pollutants (regression results in the appendix). There is no labour supply reduction when pollution increases in the magnitudes observed in Chile, except for CO (descriptives available in the appendix). Workers in the construction sector reduce their working hours following weeks with higher pollution (except for SO_2). The gendered and childcare-related penalty associated to air pollution is seen with $PM_{2.5}$, NO_2 and CO (it is non-significant for O_3 and in the opposite direction for SO_2, see the appendix).[10]

The general results observed for PM_{10} hold when restricting the sample to the ten-year period between 2007 and 2016. They also hold after including controls for educational attainment (and restricting the sample to the June surveys as only these surveys include educational attainment information). Findings lose significance after including controls for family income, suggesting complex interactions that should be followed up in future research.

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[9] Though this is the most likely explanation, it could also be the result of women falling sick because they care. If they interact more with children, as evidenced by time-use surveys, and interact more with sick children, they are more likely to fall sick due to contagion (INE, 2016). Yet, even if men interact less with children, their interaction with women would facilitate contagion as well, which would be observed in a decline in their working hours.

[10] The general results may not hold for SO_2 as SO_2 levels are generally low in Chile when compared to other urban areas (O'Ryan and Larraguibel, 2000) so there may not be enough variation in SO_2 levels to capture its health effects on children or other population groups.

Table 3: **The relationship between hours worked, air pollution, gender and care in Santiago, Chile (Models 3-5)**

	Model 3		Model 4		Model 5	
PM_{10}	0.0077	**	0.0101	***	0.0021	
	(0.0025)		(0.0023)		(0.0026)	
x Female	-0.0124	***	-0.0226	***	-0.0110	***
	(0.0030)		(0.0025)		(0.0032)	
x Female x Children	-0.0155	***			-0.0231	***
	(0.0030)				(0.0026)	
x Female x Elderly			0.0218	*		
			(0.0109)			
x Female x Non-working adult					0.0492	***
					(0.0101)	
x Female x Children x Non-working adult					0.0017	
					(0.0101)	
x Children	0.0032				0.0116	***
	(0.0019)				(0.0008)	
x Elderly			-0.0074			
			(0.0078)			
x Non-working adult					-0.0001	
					(0.0040)	
Female	-2.2601	***	-2.3260	***	-2.0423	***
	(0.2160)		(0.1792)		(0.2252)	
x Children	-0.1368				0.6318	***
	(0.2073)				(0.1663)	
x Non-working adult					-4.4263	***
					(0.7248)	
x Children x Non-working adult					-1.2015	
					(0.7201)	
x Elderly			-0.4203			
			(0.7255)			
Children	0.7741	***				
	(0.1315)					
x Non-working adult					0.3036	**
					(0.1093)	
Elderly			-0.2751			
			(0.5493)			
Non-working adult					1.3750	***
					(0.3001)	
N	255418		255418		255418	
R-squared	0.0293		0.0276		0.0303	
Year, quarter and area fixed effects	YES		YES		YES	

* p<0.05, ** p<0.01, *** p<0.001.
Source: Own calculation based on the Encuesta de Ocupación y Desocupación en el Gran Santiago and the Sistema de Información Nacional de Calidad del Aire.

5. Conclusions

This paper draws on 20 years of systematic data collection on employment and air pollution to explore the link between air pollution and labour supply. Findings suggest that, on the aggregate, air pollution in the levels commonly observed in Santiago, Chile, do not reduce overall labour supply. This general trend hides, however, an important gendered effect. Women, and women with children in particular, tend to reduce their hours worked in weeks of high pollution and there is some indication that this reduction is compensated by men, so that the aggregate effect is nil.

This gendered effect is rooted in the inequalities in the distribution of care obligations and perpetuates gender inequalities in the labour market. Chile is noted as an exception, as the high levels of female educational attainment have not allowed for a stronger labour force participation, with the gendered perceptions of caring responsibilities having a prominent role in explaining gender-related labour market outcomes (Contreras, Hurtado, and Sara, 2012). Workers who work fewer hours are less likely to earn a promotion, particularly in countries with high levels of inequality (Bell and Freeman, 2001). Policy that reduces air pollution and its effects on children's health advances gender equality in the labour market.

