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THE UNEQUAL EFFECTS OF POLLUTION ON LABOR SUPPLY

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We use high-frequency data on fine particulate matter air pollution (PM 2.5) at the locality level to study the effects of high pollution on daily labor supply decisions in the metropolitan area of Mexico City. We document a negative, non-linear relationship between PM 2.5 and same-day labor supply, with strong effects on days with extremely high pollution levels. On these days, the average worker experiences a reduction of around 7.5% of working hours. Workers partially compensate for lost hours by increasing their labor supply on days that follow high-pollution days. We find that low-income workers reduce their labor supply significantly less than high-income workers. Unequal responses to high pollution along other dimensions (job quality, flexibility, gender) matter, but less than income. We provide suggestive evidence that reductions in labor supply due to high pollution are consistent with avoidance behavior.

KEYWORDS: Air pollution, labor supply, inequality, Mexico.

1. INTRODUCTION

AIR POLLUTION IS THE LARGEST ENVIRONMENTAL risk to health with approximately 3 million lives lost to ambient air pollution in a single year (WHO (2016)). A vast medical and economics literature has documented the causal effects of pollution on mental health (Zhang, Zhang, and Chen (2017)), respiratory and other diseases (Currie and Neidell (2005), Graff Zivin and Neidell (2013), Guarnieri and Balmes (2014)), subsequent hospitalizations (Moretti and Neidell (2011), Schlenker and Walker (2016)), and mortality (Chay and Greenstone (2003), Arceo, Hanna, and Oliva (2016), Anderson (2019), Deryugina, Heutel, Miller, Molitor, and Reif (2019)).[1] Can workers avoid the damaging effects of high levels of air pollution? On high pollution days, workers may face a trade-off between exposure to a harmful environment and income, as performing their usual income-generating activities may increase their exposure to pollution. This trade-off is

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[1]PM 2.5 has been documented to have severe short-term and long-term health impacts (see, e.g., Guarnieri and Balmes (2014) and Deryugina et al. (2019)).

particularly acute for poorer workers, whose income is closely linked to the daily number of hours worked.

In this paper, we use high frequency measures of air pollution and actual working hours to study the response of daily labor supply to particulate matter in the metropolitan area of Mexico City. More precisely, we use hourly readings of fine particulate matter (PM 2.5) from ground monitoring stations combined with the WHO's air quality thresholds to capture peaks in air pollution across days and localities. We match the air pollution data with detailed labor market data from the National Survey of Occupation and Employment (ENOE, for its acronym in Spanish) for 2005–2016. ENOE is a rolling panel of households that contains information on daily hours worked for each day in a reference week, socio-demographic information, income, and labor market characteristics, such as formality, self-employment status, and sector of occupation.

The richness and granularity of the data allows us to investigate whether workers adjust daily labor supply to mitigate environmental shocks and whether workers can adapt to environmental degradation. We estimate a panel model of labor supply. We include a comprehensive set of time-varying weather controls, variables to control for demographic and labor market characteristics, and a rich set of fixed effects to address unobserved, time-invariant and time-varying factors that could affect both air pollution and labor supply.

We find economically and statistically significant evidence that the relationship between particulate matter and daily labor supply is large, negative, and nonlinear. Using alternative air quality thresholds, we show that workers do not respond to less extreme levels of pollution that regularly exceed air quality guidelines and that the marginal effect of pollution is larger at higher levels of pollution. On an average day with PM 2.5 above the highest threshold, our results show an average reduction of same-day hours worked of 7.5%. This amounts to a loss or reallocation of around 635,000 person-days of labor on a high pollution day in the metropolitan area of Mexico City during the period analyzed. These responses are three times larger during the peak pollution season when air pollution shocks are longer and more frequent. Our results are robust, and of similar magnitude, when controlling for worker fixed effects, that is, the same individual adjusts their working hours when exposed to different levels of pollution. Results are also robust to a variety of specification checks, including an instrumental variables approach using wind as a predictor of local pollution levels.

We also document evidence of a dynamic adjustment of labor supply at the daily level. Using lags of pollution over a 6-day period, we find that workers partially compensate for same-day decreases in labor supply by *increasing* their hours worked in the following days. These intertemporal responses show that workers mitigate the effects of pollution shocks by reallocating their working hours. Relative to the literature looking at longer times frames (e.g., weeks, as in Hanna and Oliva (2015), Aragón, Miranda, and Oliva (2017)), this result provides new insights about how individuals adapt to worse environmental conditions.

The average effects of high pollution on labor supply encompass substantial heterogeneity. We use information on workers' regular monthly income to explore responses along the income distribution. We find that the responses at the top of the income distribution are significantly larger, both statistically and in terms of magnitude, than the responses at the bottom. The reduction in hours worked for a worker in the bottom decile is 61% lower than for a worker in the top decile. Overall, we find that the responses to one additional hour above the pollution threshold reduces labor supply by 1.6–2.3% for the poorest and 2.4–4% for the richest workers, using the average number of hours worked by decile. This increases to 4.5% and 5.1%, respectively, in the high pollution season. For illustration, on an average day with high pollution, high-income workers reduce daily hours worked by almost 31 minutes compared to 12 minutes for low-income workers. In the peak pollution season, high-income workers reduce daily hours worked by around 1 h and 40 minutes while a low-income worker reduces average daily hours worked by 48 minutes. As documented in other contexts (Jayachandran (2006), Bandiera, Lemos, and Sadun (2018)), this shows that the ability to reallocate labor is different for richer and poorer workers.

We provide evidence of unequal responses along other job characteristics (such as job quality, flexibility, or tasks) that are substantially less important. For example, the difference in response between formal and informal workers and between self-employed and employed workers are not as large as the difference in response between workers with income in the top and bottom deciles of the income distribution. Further, restricting the sample to informal or self-employed workers does not substantially change the heterogeneity that we observed across income levels, suggesting that other dimensions of heterogeneity are not as relevant as income for explaining unequal responses to pollution. This result is key to understanding how unequal behavioral responses to environmental shocks can exacerbate existing health inequalities.

Next, we explore the potential mechanisms that could link air pollution and labor supply. First, we investigate whether our aggregate or heterogeneous results could be driven by gender or household composition since the ability to adjust labor supply in response to high pollution may be correlated with the type of jobs men and women hold, household roles, or sector specialization. We find that, on average, women tend to reduce their hours worked *less* than men, that is, they work more on highly polluted days, and that their response is independent of whether or not they have children. We look at differences across high-income and low-income workers within each gender and we find that while low-income men and women respond similarly, high-income women reduce their hours worked less than high-income men on days with high pollution.[2]

Second, we look at the differential response of labor supply to air pollution across sectors to investigate three mechanisms. First, we show that our results are not driven by workers in sectors where the workplace is likely to be outdoors. For example, the point estimates are similar (overall and for high-income and low-income workers) in the construction industry and in industries that are more likely to happen indoors, such as manufacturing or professional services. Second, we show that the reduction in working hours is not driven by workers in sectors that are vulnerable to changes in demand for labor, for example, due to a reduction in consumer demand on high pollution days. The point estimates are slightly smaller, not larger, in magnitude for sectors that may experience a drop in product or service demand on high pollution days, such as the retail and hospitality and low-productivity services sectors, than for sectors that are less likely to be affected by daily demand fluctuations, such as professional services, manufacturing, or construction. Third, the reduction in working hours on high pollution days is not explained by public sector policy, such as closing schools or public offices on high pollution days. Across all sectors, we find the lowest point estimates in absolute terms for public sector workers (including education and healthcare). These results suggest that reductions in hours worked on high pollution days plausibly reflect workers' decisions instead of reductions in labor demand or public policy restrictions on high pollution days.

[2]Due to this phenomenon, we find that the unequal response between high-income and low-income workers is more pronounced in the sample of men than in the full sample.

Third, we use the government's air quality alerts to show that public sector restrictions and official air quality alerts cannot be the only mechanisms linking air pollution and labor supply. Our results hold when excluding weeks in which official alerts were issued, indicating that temporarily heightened attention to air pollution is not driving our main results.[3] As further evidence that reductions in labor supply reflect workers' decisions, public sector workers tend to work more than private sector workers on high pollution days whether or not we focus on weeks in which official alerts were issued. The same pattern holds for high-income and low-income workers in weeks in which an alert was issued indicating that access to information on air pollution is not likely to be driving the heterogeneous response to air pollution that we document.

Finally, we provide evidence suggesting that workers' decisions to reduce their hours worked on high pollution days reflects avoidance behavior, especially by high-income workers. We find that after consecutive days of high pollution, workers no longer reduce their hours worked in response to high pollution. This pattern is inconsistent with reductions in working hours being driven by short-term negative health impacts because these effects should not subside after consecutive days of high pollution.[4] More specifically, workers reduce their labor supply in response to contemporaneous PM 2.5 most on days in which neither of the previous 2 days had high levels of PM 2.5. As high pollution persists across days, the response to contemporaneous pollution decreases and becomes indistinguishable from zero on days in which both of the prior 2 days had high pollution. Furthermore, low-income workers seem to reduce their response quicker than high-income workers. As high pollution becomes more persistent, workers, especially low-income workers, are unable to sustain labor supply reductions. These results highlight the limitations of workers' ability to adapt to persistent high pollution using adjustments in labor supply as avoidance behavior.

Together, our results have implications for labor supply in higher pollution environments. The larger labor supply reductions that we document in the peak pollution season suggest that workers will respond to larger pollution shocks with larger decreases in labor supply. The dynamic responses and the effects on consecutive days of high pollution hint that there are limits to avoidance as an adaptive behavior. Workers partially compensate for hours of work lost due to high pollution, but as high pollution persists across successive days, workers reduce their response. Further, if pollution were to increase so that currently extreme levels of pollution were to become more frequent, our nonlinear results suggest that workers may shift their responses to a new, higher threshold, and work their normal hours in the new, more polluted environment.