The results in this study find a relationship between air pollution and hours worked through gender and child care, but not through elderly care. Though both children and the elderly's health is especially sensitive to air pollution, this finding does not mean that elderly care is unrelated to labour supply. This study measures labour supply in the form of hours worked, assuming that the carer for the sick child or elderly works for pay. However, the lack of policies to support elderly care mean that elderly carers are generally out of the labour force altogether (Palacios, 2017). Were policies to support elderly care develop in Chile and allow carers to work for pay at the same time, air pollution may affect labour supply like it does for children when their parents work while they are at school.

The findings in this paper do not show an overall reduction in labour supply as a result of air pollution, as observed in other studies for Peru (Aragon, Miranda, and Oliva, 2016), India (ASSOCHAM, 2016) or Indonesia (Kim, Manley, and Radoias, 2017), which draw on a different research design, a shorter time period of analysis or extreme pollution events. In this study it is seen, though small, for women with no children, but compensated for by men. The lack of an overall reduction in labour supply may be also be due to the fact that given the long tradition of air pollution in Santiago (O'Ryan and Larraguibel, 2000), individuals are more familiar with actions to reduce outdoor air pollution's health effects.

These findings, and the data on which they are based, do not speak to the long term effects of exposure to sustained or peak air pollution, which do exist (Kim, Manley, and Radoias, 2017). Unfortunately, the household income data in the employment survey does not allow for a robust assessment of the extent to which income attenuate the care-related effects seen in the regression models. It could be the case, for example, that this care-related pollution effect on women's work does not apply to high-income households who employ housemaids (Stefoni, 2009). Full-time housemaids who can, when children fall sick, add caring duties to their usual work. Full-time housemaids are common in Latin America and other parts of the world. Usually, their work involves flexibility in the number and type of tasks to be carried out so housemaids can care for sick dependents on a sporadic basis if needed (Stefoni, 2009; Palacios, 2017).

Several policies can help reduce the gendered effects of air pollution on labour supply, as they operate mostly through care and dependent's health. First and foremost, policies to reduce air pollution, and air pollution peaks in particular, will eliminate this source of gender inequality. This requires addressing the main sources of air pollution: inefficient fossil fuel combustion from motor vehicles, power generation, improve energy efficiency in buildings and manufacturing and reduce the sources of solid particulates (WHO, 2010). Policies can also help reduce the health impacts given air pollution levels, which will reduce children's risk of illness. These include reducing exposure to ambient air pollution by staying indoors, reducing outdoor air infiltration indoors, cleaning indoor air with air filters and limiting physical exertion (Laumbach, Meng, and Kipen, 2015). Finally, if air pollution and children's deteriorated health are given, policies can also help reduce the gendered effects by promoting a more equal distribution of care across gender, as outlined by Contreras et al. (2012) for the specific case of Chile.

Future research should explore in more detail the relationship between air pollution, labour supply and income, insofar mitigation policies could also be considered pro-poor and contribute to social equity. Future research should examine care for dependent's mediating role in the relationship between air pollution and female labour supply by checking the effect of air pollution on school attendance, for example. Future research should explore the generalizability of these findings to other social contexts and care regimes by applying the methodology to cities in developed countries as well as cities in other emerging and developing countries and by complementing these results to measures of indoor air pollution.

References

Aragon, F.M.; Miranda, J.J.; Oliva, P. 2016. Particulate matter and labor supply: Evidence from Peru, in Working Papers, No. 16-01 (Department of Economics, Simon Fraser University).

ASSOCHAM. 2016. Smog hitting employees at India Inc. hard and fast in Delhi-NCR: Survey (New Delhi, The Associated Chambers of Commerce & Industry of India).

Bell, L.A.; Freeman, R.B. 2001. "The incentive for working hard: Explaining hours worked differences in the US and Germany", in Labour Economics, Vol. 8, No. 2, pp. 181–202.

Contreras, D.; Hurtado, A.; Sara, M.F. 2012. "La excepción Chilena y las percepciones de género en la participación laboral femenina", in Documentos de Trabajo, No. 374 (Departmento de Economía, Universidad de Chile).

Currie, J.; Hanushek, E.; Kahn, M.; Neidell, M.; Rivkin, S. 2009. "Does pollution increase school absences?", in The Review of Economics and Statistics, Vol. 91, No. 4, pp. 682–694.

EPA. 2017. Basic information about lead air pollution (Washington, DC, Environmental Protection Agency).

Eriksson, R.; Nermo, M. 2010. "Care for sick children as a proxy for gender equality in the family", in Social Indicators Research, Vol. 97, No. 3, pp. 341–356.

Heymann, S.J.; Penrose, K.; Earle, A. 2006. "Meeting Children's Needs: How Does the United States Measure Up?", in Merrill-Palmer Quarterly, Vol. 52, No. 2, pp. 189–215.

Hollingsworth, B.; Ohinata, A.; Picchio, M.; Walker, I. 2017. "Labour supply and informal care supply: The impacts of financial support for long-term elderly care", in IZA Discussion Paper Series, No. 10988.

ILO. 2018. WESO 2018: Greening with jobs (Geneva, International Labour Office). Forthcoming.

INE. 2016. Encuesta nacional sobre uso del tiempo (Santiago, Instituto Nacional de Estadísticas).

Kim, Y.; Manley, J.; Radoias, V. 2017. "Medium- and long-term consequences of pollution on labor supply: Evidence from Indonesia", in IZA Journal of Labor Economics, Vol. 6, No. 1, p. 5.

Laumbach, R.; Meng, Q.; Kipen, H. 2015. "What can individuals do to reduce personal health risks from air pollution?", in Journal of Thoracic Disease, Vol. 7, No. 1, pp. 96–107.

Martínez Franzoni, J. 2008. "Welfare Regimes in Latin America: Capturing Constellations of Markets, Families, and Policies", in Latin American Politics and Society, Vol. 50, No. 2, pp. 67–100.

Muñoz, M. 1991. La contaminación atmosférica en Santiago: impacto sobre la salud de su población (Centro de Estudios Públicos).

OECD. 2014a. The cost of air pollution: Health impacts of road transport (Paris, OECD Publishing).

—. 2014b. Unpaid care work: The missing link in the analysis of gender gaps in labour outcomes (Paris, Organisation for Economic Co-operation and Development).

—. 2016a. The economic consequences of outdoor air pollution (Paris, OECD Publishing).

—. 2016b. Education at a Glance 2016 (Paris, OECD Publishing).

O'Ryan, R.; Larraguibel, L. 2000. Contaminación del aire en Santiago: Estado actual y soluciones, No. 75 (Centro de Economía Aplicada, Universidad de Chile).

Palacios, J. 2017. Caring for the elderly in Chile (Rennes, University of Rennes).

Park, H.; Lee, B.; Ha, E.-H.; Lee, J.-T.; Kim, H.; Hong, Y.-C. 2002. "Association of air pollution with school absenteeism due to illness", in Archives of Pediatrics & Adolescent Medicine, Vol. 156, No. 12, pp. 1235–1239.

Rodríguez, J.; Arriagada, C. 2004. "Segregación residencial en la ciudad latinoamericana", in EURE, Vol. 30, No. 89, pp. 05-24.

Romley, J.; Hackbarth, A.; Goldman, D. 2010. The impact of air quality on hospital spending (Santa Monica, RAND Corporation).

Sabatini, F.; Wormald, G.; Sierralta, C.; Peters, P.A. 2009. "Residential segregation in Santiago: Scale-related effects and trends, 1992–2002", in Roberts, B.R. and Wilson, R.H. (eds.): in Urban Segregation and Governance in the Americas (Palgrave Macmillan US), pp. 121–143.

Stefoni, C. 2009. "Migración, género y servicio doméstico: Mujeres peruanas en Chile", in Trabajo Doméstico: Un Largo Camino Hacia El Trabajo Decente (Santiago, Organización Internacional del Trabajo), pp. 191–232.

Unsworth, M.H.; Ormrod, D.P. 1982. Effects of Gaseous Air Pollution in Agriculture and Horticulture (London, Butterworth Scientific).

WHO. 2006. Air quality guidelines: Global update 2005 (Geneva, World Health Organization).

—. 2010. Exposure to air pollution: A major public health concern (Geneva, World Health Organization).

—. 2016. Urban ambient air pollution database: Update 2016 (Geneva, World Health Organization).