Our results are consistent with other studies across different contexts (including richer and poorer countries) that identify the short-term causal relationship between particulate matter and labor outcomes (Hanna and Oliva (2015), Aragón, Miranda, and Oliva (2017), Kim, Manley, and Radoias (2017), Borgschulte, Molitor, and Zou (2022), Chan, Pelli, and Arancibia (2023)) and estimate (nonlabor-market-related) avoidance behavior on highly polluted days (Neidell (2004), Currie, Hanushek, Kahn, Neidell, and Rivkin (2009), Bharadwaj, Gibson, Zivin, and Neilson (2017)). We can also relate our findings to the

[3]In our sample, there were only 40 days with official alerts.

[4]A decrease in labor productivity on high pollution days could reduce labor supply through a substitution effect, that is, by reducing the opportunity cost of leisure. This effect has been documented in both indoor and outdoor settings (Graff Zivin and Neidell, 2012; Chang, Zivin, Gross, and Neidell (2016); Chang et al., 2019). There is additional evidence that pollution reduces productivity in other settings, such as performance on exams or cognitive abilities more generally (Stafford (2015), Ebenstein, Lavy, and Roth (2016), Roth (2018), Zhang, Chen, and Zhang (2018)).

literature that finds stronger health effects of air pollution for households or individuals with lower socioeconomic status (Arceo, Hanna, and Oliva (2016), Jans, Johansson, and Nilsson (2018), Zhang, Chen, and Zhang (2018)).

We unite these strands of the literature to make a novel contribution. Our paper is unique in its focus on labor supply adjustments as a short-term adaptive response to environmental shocks and in documenting unequal labor supply adjustments in response to pollution across the income distribution. Our rich, high-frequency data allow us to contribute new results to the literature linking air pollution to labor supply that could be disguised when using temporal aggregates, such as weekly averages. Specifically, we document that workers intertemporally substitute labor supply in response to high levels of PM 2.5 to mitigate pollution shocks and that high-income workers are able to sustain avoidance behavior over more consecutive high pollution days than low-income workers. Importantly, our results suggest that aggregate measures could mask differences in high-income and low-income workers' mitigation of the impacts of pollution shocks and ability to adapt to pollution shocks, overlooking a source of health inequalities.

The remainder of the paper proceeds as follows. Section 2 provides background on the context and describes the data used in the analysis. Section 3 presents an analytical framework that models workers' labor supply decision on high pollution days and discusses the empirical strategy. In Section 4, we present the main set of results, and in Section 5, we explore the role of income inequality. Section 6 discusses alternative mechanisms, and Section 7 concludes.

2. CONTEXT AND DATA

2.1. *Context*

Levels of particulate matter are high in Mexico City. This is reflected in Mexico City residents' concerns about local air quality. In a 2019 survey of 1869 households in lower-income neighborhoods of Mexico City, nearly 95% reported that air pollution was a "problem" or a "big problem" in Mexico City (Hanna, Hoffmann, Oliva, and Schneider (2021)).[5]

Particulate matter impacts visibility, and some particles are large or dark enough to be visible to the naked eye (EPA (2009)). Unlike other commonly regulated pollutants, particulate matter is not a single pollutant, but a mixture of many types of particles of different shapes, sizes, and chemical compositions. For regulatory purposes, particulate matter is monitored and regulated according to the size of particles. Two of the most commonly monitored types of particulate matter are inhalable particulate matter with a diameter of less than 10 μm (PM 10) and fine particulate matter with a diameter of less than 2.5 μm (PM 2.5). Therefore, PM 2.5 is a subset of PM 10.

In Mexico City, the principal sources of PM 2.5 and PM 10 are emissions from gasoline and diesel powered vehicles, resuspension of particles from paved and unpaved roads, construction, residential combustion, and industrial processes, particularly in the chemicals, minerals, cement, and power sectors (Mugica et al. (2009), Molina et al. (2010), Mancera, Muller, Mediavilla, and Guzmán (2014)). In addition, air pollution levels are affected by wildfires, wind speed and direction, air temperature, humidity, precipitation,

[5]The (translated) survey question is: "In general, do you think air pollution is a problem in Mexico City?" and the response categories are "No, it is not a problem," "It is a problem to some extent," "It is a problem," and "It is a very big problem.".

thermal inversions, and vegetation (Beckett, Freer-Smith, and Taylor (2000), Hien, Bac, Tham, Nham, and Vinh (2002), Secretaria del Medio Ambiente (2005), Janhäll (2015)).

Particulate matter is causally linked to respiratory and cardiovascular diseases and mortality in the health literature. Many studies provide evidence that short-term exposure to high levels of ambient particulate matter leads to negative health impacts on the day of exposure and the following days (Lin, Chen, Burnett, Villeneuve, and Krewski (2002), Tertre et al. (2002)). Short-term exposure to particulate matter can cause irritation of eyes, nose, throat, and lungs, coughing, sneezing, running nose, and shortness of breath. More seriously, short-term exposure to particulate matter can cause acute bronchitis, exacerbate asthma, causing asthma attacks, increase susceptibility to respiratory infections, and worsen heart conditions (EPA (2010)). Long-term exposure to particulate matter leads to severe negative health impacts, including mortality (Anderson, Thundiyil, and Stolbach (2011), Cesaroni et al. (2014)).

In cross-sectional data for the metropolitan area of Mexico City from the 2011/12 National Health and Nutrition Survey (Gutiérrez et al. (2013)), in January, the high pollution season, around 65% of all health issues reported were related to respiratory issues. This number drops to 41% in October, when pollution levels are significantly lower. Most of the reported ailments are cough, catarrh, or sore throat and respiratory infections. Only a third of the respondents sought medical help.

We focus on PM 2.5 in our main specifications for two reasons. First, the fine particulates that comprise PM 2.5 have stronger health impacts and cause a broader range of health impacts than coarser particulate matter. The fine size of PM 2.5 allows these particles to penetrate into the lungs and into the bloodstream, which allows them to travel to other organs (Bell, Samet, and Dominici (2004), Pope and Dockery (2006)). Second, its small size allows ambient PM 2.5 to more readily permeate buildings than ambient PM 10, making it more difficult to avoid exposure (Pope and Dockery (2006), CARB (2021)).[6]

2.2. *Data*

We combine data from three sources to create a data set of labor market outcomes, air pollution, and weather data for the metropolitan area of Mexico City.

We use detailed labor market data for 2005–2016 from the National Survey of Occupation and Employment (ENOE) collected by the National Institute of Statistics and Geography (INEGI) (INEGI (2005–2016)).[7] ENOE is a rolling panel that is conducted quarterly, with an individual interviewed in up to five consecutive quarters before being replaced in the sample.[8] The survey collects information on days worked and hours worked per day during the reference week. The reference week is the full week, starting on Monday, prior to the interview date. Daily hours worked is coded as missing for days in which the worker reported working more than 15 hours and daily hours worked is coded as 0 on days of the reference week in which the worker did not work. The survey also collects information on sector of employment, and type of position. In addition, ENOE contains sociodemographic data, including gender, age, education level, and household composition data, and locality of residence.[9] Some of the key variables for our analysis

[6]https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health.

[7]The labor supply survey is representative of the metropolitan area of Mexico City.

[8]All weeks in the period 2005–2016 are included in the sample.

[9]Mexico has 32 federal entities that are divided in around 2500 municipalities. Municipalities consist of one or more localities, that is, areas with settlements that have a name, legally or customary. In our sample, there

are related to earnings and job characteristics. In terms of income, the survey focuses on the regular net monthly earnings (after taxes and contributions). The survey also includes a categorical variable generated by the statistical agency that sorts workers' earnings in multiples of the minimum wage. The classification of workers as formal or informal is produced by INEGI, following international criteria. Workers are classified as informal if they work in small economic units (including self-employment or household firms) that are not legally registered, pay no taxes, and have basic or non-existent accounting practices. In addition, workers are also deemed to be informal if they are paid off-the-books by legally constituted firms, and thus, have no access to work rights (such as pension, social security, nonwage benefits, or severance payments). Self-employed workers work for their own account and may be formal or informal.

We obtained air pollution and weather variables, that is, levels of air pollutants, temperature, wind speed, and wind direction data at the hour level from the Secretary of the Environment's (SEDEMA) website (SEDEMA (2005–2016)). These data are collected by more than 40 ground monitoring stations across the metropolitan area. We create an hourly air pollution and weather series for each locality in the ENOE sample by weighting the data from each monitoring station within 20 km of the locality in proportion to the inverse of the distance between the centroid of the locality and the monitoring station. We use daily gridded precipitation data from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) at the University of California Santa Barbara (Funk et al. (2014)). CHIRPS incorporates 0.05-degree resolution satellite imagery with station data to create a gridded daily rainfall time series, which we average at the municipality level.

We match the air pollution and weather data to the labor market data by municipality (rainfall) or locality (all other air pollution and weather variables) of each worker's residence. Supplemental Appendix Figure B1 (Hoffmann and Rud (2024)) shows the geographical reach of the data we use for our analysis of labor supply. These include all localities in Mexico City (in light color) and in Estado de Mexico (in darker color) with a centroid that is within 20 kilometers of at least one pollution monitoring station (dots).

We code daily air pollution variables as the number of hours above the WHO air quality guideline (AQG) and 3 Interim Targets (IT1-IT3) for 24-hour concentrations of particulate matter (WHO (2005)). The interim targets are intended to be used in high pollution areas to progressively reduce air pollution. The annual air quality guideline for PM 2.5 represents the lowest level of air pollution at which total lung and cardiopulmonary cancer mortality have been shown to increase in response to long-term exposure to PM 2.5 with 95% confidence, and the annual air quality guideline for PM 10 is defined as twice the PM 2.5 concentration. The 24-hour air quality guidelines are based on the relationship between the 24-hour and annual concentrations of particulate matter. Interim Targets 1 are the levels that represent a 5% higher short-term mortality risk than the AQG based on multicenter studies and meta-analysis (WHO (2005)). In between, PM 2.5 IT1 and PM 2.5 AQG are Interim Targets 2 and 3.