—. (n.d.). "Background information on urban outdoor air pollution", in Public Health, Environmental and Social Determinants of Health. Available at: http://www.who.int/phe/health_topics/outdoorair/databases/background_information/en/ [Accessed: January 15, 2018].

WHO; OECD. 2015. Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth (Copenhagen, WHO Regional Office for Europe).

World Bank; Institute for Health Metrics and Evaluation. 2016. The cost of air pollution: Strengthening the economic case for action (Washington DC, The World Bank Group).

Appendices

Appendix A: Air pollution trends for non-PM$_{10}$ pollutant, Santiago, Chile, 1997-2017
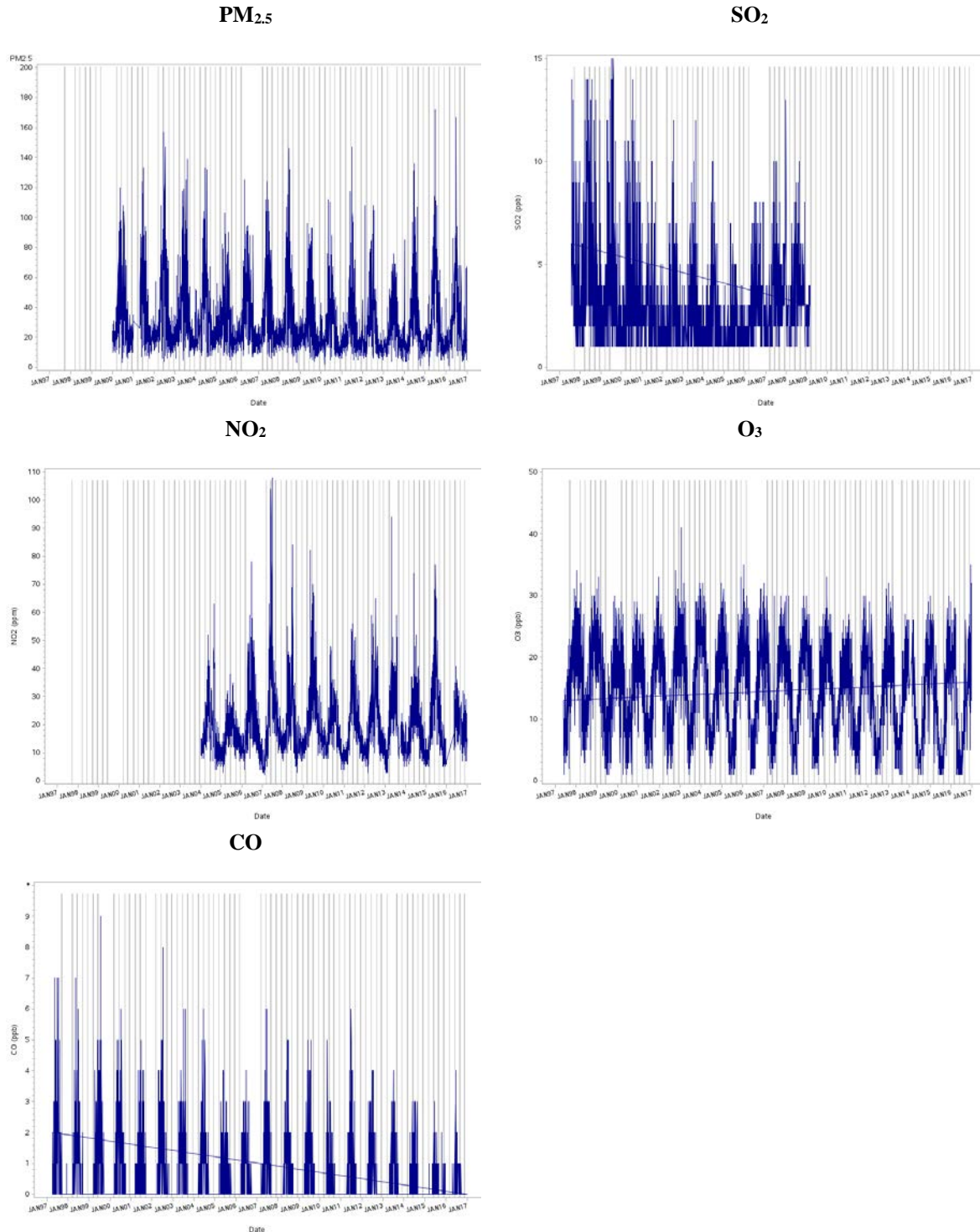
PM$_{2.5}$

SO$_2$

NO$_2$

O$_3$

CO

Note: Shaded area corresponds to the week prior to the employment survey reference week.
Source: Sistema de Información Nacional de Calidad del Aire, Estación Pudahuel.

Appendix B: Correlation between daily pollutant measurements, Santiago, Chile, 1997-2017

	PM10	PM2.5	SO_2	NO_2	O_3	CO
PM10	1					
	7138					
PM2.5	0.89	1				
	6001	*6134*				
SO_2	0.77	0.75	1			
	4407	*4515*	*4546*			
NO_2	0.71	0.70	0.59	1		
	4109	*3147*	*1780*	*4125*		
O_3	-0.20	-0.41	-0.48	-0.14	1	
	6944	*5991*	*4427*	*4098*	*7083*	
CO	0.79	0.83	0.70	0.66	-0.40	1
	6988	*6040*	*4482*	*4060*	*6950*	*7146*

Notes: In italics the number of observations used to calculate the correlation. All available daily information is used to calculate this table; it is not restricted to the pollution associated to each reference week.
Source: Sistema de Información Nacional de la Calidad del Aire, Estación Pudahuel.

Appendix C: Regression results for PM$_{2.5}$

	Model 1		Model 2		Model 3		Model 4		Model 5	
PM$_{2.5}$	-0.0004 (0.0046)		0.0122 (0.0092)		0.0032 (0.0055)		0.0079 (0.0050)		-0.0173 (0.0057)	**
x Female			-0.0294 (0.0052)	***	-0.0084 (0.0064)		-0.0254 (0.0052)	***	0.0069 (0.0067)	
x Female x Children					-0.0261 (0.0065)	***			-0.0394 (0.0057)	***
x Female x Elderly							0.0255 (0.0221)			
x Female x Non-working adult									0.0308 (0.0210)	
x Female x Children x Non-working adult									-0.0031 (0.0217)	
x Children					0.0088 (0.0040)	*			0.0233 (0.0021)	***
x Elderly							0.0137 (0.0163)			
x Non-working adult									0.0315 (0.0083)	***
x Age			0.0001 (0.0002)							
x Agriculture and Mining			-0.0208 (0.0232)							
x Manufacturing			-0.0135 (0.0072)							
x Construction			-0.0285 (0.0090)	**						
Female			-2.7489 (0.1601)	***	-2.8230 (0.1915)	***	-3.0089 (0.1584)	***	-2.9460 (0.1989)	***
x Children					-0.3080 (0.1851)				0.4048 (0.1481)	**
x Non-working adult									-2.1545 (0.6285)	***
x Children x Non-working adult									-1.2617 (0.6256)	*
x Elderly							0.0861 (0.6066)			
Children					0.7039 (0.1182)	***				
x Non-working adult									0.5399 (0.1171)	***
Elderly							-0.8549 (0.4782)			
Non-working adult									0.4073 (0.2702)	
Age			0.0625 (0.0057)	***						
Agriculture and Mining			1.5627 (0.6601)	*						
Manufacturing			0.7414 (0.2253)	**						
Construction			0.7595 (0.2790)	**						
N	177034		177034		177034		177034		177034	
R-squared	(0.0091)		(0.0286)		(0.0267)		(0.0249)		(0.0280)	
Year, quarter, area fixed effects	YES		YES		YES		YES		YES	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$. Source: Own calculation based on EOD and SINCA data.