During our study period 2005–2016, across all localities and days in our sample, pollution in Mexico City and surrounding localities is high. Figure 1 shows the distribution of the highest hourly PM 2.5 reading per locality-day, relative to the World Health Organization's Air Quality Guideline (AQG) and 3 Interim Targets (IT1-IT3) for 24-hour concentrations of particulate matter (WHO (2005)). The distribution has wide support

are 57 municipalities of the metropolitan area of Mexico City that contain 229 localities within 20 km of at least one monitoring station.

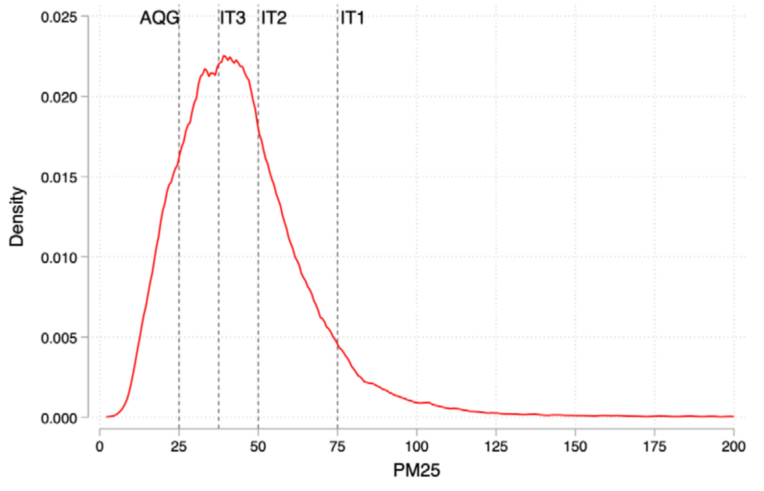

FIGURE 1.—Distribution of Maximum Daily—Locality PM 2.5. Note: Distribution of the daily maximum PM 2.5 hourly-location readings for 2005–2016 and the World Health Organization's (WHO) air quality guidelines (AQG) and interim targets (IT1-IT3).

with a large share of days experiencing at least 1 hour above the recommended pollution levels. Table I shows the targets, the share of hours in all locality-days above each target, and the share of days that have at least 1 hour above the target. In more than 40% of all hours and in almost 2 out of 3 days between 2005 and 2016, residents in Mexico City and surrounding localities experienced levels of pollution above the air quality guidelines for PM 2.5. The latter share increases to almost 80% for PM 10. Pollution has also exceeded the least ambitious of Interim Targets (IT1) in around 5.5% of days for PM 2.5 and almost 12% for PM 10.[10] The variation in PM 2.5 levels across days allows us to estimate the nonlinear effects of PM 2.5 and the impact of consecutive high pollution days.

Our measures of daily air pollution leverage our high frequency air pollution data to capture peaks in air pollution. Relative to the literature that studies daily or weekly average levels of particulate matter, which smooth peaks in air pollution, our measures represent an improvement for studying the nonlinear relationship between PM 2.5 and labor supply and estimating the impact of extreme levels of PM 2.5 on labor supply.

TABLE I

WHO AIR QUALITY GUIDELINES (AQG) AND INTERIM TARGETS (IT) AND POLLUTION INCIDENCE IN MEXICO CITY AND SURROUNDINGS (2005–2016).

	PM2.5			PM10		
	Target	Hour-locality (%)	Days-locality (%)	Target	Hour-locality (%)	Days-locality (%)
Interim Target 1 (IT1)	75	0.94	5.45	150	1.24	11.94
Interim Target 2 (IT2)	50	6.02	24.14	100	6.34	34.68
Interim Target 3 (IT3)	37.5	16.22	44.00	75	15.64	55.48

Note: PM 2.5 and PM 10 measured in $\mu g/m^3$ (WHO (2005)).

[10]There is substantial variation across localities and time within localities (see Figure B2).

TABLE II

SUMMARY STATISTICS—EMPLOYMENT AND ENVIRONMENT.

	N	Mean	Std Dev	Min	Max
A. Individual characteristics					
Age	318,103	39.20	13.52	12	98
Male (%)	318,103	0.59	0.49	0	1
Years of schooling	318,103	10.52	4.15	0	24
Informal (%)	318,103	0.53	0.50	0	1
Self-employed (%)	318,103	0.23	0.42	0	1
Wage employee (%)	318,074	0.57	0.50	0	1
Works in retail or services (%)	318,103	0.78	0.41	0	1
Earns up to one minimum wage (%)	318,103	0.09	0.29	0	1
B. Daily observations					
Hours Worked	2,227,363	6.26	4.04	0	15
Days Worked (%)	2,227,363	0.76	0.43	0	1
Hours Above PM2.5 IT1 Threshold	2,227,363	0.17	0.95	0	22
Hours Above PM2.5 IT2 Threshold	2,227,363	1.38	2.89	0	24
Hours Above PM2.5 IT3 Threshold	2,227,363	4.09	5.19	0	24
Hours Above PM2.5 AQG Threshold	2,227,363	10.20	7.70	0	24
Maximum Temperature (C)	2,227,363	23.32	3.06	8	34
Rainfall (mm)	2,227,363	1.95	4.52	0	70

In Table II, we provide summary statistics to characterize the sample that we use in the empirical analysis. As shown in Panel A, the average worker in our sample is around 39 years old with more than 10 years of schooling. 59% of the sample is male, 53% are informal, and nearly 80% of our sample works in the retail and services sector. Approximately 10% of our sample earn one minimum wage or less. In Panel B, we match workers' daily observations with air pollution and weather information. Workers work around 6.3 hours per day on 76% of days (i.e., more than 5 days a week). Note that on an average day, PM 2.5 levels are above the AQG threshold for more than 10 hours and above the highest threshold (IT1) for about 0.17 hours (equivalent to 10 minutes).

3. EMPIRICAL STRATEGY

3.1. *Analytical Framework*

In this section, we develop a simple framework to examine the channels through which high levels of pollution can affect labor supply on a given day.

Assume individuals choose the optimal labor supply to maximize a 1-day horizon utility function that depends on consumption c and health h and, for simplicity is additive and separable, that is, $U(c; h) = v(c) + u(h)$.[11] Daily hours (T) are spent either working (L) or in leisure (l), that is, $T = L + l$. Consumption is a function of an individual's fixed income y and of a variable income that depends on hours worked on that day, L, and a measure of the return to working an additional hour, $w(p)$. This variable is decreasing in excess pollution p, accounting for the fact that labor productivity is lower on days with pollution that exceeds recommended guidelines, as in Graff Zivin and Neidell (2012),

[11]See Camerer, Babcock, Loewenstein, and Thaler (1997) for a similar treatment of daily labor supply among cab drivers in New York City.

Chang et al. (2016), Chang et al. (2019), and Shihe, Viard, and Zhang (2017).[12] Health h is a function of individual characteristics a, leisure l, and pollution p.[13] The utility and the health functions have standard properties.

The first-order condition yields an optimal labor supply $L(p, y, a)$ that is a function of pollution, nonwage income, and individual characteristics. Differentiating with respect to pollution gives us the following expression:

$$\frac{dL}{dp} = \frac{\overbrace{w_p[v_c + v_{cc}wL]}^{\text{Productivity effect}} + \overbrace{u_{hh}h_p h_l + u_h h_{pl}}^{\text{Avoidance effect}}}{v_{cc}w^2 + u_{hh}h_l^2 + u_h h_{ll}} \tag{1}$$

From equation (1), we can identify two main channels through which pollution affects labor supply. First, there is an avoidance effect: the health reducing effect of pollution may be countered by increasing leisure time (i.e., reducing labor supply). The magnitude of this response will depend on the concavity of the utility function with respect to health, on the marginal responses of health to leisure and pollution and on whether pollution reduces the marginal health effect of leisure, that is, the cross-derivative h_{lp}.

Second, there is a productivity effect: pollution reduces the opportunity cost of work, suggesting a flatter budget constraint and lower labor supply. The strength of this response also depends on the concavity of utility with respect to consumption. In cases where consumption levels are very low, that is, higher concavity of the utility function, the productivity channel (in the absence of strong health effects) may induce an increase in labor supply.[14]

From this analysis, we can draw two main implications for the empirical analysis. First, labor supply will decrease when pollution exceeds recommended guidelines either if avoidance and productivity effects of pollution move together or if the avoidance effect dominates an opposed productivity effect. Second, those workers for whom income effects are strong (e.g., workers who are at low consumption levels or for whom daily variable income is large relative to fixed income y) will reduce their labor supply on high pollution days by less than relatively richer workers.

3.2. *Econometric Specification*

Our objective is to identify the short-term causal effect of PM 2.5 on labor supply. There may be unobserved time-invariant determinants of both local air pollution and labor supply, such as the local level of economic activity, or time-varying factors that affect both air pollution and labor supply, such as weather conditions. To address these concerns, our empirical specifications include a comprehensive set of time-varying weather controls, variables to control for demographic and labor market characteristics, and a rich set of fixed effects.

We estimate the impact of particulate matter on same-day hours worked. As our baseline labor supply specification, we estimate the impact of contemporaneous PM 2.5 on

[12]Other papers find lower productivity in the longer run, such as He, Liu, and Salvo (2019) and Aragón and Rud (2016).