Appendix D: Regression results for SO₂

	Model 1		Model 2		Model 3		Model 4		Model 5	
SO$_2$	0.0025		-0.0608	***	0.0370	***	0.0183	*	0.0171	
	(0.0075)		(0.0165)		(0.0091)		(0.0085)		(0.0098)	
x Female			-0.0360	***	-0.0590	***	-0.0430	***	-0.0443	***
			(0.0093)		(0.0108)		(0.0093)		(0.0118)	
x Female x Children					0.0330	***			-0.0116	
					(0.0094)				(0.0093)	
x Female x Elderly							0.0068			
							(0.0394)			
x Female x Non-working adult									0.0597	
									(0.0363)	
x Female x Children x Non-working adult									0.0112	
									(0.0346)	
x Children					-0.0344	***			0.0099	*
					(0.0053)				(0.0045)	
x Elderly							0.0142			
							(0.0249)			
x Non-working adult									-0.0225	
									(0.0150)	
x Age			0.0017	***						
			(0.0003)							
x Agriculture and Mining			0.0704							
			(0.0389)							
x Manufacturing			0							
			0.0139							
x Construction			0.0218							
			(0.0162)							
Female			-3.7319	***	-2.7642	***	-3.7706	***	-3.0613	***
			(0.0924)		(0.1121)		(0.0921)		(0.1164)	
x Children					-1.6593	***			-0.1735	
					(0.1166)				(0.0948)	
x Non-working adult									-0.8650	*
									(0.3876)	
x Children x Non-working adult									-2.1689	***
									(0.3910)	
x Elderly							1.2322	**		
							(0.4490)			
Children					1.4177	***				
					(0.0733)					
x Non-working adult									1.1885	***
									(0.1143)	
Elderly							-0.7998	**		
							(0.2984)			
Non-working adult									1.0393	***
									(0.1678)	
Age			0.0384	***						
			(0.0033)							
Agriculture and Mining			1	*						
			0.3975							
Manufacturing			0.2385							
			(0.1246)							
Construction			-0.6125	***						
			(0.1607)							
N	196533		196533		196533		196533		196533	
R-squared	0.0117		0.0294		0.0294		0.0273		0.0291	
Year, quarter, area fixed effects	YES		YES		YES		YES		YES	

* p<0.05, ** p<0.01, *** p<0.001. Source: Own calculation based on EOD and SINCA data.

Appendix D: Regression results for NO$_2$

	Model 1	Model 2		Model 3		Model 4		Model 5	
NO$_2$	-0.0052	-0.0206		0.0047		-0.0029		-0.0258	**
	(0.0062)	(0.0131)		(0.0075)		(0.0070)		(0.0079)	
x Female		-0.0167	*	-0.0003		-0.0125		0.0234	*
		(0.0073)		(0.0087)		(0.0073)		(0.0092)	
x Female x Children				-0.0168	*			-0.0415	***
				(0.0082)				(0.0071)	
x Female x Elderly						0.0128			
						(0.0291)			
x Female x Non-working adult								0.0319	
								(0.0283)	
x Female x Children x Non-working adult								-0.0333	
								(0.0280)	
x Children				-0.0104	*			0.0172	***
				(0.0051)				(0.0026)	
x Elderly						0.0372			
						(0.0219)			
x Non-working adult								0.0448	***
								(0.0116)	
x Age		0.0006	*						
		(0.0003)							
x Agriculture and Mining		0.0273							
		(0.0298)							
x Manufacturing		0							
		0.0108							
x Construction		-0.0331	**						
		(0.0127)							
Female		-3.0682	***	-3.1433	***	-3.3529	***	-3.5060	***
		(0.1800)		(0.2120)		(0.1780)		(0.2202)	
x Children				-0.3438				0.5660	***
				(0.1988)				(0.1568)	
x Non-working adult								-1.6057	*
								(0.6969)	
x Children x Non-working adult								-0.7402	
								(0.6772)	
x Elderly						0.5228			
						(0.6512)			
Children				0.9124	***				
				(0.1291)					
x Non-working adult								0.3613	**
								(0.1312)	
Elderly						-1.4182	**		
						(0.5296)			
Non-working adult								0.0665	
								(0.3018)	
Age		0.0560	***						
		(0.0064)							
Agriculture and Mining		1.0182							
		(0.6948)							
Manufacturing		0.7951	**						
		(0.2662)							
Construction		0.8351	**						
		(0.3151)							
N	115864	115864		115864		115864		115864	
R-squared	0.0048	0.0261		0.0224		0.0211		0.0231	
Year, quarter, area fixed effects	YES	YES		YES		YES		YES	

* p<0.05, ** p<0.01, *** p<0.001. Source: Own calculation based on EOD and SINCA data.