[13]This is consistent with existing evidence that longer hours of work are detrimental to workers' health (Cygan-Rehm and Wunder (2018), Lepinteur (2019)). Avoiding pollution can also reduce other related effects, such as crime (Bondy, Roth, and Sager (2020)) or traffic accidents (Sager (2019)).

[14]The condition for this to happen is similar to results found in Aragón, Oteiza, and Rud (2021) and Camerer et al. (1997), namely if $-\frac{v_{cc}}{v_c} > \frac{1}{wL}$, or if the income effect dominates the substitution effect.

labor supply using the following regression:

$$y_{ilm,tw} = \alpha_m + \phi_w + \eta_d + \beta PM2.5_{lm,tw} + \gamma X_{ilm,tw} + \epsilon_{ilm,tw}, \tag{2}$$

where the unit of observation is individual i who resides in locality l of municipality m on day t that falls within week w. The outcome $y_{ilm,tw}$ is the number of hours that individual i reported working on day t.[15] $PM2.5_{lm,tw}$ is the number of hours in which fine particulate matter exceeded the WHO's IT1, IT2, IT3, or AQG in locality l of municipality m on day t in week w. $X_{ilm,tw}$ is a vector of time-varying weather and demographic controls that consists of maximum temperature in locality l on day t, precipitation in municipality m on day t and its square, age of individual i and its square, gender of individual i, and years of schooling completed by individual i and its square. Equation (2) includes a set of municipality fixed effects, α_m, to control for time-invariant unobserved determinants of labor supply that are common to a municipality, a set of day of the week fixed effects, η_d, to control for any unobserved patterns in labor supply across days of the week, and a set of week fixed effects, ϕ_w, to control for any unobserved determinant of labor supply that varies over time but is common to all individuals in Mexico City, such as seasonality in the labor market. We cluster standard errors by locality level, which is the level at which we measure pollution.

We augment the baseline specification for labor supply in multiple ways to address additional concerns about potential sources of endogeneity. First, we include additional control variables consisting of type of job and position, formality status, and sector of employment to control for labor market characteristics. Second, we include household fixed effects to control for time-invariant unobserved factors at the household level, such as preference for residing in a low-pollution neighborhood. Finally, we include individual fixed effects to control for time-invariant unobserved factors at the individual-level, such as individual preference for air pollution, health status, distance to the workplace, and working conditions. We focus on the parsimonious specification because our results are consistent with those of these additional specifications.

We corroborate our main results using an instrumental variables strategy to allay concerns associated with potential confounding factors that vary over time within a locality. A primary concern in estimating the contemporaneous or short-term effects of air pollution on labor supply is that the type of economic activity in a specific area could determine both labor supply and air pollution levels. A related concern is that local traffic levels, which increase the time and costs of commuting, could determine both labor supply and air pollution levels. Although our rich set of fixed effects should alleviate most concerns, we use wind speed from the network of ground monitoring stations as an instrument for particulate matter. We code wind speed as the daily mean wind speed. We use two-stage least squares to estimate our baseline specification. This instrumental variables identification strategy provides evidence that our results are not driven by confounding factors.

We estimate heterogeneity in the impacts of particulate matter on labor supply using a very flexible specification. We interact the characteristic capturing heterogeneity with the measure of particulate matter and with all controls and fixed effects. In this way, we allow the relationship between individual characteristics and fixed effects, for example, gender, and daily hours worked to vary across dimensions of heterogeneity.

[15] In robustness specifications, we use the probability of working the contemporaneous day as the outcome variable. In this case, the outcome $y_{ilm,tw}$ is an indicator variable that equals 1 if individual i reported working on day t.

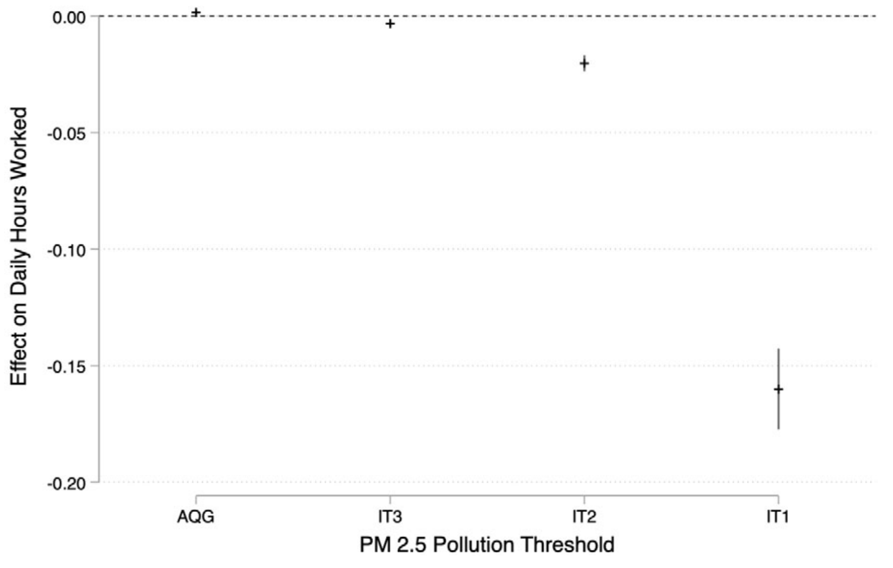

FIGURE 2.—Daily Hours Above WHO Thresholds and Daily Hours Worked. Coefficients and 90% confidence intervals are plotted from equation (2) for the number of hours above the WHO air quality threshold for PM 2.5. A separate regression is run for each threshold.

4. EFFECTS OF HIGH PM 2.5 ON DAILY LABOR SUPPLY

4.1. *Nonlinear Effects of Pollution*

We exploit our high frequency data to document that PM 2.5 has a negative nonlinear relationship with labor supply. We estimate equation (2) using the number of hours above each WHO threshold as alternative measures of air pollution.

Figure 2 plots the coefficients and 90% confidence intervals from separate regressions for each WHO threshold. We find that an hour above the WHO Air Quality Guideline has a very precise zero-effect. This is not surprising since Table I shows that around 63% of days have at least 1 hour above the Air Quality Guideline threshold. That means that most days are above this threshold, and thus, we should not expect strong deviations from the average number of working hours. Similarly, hours above the WHO Interim Target 3 have a very small, albeit negative, and significant effect on daily hours worked. Note that almost 1 of every 2 days has at least 1 hour above the lowest interim target. Workers' response is substantially larger when pollution exceeds the upper two thresholds. An hour above the WHO Interim Target 2 results in a 0.020-hour reduction in same day hours worked and an hour above the WHO Interim Target 1 implies a 0.160-hour (9.6 minutes) reduction in same day hours worked.[16] We show in Supplemental Appendix Figure B3 that the effects on whether or not workers worked that day are consistent with these effects on the number of hours worked.

As we discuss in greater detail in the next section, the magnitude of the effect is sizeable. The point estimate represents just above 2.5% of the hours worked on an average day. Considering that on days with at least an hour above IT1, the average number of hours

[16]Coefficients and standard errors are displayed in Supplemental Appendix Table AI.

exceeding the threshold is 3, this implies that on these days the number of hours worked is reduced by more than 7.5% (i.e., around half an hour).[17]

Based on these nonlinear effects of pollution on labor supply and to exploit the advantage of our high frequency data in capturing peaks in air pollution levels, we focus on WHO Interim Target 1 for the remainder of the paper.

4.2. *Impact on Contemporaneous Labor Supply*

Table III shows that the impact of an hour of PM 2.5 above the WHO IT1 threshold on contemporaneous daily hours worked is substantial and very consistent across alternative specifications.[18] Column (1) displays the results of the baseline specification. This was already discussed in relation to Figure 2. We augment our baseline specification in three ways. Column (2) presents the results of the baseline specification adding controls for a worker's type of job and position, formality status, and sector of employment. We find that that the effects on contemporaneous daily hours worked are almost identical to column (1).

In columns (3) and (4), we impose a stringent test on the relationship between labor supply and pollution, as we explore whether responses to high pollution levels generate responses within households and individuals, respectively. The response in these cases is slightly larger in magnitude than the one obtained in the baseline specification. This suggests that workers' response remains robust even when we account for individual circumstances that are not expected to vary much within a week, such as commuting distance to the workplace. In column (5), we show that the effects are slightly larger when we instrument pollution levels using a measure of wind speed to estimate our baseline specification.[19]

TABLE III

THE EFFECT OF PM 2.5 ON DAILY HOURS WORKED.

	Daily Hours Worked						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Hours Above PM2.5 IT1 Threshold	−0.160 (0.010)	−0.160 (0.011)	−0.164 (0.010)	−0.166 (0.010)	−0.289 (0.090)	−0.205 (0.014)	−0.310 (0.008)
Method	Baseline	Occupation Controls	HH FE	Individual FE	IV	Weekdays	Peak Season
N	2,227,363	2,227,363	2,227,355	2,227,328	2,220,112	1,589,914	156,076
R2	0.285	0.308	0.391	0.476	0.279	0.074	0.282

Note: Standard errors clustered by locality in parenthesis. Column (1) shows the baseline specification, equation (2). Column (2) includes type of job and position, formality status, and sector of employment as additional controls. Column (3) adds household fixed effects. Column (4) adds individual fixed effects. Column (5) is the IV specification, which instruments for PM 2.5 with wind speed. The F-Statistic for the first stage is 4905. Column (6) shows the baseline specification in the sample of weekdays, Monday to Friday. Column (7) shows the baseline specification in the first 4 weeks of the year, which is the peak pollution season.

[17]In addition, we estimate the nonlinear relationship between PM 2.5 and the semielasticity of daily hours using the natural logarithm of 1+ daily hours worked as the outcome variable in equation (2). The results shown in Supplemental Appendix Figure B4 follow a similar pattern.