Appendix E: Regression results for O₃

	Model 1		Model 2		Model 3		Model 4		Model 5	
O₃	0.0192		0.0612	***	-0.0102		0.0081		-0.0188	
	(0.0102)		(0.0170)		(0.0114)		(0.0108)		(0.0117)	
x Female			0.0322	***	0.0337	***	0.0300	***	0.0447	***
			(0.0086)		(0.0101)		(0.0085)		(0.0108)	
x Female x Children					-0.0109				-0.0348	***
					(0.0097)				(0.0084)	
x Female x Elderly							-0.0082			
							(0.0361)			
x Female x Non-working adult									-0.0028	
									(0.0340)	
x Female x Children x Non-working adult									-0.0156	
									(0.0345)	
x Children					0.0288	***			0.0527	***
					(0.0062)				(0.0036)	
x Elderly							-0.0406			
							(0.0267)			
x Non-working adult									-0.0213	
									(0.0139)	
x Age			-0.0014	***						
			(0.0003)							
x Agriculture and Mining			-0.0936	**						
			(0.0345)							
x Manufacturing			0							
			0.0120							
x Construction			0.0364	*						
			(0.0152)							
Female			-4.2256	***	-3.6183	***	-4.2808	***	-3.4789	***
			(0.1390)		(0.1642)		(0.1381)		(0.1718)	
x Children					-0.9498	***			-0.3208	**
					(0.1552)				(0.1244)	
x Non-working adult									-1.0790	
									(0.5518)	
x Children x Non-working adult									-0.9050	
									(0.5522)	
x Elderly							1.2004			
							(0.6146)			
Children					0.5804	***				
					(0.0983)					
x Non-working adult									0.3054	**
									(0.1082)	
Elderly							-0.2350			
							(0.4217)			
Non-working adult									1.7015	***
									(0.2360)	
Age			0.0728	***						
			(0.0049)							
Agriculture and Mining			2.2608	***						
			(0.5698)							
Manufacturing			0.3125							
			(0.1926)							
Construction			-0.9052	***						
			(0.2412)							
N	253669		253669		253669		253669		253669	
R-squared	0.0121		0.0293		0.0287		0.0270		0.0295	
Year, quarter, area fixed effects	YES		YES		YES		YES		YES	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$. Source: Own calculation based on EOD and SINCA data.

Appendix F: Regression results for CO

	Model 1	Model 2	Model 3	Model 4	Model 5
CO	-0.2090 * (0.0980)	0.1799 (0.1816)	-0.2000 (0.1147)	-0.1030 (0.1047)	-0.5109 *** (0.1226)
x Female		-0.5308 *** (0.1017)	-0.0456 (0.1266)	-0.3606 *** (0.1012)	0.1625 (0.1371)
x Female x Children			-0.5706 *** (0.1380)		-1.0327 *** (0.1374)
x Female x Elderly				-0.0345 (0.5093)	
x Female x Non-working adult					1.1911 ** (0.4239)
x Female x Children x Non-working adult					0.5697 (0.4384)
x Children			0.1605 (0.0851)		0.6073 *** (0.0770)
x Elderly				-0.0091 (0.3476)	
x Non-working adult					0.0954 (0.1646)
x Age		-0.0026 (0.0037)			
x Agriculture and Mining		-0.7214 (0.4545)			
x Manufacturing		0 0.1304			
x Construction		-1.0308 *** (0.1754)			
Female		-3.5669 *** (0.0750)	-3.1028 *** (0.0890)	-3.7180 *** (0.0742)	-3.1757 *** (0.0926)
x Children			-0.9419 *** (0.0859)		0.0430 (0.0685)
x Non-working adult					-1.2455 *** (0.3044)
x Children x Non-working adult					-1.9599 *** (0.3088)
x Elderly				0.9055 ** (0.3060)	
Children			0.9357 *** (0.0551)		
x Non-working adult					0.9486 *** (0.0941)
Elderly				-0.7629 ** (0.2327)	
Non-working adult					0.9956 *** (0.1377)
Age		0.0547 *** (0.0027)			
Agriculture and Mining		1.1473 *** (0.2992)			
Manufacturing		0.3793 *** (0.1033)			
Construction		0.0570 (0.1310)			
N	254419	254419	254419	254419	254419
R-squared	0.0124	0.0300	0.0293	0.0276	0.0297
Year, quarter, area fixed effects	YES	YES	YES	YES	YES

* $p<0.05$, ** $p<0.01$, *** $p<0.001$. Source: Own calculation based on EOD and SINCA data.

Appendix G: Regression results for non-continuous PM$_{10}$ measure

	Model 1	Model 2		Model 3		Model 4		Model 5	
PM$_{10}$ level: Regular (>150µg/m³)	-0.0168	0.4451	**	0.0629		0.0935		0.1151	
	(0.0656)	(0.1693)		(0.0907)		(0.0768)		(0.1022)	
x Female		-0.4360	***	-0.1282		-0.2819	**	-0.3400	***
		(0.1036)		(0.1297)		(0.1029)		(0.1418)	
x Female x Children				-0.3017	*			-0.2378	
				(0.1403)				(0.1446)	
x Female x Elderly						-0.4011			
						(0.5298)			
x Female x Non-working adult								2.1366	***
								(0.4397)	
x Female x Children x Non-working adult								-0.3197	
								(0.4667)	
x Children				0.0267				0.0122	
				(0.0841)				(0.0847)	
x Elderly						-0.2105			
						(0.3351)			
x Non-working adult								-0.1863	
								(0.1654)	
x Age		-0.0054							
		(0.0037)							
x Agriculture and Mining		-1.0753	*						
		(0.5097)							
x Manufacturing		-0.1290							
		(0.1299)							
x Construction		-0.7677	***						
		(0.1747)							
Female		-3.6958	***	-3.1208	***	-3.8071	***	-2.7024	***
		(0.0665)		(0.0794)		(0.0659)		(0.0893)	
x Children				-1.0658	***			-0.9323	***
				(0.0776)				(0.0871)	
x Non-working adult								-1.6022	***
								(0.2749)	
x Children x Non-working adult								-0.9191	**
								(0.2854)	
x Elderly						0.9540	***		
						(0.2795)			
Children				0.9771	***			0.8848	***
				(0.0493)				(0.0611)	
x Non-working adult								0.1516	
								(0.1134)	
Elderly						-0.7408	***		
						(0.2078)			
Non-working adult								1.5117	***
								(0.1296)	
Age		0.0545	***						
		(0.0024)							
Agriculture and Mining		1.0794	***						
		(0.2691)							
Manufacturing		0.3285	***						
		(0.0913)							
Construction		-0.2164							
		(0.1154)							
N	255418	255418		255418		255418		255418	
R-squared	0.0123	0.0297		0.0289		0.0273		0.0300	
Year, quarter, area fixed effects	YES	YES		YES		YES		YES	

* p<0.05, ** p<0.01, *** p<0.001. Source: Own calculation based on EOD and SINCA data.

Appendix H: Regression results adding controls for income and educational attainment

	Model 1		Model 2		Model 3	
PM10 level: Regular	0.0096	***	0.0080	*	0.0115	
	(0.0023)		(0.0032)		(0.0075)	
x Female	-0.0143	***	-0.0111	**	-0.0158	***
	(0.0028)		(0.0035)		(0.0046)	
x Female x Children	-0.0123	***	-0.0057		-0.0111	**
	(0.0024)		(0.0036)		(0.0042)	
x Children			0.0004		0.0028	
			(0.0022)		(0.0026)	
x Income			0.0003			
			(0.0003)			
x Post-secondary					0.0264	***
					(0.0045)	
Female	-2.1329	***	-2.5202	***	-1.6573	***
	(0.2025)		(0.2663)		(0.4258)	
x Children	-0.3443	*	-1.1977	***	-0.2395	
	(0.1671)		(0.2646)		(0.3727)	
Children	0.9800	***	1.0332	***	0.5556	*
	(0.0473)		(0.1647)		(0.2320)	
Income			0.1015	***		
			(0.0183)			
Post-secondary					-6.3088	***
					(0.4114)	
N	255683		158723		66453	
R-squared	(0.0293)		(0.0352)		(0.0403)	
Year, quarter, area fixed effects	YES		YES		YES	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Notes: Income measured in 2016 Chilean pesos, as 100 thousand pesos and centered at 500 000. Model 1 based on the entire sample. Due to availability of income and education data, Model 2 (income) is based on March and June surveys between 1997 and 2007 and all surveys after 2007 and Model 3 (educational attainment) is based only on June data.

Source: Own calculation based on EOD and SINCA data.