[18]Pollution levels above IT1 are, on average, more intense between 5 and 9 a.m., suggesting that people are likely aware of high pollution realizations in the morning when they may make labor supply decisions (see Figure B5).

[19]We report the first stage in column (1), Table AVIII in the Supplemental Appendix.

Column (6) shows the results of estimating our baseline specification in the sample of weekdays (Monday through Friday). The impact of high pollution on weekdays is about 28% larger than the overall effect shown in column (1). Column (7) shows the results of estimating our baseline specification in the peak pollution season. We define the peak pollution season as the first 4 weeks of the year. During the peak pollution season, 15% of days are high pollution days compared to less than 5% of days outside the peak season, and the mean high pollution day has 5 hours and fewer than 3 hours of high pollution in the peak and off-peak seasons, respectively. The magnitude of the effect during the peak season is almost double the magnitude for the full year (column (1)).[20]

Looking across specifications, we find that an hour of fine particulate matter above the WHO IT1 threshold decreases hours worked on the contemporaneous day by 0.160 to 0.310 hours (or 9.6 minutes to 18.6 minutes). Evaluated at the sample mean of 6.3 hours worked per day overall and 6.2 hours worked per day in the high pollution season, this implies a reduction of same-day hours worked in the range of 2.5% to 5.0% per hour of pollution above the IT1 threshold.

On a day above the WHO IT1 threshold, a locality would experience around 3 hours of extremely high pollution. Using the estimate from our baseline specification for a back-of-the-envelope calculation, this implies that workers reduce their labor supply by approximately 7.5%, that is, almost half an hour, on high pollution days.[21] This effect is substantially larger during the peak pollution season. During this period, a highly polluted day will experience around 5 hours of fine particulate matter above the IT1 threshold, on average. That implies a reduction of hours worked of around 25%.

These impacts represent substantial losses to economic production on high pollution days. If we consider that in 2010 there were around 8 million workers in the metropolitan area of Ciudad de Mexico, our results imply that a high pollution day results in a loss or reallocation of 4.0 million hours or around 635 thousand worker-days, evaluated at the sample mean of 6.3 hours of work per day. This represents about 0.5% of annual worker-days, implying that 0.5% of annual working hours are lost or reallocated due to contemporaneous high pollution.[22] Considering only weekdays, this estimate rises to 4.8 million hours of work that are lost or reallocated on a highly polluted weekday.[23] If pollution throughout the year were to increase to levels close to those observed in the peak season, the number of hours lost on a high pollution day could increase to 12.3 million hours or 2.0 million worker-days. This represents 3.8% of annual worker-days implying that, if pollution levels all year were similar in magnitude and frequency to those during the peak season, 3.8% of annual working hours would be lost or reallocated due to contemporaneous high pollution.

The impact of high PM 2.5 on labor supply during the peak pollution season is informative for understanding the potential impacts in a context in which high pollution shocks become longer and more frequent. Combining our results in the peak pollution season with those demonstrating the nonlinear response of labor supply to levels of particulate matter implies that the costs of pollution will increase as the frequency and magnitude of pollution shocks increase.

[20] In Supplemental Appendix Table AII, we show that the impacts of high particulate matter on the probability of working on a high pollution day are consistent with those on hours worked.

[21] The sample mean of 3 hours above IT1 on high pollution days x 2.5% change in hours worked in response to an hour above IT1.

[22] Approximately 6% of days are high pollution days.

[23] The mean number of hours above IT1 on a weekday with high pollution is 3 hours, implying a total reduction of hours worked of .6 hours on highly polluted days. Extrapolated to the 8 million workers in the metropolitan area implies a reduction of 4.8 million hours worked.

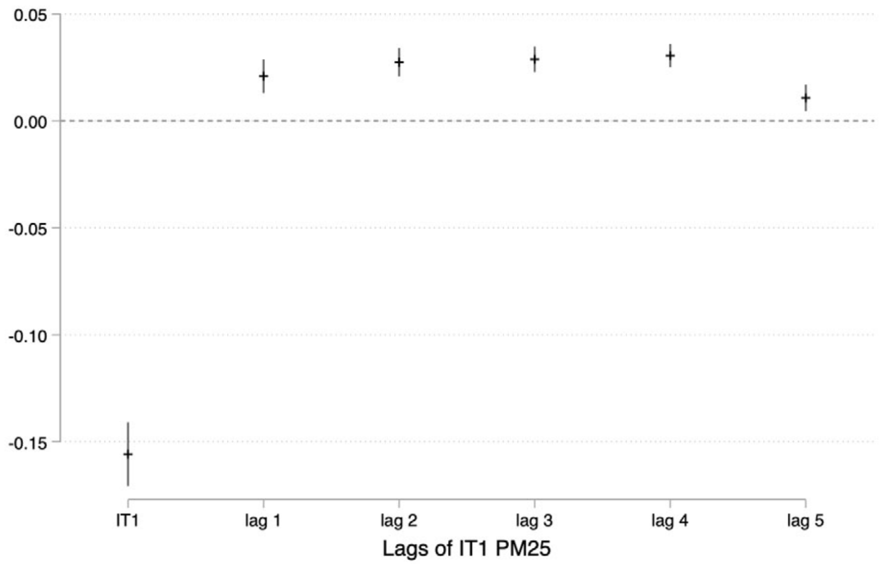

FIGURE 3.—Impact of Same-Day and Lagged PM 2.5 on Daily Hours Worked. Note: Coefficients and 90% confidence intervals are plotted from equation (2) augmented by 5 days of lagged PM 2.5 measures.

4.3. *Dynamic Adjustments*

The granularity of our data allows us to explore workers' ability to adapt to worse environmental conditions by looking at whether they adjust their hours worked in response to high pollution on prior days. We investigate workers' dynamic adjustments of labor supply by augmenting our baseline specification to include 5 days of lagged air pollution measures. Including contemporaneous pollution and lags of pollution allows us to investigate reallocations of labor supply across days and explore the extent to which workers compensate for lost labor supply on high pollution days.

We find that daily labor supply is a function of the current days' pollution level as well as the prior 5 days' pollution levels. Specifically, workers reduce their labor supply in response to same-day pollution and partially compensate for hours of work lost due to high pollution on previous days by increasing their labor supply today. We show the baseline results in Figure 3.

Table IV shows that this result is robust across specifications, including when we use individual fixed effects. As an example, imagine that today has 1 hour of pollution above the IT1 threshold. The point estimates suggest that workers would increase their labor supply tomorrow to compensate for 10% to 16% of the hours lost today. Further, summing the coefficients on the five lags indicates that workers would increase their labor supply by a total of 0.119 hours over the next 5 days in response to an hour of high pollution today. This suggests that workers compensate for 76% of hours worked lost to high pollution across the following 5 days. Specifically, summing the coefficients for the responses to high pollution on the contemporaneous day and 5 lagged days results in a decrease in daily hours worked of .037 hours, which is statistically significant.

When we focus on the peak season (column (4)), the negative impact of contemporaneous high pollution nearly doubles. Workers continue to compensate by increasing their labor supply on subsequent days, but the net effect is stronger as daily hours worked

TABLE IV

DYNAMIC ADJUSTMENTS TO DAILY LABOR SUPPLY.

	Daily Hours Worked			
	(1)	(2)	(3)	(4)
Same Day Hours Above PM2.5 IT1 Threshold	−0.156	−0.158	−0.203	−0.297
	(0.009)	(0.009)	(0.012)	(0.009)
1-Day Lag Hours Above PM2.5 IT1 Threshold	0.021	0.020	0.032	0.030
	(0.005)	(0.005)	(0.005)	(0.009)
2-Day Lag Hours Above PM2.5 IT1 Threshold	0.027	0.028	0.030	0.034
	(0.004)	(0.004)	(0.004)	(0.006)
3-Day Lag Hours Above PM2.5 IT1 Threshold	0.029	0.030	0.032	0.062
	(0.004)	(0.003)	(0.004)	(0.005)
4-Day Lag Hours Above PM2.5 IT1 Threshold	0.031	0.033	0.020	0.052
	(0.003)	(0.003)	(0.003)	(0.005)
5-Day Lag Hours Above PM2.5 IT1 Threshold	0.011	0.013	0.007	0.031
	(0.004)	(0.003)	(0.004)	(0.004)
Sample	Baseline	Individual FE	Weekdays	Peak Season
Sum of estimates	−0.037	−0.034	−0.082	−0.088
SE of sum	0.014	0.015	0.017	0.030
N	2,218,941	2,218,856	1,583,547	153,298
R2	0.285	0.476	0.074	0.283

Note: Standard errors clustered at the locality level. Column (1) shows the baseline specification, equation (2). Column (2) includes individual fixed effects. Column (3) shows the baseline specification in the sample of weekdays, Monday to Friday. Column (4) shows the baseline specification in the first 4 weeks of the year, which is the peak pollution season.

decreases by 0.088 hours. This indicates that workers will be less able to adapt in high pollution periods.

These results provide evidence that workers mitigate pollution shocks by partially compensating for labor supply lost on previous days. It also suggests that there are limitations to workers' ability to use adjustments to labor supply as a behavioral adaptation to avoid exposure in the context of persistent pollution.

5. HETEROGENEOUS RESPONSES: THE ROLE OF INCOME

Labor markets in urban areas of middle-income countries are characterized by high levels of informality, productivity dispersion as modern sectors coexist with traditional technologies, and high levels of inequality along many dimensions.[24] Mexico City is no exception. In our sample, informality averages 53%, average levels of education are below secondary school, a large part of the workforce is engaged in services and retail, and almost 1 in 4 workers are self-employed (Table II).

Our simple analytical framework in Section 3.1 suggests that low-income and high-income workers have different labor supply responses to high pollution. Guided by this implication of the analytical framework, we investigate the heterogeneity of labor supply responses across workers with different income levels. Supplemental Appendix Table AIII shows substantial earning inequalities across income deciles. Workers in the top 10% of the income distribution earn on average almost 17 times as much as workers in the

[24]See, for example, Meghir, Narita, and Robin (2015), Ulyssea (2018) for Brazil.

bottom 10% of the income distribution. The latter are on average below the legal monthly minimum wage in Mexico, which in the mid-year of our sample was around USD 120 (or 1500 Mexican Pesos).

5.1. *Heterogeneous Contemporaneous Effects*

In Table V, we explore the effects of extreme pollution levels on labor supply along the distribution of income. Panel A shows the effect of PM 2.5 on contemporaneous daily hours worked for workers in the bottom half of the income distribution, from the bottom 10% in column (1) to the bottom 50% in column (5). Similarly, panel B shows the effect of PM 2.5 on contemporaneous daily hours worked for workers in the top half of the income distribution, from the top 50% in column (1) to the top 10% in column (5). Looking across both panels shows two main results. First, all workers reduce their hours worked on days with high pollution. Second, this response becomes stronger as we move along the income distribution from low-income workers to high-income workers.

Column (1) in panel A shows that the poorest workers reduce their hours worked by much less than the average baseline estimate. The same is true for the bottom quintile (20%) (column (2) of panel A). This is consistent with the idea that income effects matter most to low-income workers. In contrast, in columns (4) and (5) of panel B, workers in the top 20% and 10% of the income distribution, reduce their labor supply substantially more than their low-income counterparts. Further, the highest income workers, those in the top decile of the income distribution, reduce their labor supply by more than the average baseline estimate.

In Table VI, we explore the differences between workers in the top and bottom of the income distribution more formally.[25] Columns (1) and (2) look at the difference in

TABLE V

EFFECT OVER THE CUMULATIVE INCOME DISTRIBUTION.

	Panel A: Bottom of the Income Distribution				
	(1) 10%	(2) 20%	(3) 30%	(4) 40%	(5) 50%
Hours Above PM2.5 IT1 Threshold	−0.069	−0.109	−0.128	−0.138	−0.143
	(0.013)	(0.012)	(0.011)	(0.012)	(0.012)
N	151,442	325,711	466,636	614,082	764,486
R2	0.075	0.127	0.156	0.185	0.208

	Panel B: Top of the Income Distribution				
	(1) 50%	(2) 40%	(3) 30%	(4) 20%	(5) 10%
Hours Above PM2.5 IT1 Threshold	−0.159	−0.151	−0.157	−0.161	−0.174
	(0.012)	(0.014)	(0.015)	(0.016)	(0.015)
N	724,550	578,636	433,208	294,682	138,442
R2	0.361	0.375	0.394	0.419	0.474

Note: Standard errors clustered at the locality level. Results use the baseline specification as in column (1), Table III.

[25]Supplemental Appendix Figure B6 shows the nonlinear effects of pollution for workers in the top and bottom deciles of the income distribution. Both low-income and high-income workers do not respond to less

TABLE VI

THE UNEQUAL RESPONSE TO POLLUTION BY INCOME LEVEL.

	Top and Bottom Deciles	Top and Bottom Quintiles	≤ 1 & > 5 Min. Wage	Top and Bottom Deciles (hourly)	Top and Bottom Deciles	
	(1)	(2)	(3)	(4)	(5)	(6)
Hours Above PM2.5 IT1 Threshold	−0.174 (0.015)	−0.161 (0.016)	−0.165 (0.015)	−0.177 (0.013)	−0.187 (0.016)	−0.332 (0.019)
Low Income × Hours Above IT1	0.106 (0.017)	0.053 (0.015)	0.070 (0.017)	0.063 (0.016)	0.110 (0.019)	0.171 (0.023)
Specification	Baseline	Baseline	Baseline	Baseline	Individual FE	Peak Season
N	289,884	620,393	431,426	296,960	289,860	19,435
R2	0.391	0.314	0.369	0.405	0.618	0.384

Note: Standard errors clustered at the locality level. Columns (1)–(4) show the baseline specification, equation (2) using alternative ways of calculating top and bottom earners. Column (5) includes individual fixed effects. Column (6) shows the baseline specification in the first 4 weeks of the year, which is the peak pollution season.

responses between the poorest and richest 10% and 20% of workers, respectively. The differences are statistically significant and sizeable. A worker's response in the lowest decile (quintile) is 61% (33%) lower than the average worker in the top decile (quintile). We obtain similar results when looking at workers earning up to a minimum wage relative to workers earning more than 5 minimum wages (column (3)) or if we use deciles of imputed hourly wages (column (4)). In columns (5) and (6), we show that the difference in response between workers in the top and bottom deciles is robust to the inclusion of individual fixed effects and to restricting the sample to the peak season.

The responses of workers in the top and bottom deciles are significantly different from each other statistically and also in terms of magnitude. Looking across specifications in Table VI, and using the average number of hours worked by decile, we find that the responses to one additional hour above the pollution threshold reduces labor supply by 1.6–2.3% for the poorest and 2.4–4% for the richest workers. This increases to 4.5% and 5.1%, respectively, in the high pollution season. These magnitudes are informative of the responsiveness of workers of different income levels that can be used for policy purposes (environmental or other). For example, it may well be the case that a public information policy of pollution levels may not generate similar avoidance responses for poorer and richer workers.

In terms of health effects of exposure to pollution, the absolute reduction may be more relevant. To illustrate the magnitude of the effects, on an average day with high pollution, an average richer worker reduces hours worked by more than 31 minutes. In contrast, an average poorer worker reduces hours worked by 12 minutes. When we look at the peak season, when pollution is both higher and more frequent, an average rich worker would reduce hours worked by around around 1 h and 40 minutes while an average poor worker would reduce working hours by 48 minutes. Although the differences are slightly lower, they remain similar when comparing top and bottom 20% or workers earning up to one minimum wage relative to those earning more than five (see Supplemental Appendix Table AIV).

extreme levels of pollution. Responses of high-income and low-income workers start to separate at the IT2 level of pollution but do not become statistically different until IT1, the most extreme pollution level.

TABLE VII

EFFECTS OF PM 2.5 BY JOB CHARACTERISTIC.

	Full Sample			Bottom and Top Deciles: Informal	Bottom and Top Deciles: Self-Employed
	(1)	(2)	(3)	(4)	(5)
Hours Above PM2.5 IT1 Threshold	−0.170 (0.011)	−0.164 (0.011)	−0.165 (0.011)	−0.181 (0.026)	−0.179 (0.032)
Characteristic × Hours Above IT1	0.016 (0.008)	0.016 (0.009)	0.006 (0.009)	0.108 (0.027)	0.099 (0.035)
Characteristic	Informal	Self-Employed	Low Tasks	Bottom Decile	Bottom Decile
N	2,227,363	2,227,363	2,225,096	175,363	91,222
R2	0.315	0.309	0.313	0.540	0.624

Note: Standard errors clustered at the locality level. Results use the baseline specification as in column (1), Table III.

Next, we explore to what extent the different response between poorer and richer workers is driven by job characteristics that may be correlated with income. For example, the response could be driven by the job security that well-paying formal jobs provide. Alternatively, it may be related to the income predictability that wage employment offers over self-employment. A third potential explanation is that more technical or professional tasks in the workplace may be delayed or performed from home while others (like driving vehicles or staffing a shop) need to be done in the workplace.[26]

We explore these alternative explanations in Table VII. First, we use individual-level indicators of job characteristics in the heterogeneity specification. The results for informality are shown in column (1), for self-employment in column (2), and for a measure of low-skill tasks in column (3). In the first two cases, the results go in the expected direction as informal and self-employed workers respond to high pollution less than formal workers and employees, respectively. However, the difference is substantially smaller than when comparing richer and poorer workers. We do not find a differential response across workers engaged in tasks requiring different skill levels.

The smaller difference in the point estimates by job characteristics than by income levels may be attributed in part to the fact that we can better separate richer and poorer workers by splitting the sample by income deciles or quintiles than when we use coarse measures of formality and self-employment. However, if these job characteristics played a larger role than income, we should not observe a large difference in response across low-income and high-income workers once we restrict the sample to informal or self-employed workers. In columns (4) and (5) of Table VII, we show that both the response of workers in the top income decile and the difference in the responses of workers in the top and bottom deciles are very similar to the results that we obtained in the full sample of workers in the top and bottom deciles of the income distribution in Table VI.

[26]While we only have information for workers' place of residence, the data allows us to identify workers that work from home, at various changing locations, or at a fixed workplace. In Table AVI in the Supplemental Appendix, we find the same pattern of response to same-day pollution across high-income and low-income workers across all three groups. For example, even for workers who work from home, we find that high-income workers decrease their labor supply significantly more than low-income workers in response to same-day pollution (despite both being subject to similar shocks). Results are qualitatively similar across different workplaces, suggesting that the income gradient may not be affected by the potential differences between pollution levels at home and at work.

Taken together, these results suggest that there are unequal responses by job characteristics, but that the unequal response across rich and poor workers is primarily due to differences in income. Low-income workers, regardless of whether they are informal or self-employed, are substantially less likely to reduce working hours on highly polluted days than their high-income counterparts.[27] The results that workers with lower, and possibly more uncertain income, reduce their labor supply by less than high-income workers on high pollution days is consistent with evidence from labor markets in other settings. For example, in rural India, Jayachandran (2006) documents inelastic labor supply among poor workers. Further, among Chief Executive Officers of manufacturing firms in six countries, Bandiera et al. (2018) find that family CEOs have a more elastic labor supply with respect to the cost of effort than professional CEOs and that this may be because family CEOs are wealthier.

5.2. *Heterogeneous Dynamic Effects*

In this section, we explore differences in the intertemporal response to pollution across low-income and high-income workers. In Table VIII, we show results separately in the sample of low-income workers and high-income workers for the full sample, peak pollution season, and weekdays. Consistent with the results discussed in the previous section, workers with income in the top decile of the income distribution reduce their same-day

TABLE VIII

HETEROGENEOUS DYNAMIC EFFECTS.

	Daily Hours Worked					
	(1) Bottom 10%	(2) Top 10%	(3) Bottom 10%	(4) Top 10%	(5) Bottom 10%	(6) Top 10%
Same Day Hours Above PM2.5 IT1 Threshold	−0.069 (0.012)	−0.168 (0.015)	−0.149 (0.014)	−0.324 (0.016)	−0.092 (0.013)	−0.214 (0.020)
1-Day Lag Hours Above PM2.5 IT1 Threshold	0.023 (0.010)	0.031 (0.014)	0.037 (0.012)	0.027 (0.024)	0.030 (0.011)	0.038 (0.015)
2-Day Lag Hours Above PM2.5 IT1 Threshold	0.012 (0.011)	0.035 (0.014)	0.028 (0.012)	0.039 (0.023)	0.015 (0.012)	0.038 (0.014)
3-Day Lag Hours Above PM2.5 IT1 Threshold	0.025 (0.011)	0.042 (0.010)	0.046 (0.015)	0.063 (0.016)	0.021 (0.012)	0.040 (0.010)
4-Day Lag Hours Above PM2.5 IT1 Threshold	0.020 (0.011)	0.043 (0.012)	0.034 (0.013)	0.065 (0.017)	0.022 (0.012)	0.022 (0.009)
5-Day Lag Hours Above PM2.5 IT1 Threshold	0.019 (0.011)	0.001 (0.012)	0.023 (0.009)	0.022 (0.016)	0.013 (0.012)	−0.008 (0.011)
Sample	All	All	Peak Season	Peak Season	Weekdays	Weekdays
Sum of estimates	0.031	−0.014	0.018	−0.109	0.009	−0.084
SE of sum	0.038	0.050	0.051	0.083	0.050	0.052
N	150,825	138,036	10,317	8754	107,688	98,489
R2	0.075	0.475	0.098	0.474	0.067	0.076

Note: Standard errors clustered at the locality level. Columns (1)–(2) show the baseline specification, equation (2). Columns (3)–(4) show the baseline specification in the first 4 weeks of the year, which is the peak pollution season. Columns (5)–(6) show the baseline specification in the sample of weekdays, Monday to Friday.

[27]Similarly, Holub and Thies (2023) show that highly skilled software developers adjust their working hours downwards and substitute toward easier tasks when air pollution is high.

hours worked due to high pollution more than workers with income in the bottom decile of the income distribution.

Although the coefficients for each lagged pollution variable for low-income and high-income workers are not always significantly different from each other, the general pattern is that the coefficients on lagged values of pollution tend to be larger in the sample of high-income workers than in the sample of low-income workers.[28] This suggests that high-income workers may increase their labor supply today more than low-income workers in response to high pollution on previous days. This would imply that high-income workers compensate for labor supply reductions on prior days more than low-income workers. Together with the smaller contemporaneous effect of high pollution, the labor supply of low-income workers appears to be less flexible than that of high-income workers.

Considering the sum of contemporaneous and lagged coefficients, in all cases, including the high pollution season and weekdays only, the sum of the coefficients is not statistically different from zero. This implies that when high pollution persists at a constant level, both low-income and high-income workers do not significantly adjust their labor supply after accounting for contemporaneous reductions to labor supply and compensation for lost hours of work on prior days. However, this obscures potentially different patterns of contemporaneous response and compensation across low-income and high-income workers that could have implications for their exposure to air pollution.

6. MECHANISMS

In this section, we explore several mechanisms that could link air pollution and labor supply and could explain the differential effects across low-income and high-income workers. First, we investigate whether our aggregate and heterogeneous results are driven by gender or household composition. We show that channels such as caregiving due to school closures or illness on high pollution days, female selection into more flexible jobs, and overrepresentation of women at the bottom of the income distribution cannot explain our results. Second, we explore whether our results are driven by workers in specific sectors of the economy. The similar pattern of results across sectors with different characteristics demonstrates that channels such as public sector closures, outdoor exposure to air pollution at work, and real-time changes in consumer demand due to high pollution are not driving our results. Focusing on sectors that are unlikely to be affected by changes in consumer demand on high pollution days allows us to isolate the role of workers' decisions from changes in labor demand. Third, we use official air quality alerts to show that temporarily heightened attention to pollution and any public sector restrictions associated with the alerts cannot be the only mechanisms linking air pollution and labor supply. We explore differences across private and public sector workers in weeks with alerts to provide additional evidence that labor supply reductions on high pollution days reflect workers' decisions rather than public policy restrictions. Further, focusing on weeks in which official alerts were issued, we show that differential pollution information between low-income and high-income workers cannot fully explain the heterogeneity in labor supply responses that we observe. Fourth, because labor supply reductions appear to be driven by worker decisions, we investigate whether these decisions reflect avoidance behavior or negative health impacts on high pollution days. We show evidence suggesting

[28]Table AV in the Supplemental Appendix shows similar results when focusing on top and bottom quintiles of the income distribution or on workers who earn less than one minimum wage or more than five times the minimum wage.

that income constraints and work commitments likely play a role in workers' labor supply adjustments, as workers eventually return to work after a few days of high pollution. This suggests that workers' reductions in labor supply more plausibly reflect avoidance behavior and are not fully explained by reductions in labor supply due to contemporaneous negative health impacts or lower productivity due to PM 2.5.

6.1. *Gender and Household Composition: Caregiving, Female Selection Into Flexible Jobs, Gender Composition*

Can the role of gender and household composition explain our findings? We turn our attention to the possibility that our results are driven by a specific gender. Women may select jobs with more flexible schedules and they may have greater caregiving responsibilities that could require staying at home with more vulnerable dependants on high pollution days (as in Aragón, Miranda, and Oliva (2017)). Column (1) of Table IX shows that women work *more* hours than men on high pollution days. Further, among women, those with children in the household reduce their hours worked by slightly less than those without children in the household (column (4)). These results suggest that the mechanism behind our main results is not that women have more flexible jobs or that women reduce their hours worked on high pollution days to fulfill caregiving responsibilities.

Because women reduce their labor supply by less than men on high pollution days, if women are overrepresented in low-paying jobs, then we may be conflating a gender gradient for an income gradient. In columns (2) and (3), we explore the differential effects between the top and bottom deciles within gender. In column (2), the difference between low-income and high-income women shows a similar pattern to that in the full sample. High-income women respond by reducing their working hours more than low-income women. In column (3), we find a similar pattern focusing on men.

Columns (2) and (3) jointly provide two insights. First, we find that the unequal response between low-income and high-income workers is larger for men (low-income men's response is 74% lower) than for the full sample (61%) and for women (53%). Second, comparing the point estimates of women and men in the top decile of the income distribution, women work more than men on days with high pollution. However, for workers in the bottom decile of the income distribution, the effect is similar for men and women (−0.05 and −0.07, respectively). These results suggest that any gender differences in the labor supply response to high pollution come from the fact that high-income

TABLE IX

EFFECTS OF GENDER AND HOUSEHOLD COMPOSITION.

		Bottom and Top Deciles		
	(1)	(2)	(3)	(4)
Hours Above PM2.5 IT1 Threshold	−0.173	−0.145	−0.195	−0.164
	(0.012)	(0.029)	(0.017)	(0.012)
Characteristic × Hours Above IT1	0.033	0.077	0.145	0.023
	(0.008)	(0.028)	(0.025)	(0.010)
Characteristic	Women	Bottom Decile	Bottom Decile	Have Children
Sample	Full Sample	Women	Men	Women
N	2,227,363	145,660	144,224	914,428
R2	0.288	0.333	0.379	0.258

Note: Standard errors clustered at the locality level. Results use the baseline specification as in column (1), Table III.

women respond less than high-income men.[29] Importantly, these results also suggest that an overrepresentation of women in low-paying jobs and an underrepresentation of women in high-paying jobs is not driving the heterogeneity that we find across income levels.

6.2. *Sector Characteristics: Outdoor Exposure, Consumer Demand, and Public Sector Closures*

We next use information on workers' sector of occupation to investigate whether the reduction in working hours on high pollution days is driven by specific sectors. This allows us to explore three main mechanisms. First, we explore the extent to which our results are driven by workers whose workplace is outdoors. Second, we explore whether the reduction in working hours can be explained by changes in demand for labor, for example, due to changes in consumer demand, on high pollution days. Third, we investigate whether there is a reduction in working hours that could be explained by public sector policy, such as closing schools or public offices on high pollution days.

Our results are presented in Table X. Panel A shows the aggregate results and panels B and C show the unequal responses by low-income and high-income workers, respectively. In panels B and C, while the pattern of response between top- and bottom-decile workers is broadly consistent, a point of caution has to be made since some sectors have relatively few workers in the bottom decile (e.g., professional services or public sector) and others in the top decile (e.g., retail and hospitality or low productivity services).

First, we do not find evidence that the results are driven by workers in sectors likely to have outdoor workplaces. Panel A shows that the drop in hours worked due to high

TABLE X

EFFECTS BY ECONOMIC SECTOR.

	Construction	Manufacturing	Retail and Hospitality	Professional Services	Public Sector	Low Productivity Services
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: Full Sample			
Same Day Hours Above PM2.5 IT1 Threshold	−0.198	−0.200	−0.166	−0.187	−0.079	−0.139
	(0.020)	(0.015)	(0.012)	(0.017)	(0.013)	(0.011)
N	136,391	322,930	672,082	256,985	361,124	272,785
R2	0.555	0.479	0.132	0.447	0.504	0.287
			Panel B: Bottom Decile			
Same Day Hours Above PM2.5 IT1 Threshold	−0.063	−0.136	−0.071	−0.115	0.076	−0.061
	(0.047)	(0.033)	(0.018)	(0.085)	(0.091)	(0.014)
N	4131	13,704	73,664	6337	4659	40,125
R2	0.367	0.283	0.080	0.338	0.447	0.148
			Panel C: Top Decile			
Same Day Hours Above PM2.5 IT1 Threshold	−0.268	−0.231	−0.207	−0.149	−0.122	−0.046
	(0.038)	(0.044)	(0.032)	(0.028)	(0.025)	(0.075)
N	7086	15,505	23,727	27,191	43,570	7089
R2	0.682	0.660	0.294	0.672	0.606	0.436

Note: Standard errors clustered at the locality level. Results use the baseline specification as in column (1), Table III.

[29]The response is 0.05 lower for high-income women, significant at the 10% level of confidence.

pollution is very similar across sectors in which most activities likely take place outdoors (e.g., construction) and those in which most activities likely take place indoors, whether in a workshop, factory or office (e.g., manufacturing or professional services). While high-income workers in sectors such as construction may work primarily indoors, many low-income workers in construction are likely to be exposed to the outdoor environment. In panel B, the point estimates often show larger responses in presumably indoor activities among low-income workers, such as manufacturing or professional services (columns (2) and (4)), than occupations that are more likely outdoors, such as construction or low productivity services (columns (1) and (6)).

Second, the point estimates are slightly smaller in magnitude for sectors that may experience a drop in product or service demand on high pollution days, such as the retail and hospitality and low productivity services sectors (columns (3) and (6)). Further, the point estimates are slightly larger in magnitude for sectors that are less likely to be affected by daily demand fluctuations, such as professional services, manufacturing, or construction (columns (1), (2), and (4)). This suggests that the overall reduction in working hours is unlikely to be explained by lower labor demand associated with high pollution. It is more likely that the sector composition of workers (e.g., lower income) explains any differences in response across sectors.

Third, it is plausible that public sector workers are not deciding to reduce their labor supply on high pollution days, but instead, their workplace is closed or operating at reduced capacity due to public policies. In panel A, the lowest point estimates in absolute terms comes from public sector workers (column (5)), suggesting that it is unlikely that our results are driven by a policy of closing schools or public administration offices on days of extreme pollution.

An important implication of these results is that reductions in hours worked on high pollution days reflects workers' decisions instead of reductions in labor demand or public policy restrictions on high pollution days.

6.3. *Public Information*

Next, we turn to the possibility that the reduction in working hours associated with PM 2.5 is explained by pollution alerts issued by the environmental authority in Mexico City. Local media, including newspapers, radio, and television, and official media, including the AIRE CMDX app, official websites, and social networks, are mandated by law to publish the alerts (Aguilar-Gomez (2020)). In the period 2005–2016, these alerts were activated fewer than 40 times overall.

In columns (1)–(4) of Table XI, we exclude weeks in which an alert was issued. We exclude the entire week because any increase in attention to air pollution caused by alerts could persist in the following days. Columns (1)–(4) provide evidence that our prior results documenting the effects of same-day pollution, the dynamic responses, larger response by private sector workers, and differences in responses across the income distribution hold when excluding weeks with alerts. These results show that the response of daily hours worked to pollution described above is not explained by public alerts, implying that heightened attention to air pollution or public sector closures on days with alerts cannot be the only mechanisms linking high pollution and labor supply.

In contrast, in columns (5)–(8) of Table XI, we use the same specifications but restrict the sample to days of weeks in which at least one alert was issued. In weeks with alerts, the point estimates for both same-day and lagged pollution (columns (5) and (6)) are larger in magnitude than in the full sample (Tables III and IV) and weeks without alert

TABLE XI

OFFICIAL AIR POLLUTION ALERTS AND LABOR SUPPLY RESPONSES.

	Weeks with no alert days				Weeks with alert days			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hours Above PM2.5 IT1 Threshold	−0.145 (0.011)	−0.142 (0.010)	−0.160 (0.011)	−0.159 (0.017)	−0.242 (0.015)	−0.247 (0.015)	−0.255 (0.016)	−0.266 (0.033)
Lag 1 IT1 PM2.5		0.014 (0.005)				0.055 (0.011)		
Lag 2 IT1 PM2.5		0.024 (0.004)				0.045 (0.016)		
Lag 3 IT1 PM2.5		0.023 (0.004)				0.073 (0.013)		
Lag 4 IT1 PM2.5		0.024 (0.003)				0.085 (0.013)		
Lag 5 IT1 PM2.5		0.009 (0.004)				0.008 (0.014)		
Characteristic × Hours Above IT1			0.089 (0.009)	0.089 (0.019)			0.105 (0.038)	0.178 (0.040)
Characteristic			Public Sector	Bottom Decile			Public Sector	Bottom Decile
N	2,100,862	2,093,753	1,990,319	274,141	126,501	125,188	119,667	15,743
R2	0.285	0.286	0.300	0.391	0.280	0.278	0.294	0.404

Note: Standard errors clustered at the locality level. Results use the baseline specification as in column (1), Table III.

days (columns (1) and (2)). In alert weeks, the average number of hours above the IT1 threshold almost triples (from 0.16 to 0.45). Therefore, we cannot distinguish whether the stronger response during alert weeks is due to the higher level of pollution, the information disseminated by the alerts, which could encourage additional avoidance behavior, or changes in labor demand due to the alerts.[30]

In column (7), we further investigate the role that public sector decisions to close or reduce work in its offices, schools, or hospitals could play by investigating the differential response of public and private sector workers to high pollution in weeks with alerts. Our results show that the labor supply response is stronger among private sector workers than public sector workers, even on weeks with officially issued alerts. The result is statistically significant and large in magnitude (i.e., public sector workers' response is around one-third smaller). Consistent with columns (5)–(6) showing larger effects in weeks with alerts, point estimates are larger on alert weeks (column (7)), but the pattern is the same as in weeks with no pollution alerts (column (3)) with public sector workers reducing their labor supply significantly less than private sector workers. These results suggest that labor supply reductions reflect worker's decisions rather than public sector closures in response to official pollution alerts that reduce labor demand.

The widespread publication of public alerts indicates that the population is likely to be aware of alerts and that it is less likely that high-income workers and low-income workers have differential access to pollution information on days with alerts. Therefore, if the heterogeneity that we observe in labor supply responses across low-income and high-income workers persists in the sample of weeks with alerts, then this indicates that differential access to pollution information is unlikely to be the only mechanism driving the heterogeneity that we observe in labor supply reductions on high pollution days. Interestingly, the difference in labor supply response between high-income and low-income workers (column (8)) almost doubles in magnitude relative to weeks without alerts (column (4)), implying that differential access to information is not the only mechanism driving the heterogeneity that we observe.

Unfortunately, we cannot determine whether the larger differences between low-income workers and high-income workers during alert weeks is due to the higher level of pollution, differential avoidance behavior by income level in response to alerts or associated changes in labor demand that could affect high-income workers more than low-income workers. However, in the peak pollution season, we also see a substantial difference in response to high pollution by low-income and high-income workers and the magnitude of the differential response in the sample of weeks with alerts is comparable to that in the peak pollution season (column (5) of Table VI), suggesting that higher pollution levels during weeks in which a public alert is issued plays a role in the larger responses.

In brief, we find no evidence that public sector closures on alert days are driving the reduction in working hours on high pollution days. Instead, consistent with the results in Section 6.2, these results suggest that labor supply reductions on high pollution days are due to workers' labor supply decisions. In addition, we find no evidence suggesting that temporarily heightened attention to air pollution due to public alerts is driving the reduction in working hours on high pollution days. Further, our results suggest that differential access to pollution information between low-income and high-income workers cannot

[30] Aguilar-Gomez (2020) shows evidence consistent with avoidance in Mexico City. In the time period 2013–2016, people reduced car trips on high alert days. Alerts, however, do not seem to be associated with a reduction in air pollution.

fully explain the heterogeneity in response to high pollution that we observe. These results imply that the provision of air pollution information is unlikely to reduce the disparity between low-income and high-income workers' responses to air pollution. If reducing hours worked on high pollution days is an effective avoidance behavior (i.e., reduces exposure to air pollution), then public information provision would have limited ability to close the gap in exposure between low-income and high-income workers.

6.4. *Workers' Decisions: Avoidance or Health?*

In the previous sections, we documented that the reduction in labor supply on high pollution days reflects workers' decisions. In this section, we investigate whether workers' decisions to reduce labor supply on high pollution days represent avoidance behavior or deteriorating health. Avoidance behavior refers to any action taken to mitigate the negative impacts of air pollution. In our context, this includes actions that reduce exposure to high pollution, for example, by avoiding high pollution areas or physically demanding activities during high pollution periods, and actions that reduce its effects on productivity, for example, by avoiding work during periods of high pollution and low productivity.

The analytical framework in Section 3.1 suggests that workers will engage in avoidance behaviour to protect themselves from harmful pollution levels, particularly higher-income workers for whom the income effect is not strong enough to dominate the substitution effect. This prediction is consistent with our primary finding that workers reduce working hours on high pollution days and that this effect is stronger for high-income workers. This type of avoidance behavior may not be sustainable, especially for low-income workers, when pollution is high on consecutive days since income needs and work commitments become increasingly pressing. Therefore, if workers' reductions to labor supply on high pollution days were partly attributable to avoidance behavior, income needs and work commitments would imply that the impacts of PM 2.5 on working hours would decrease over consecutive days of high pollution. An alternative explanation for workers' decisions to reduce working hours on high pollution days is that workers experience a deterioration of their health due to air pollution exposure. If this were the case, we would expect that repeated exposure to high levels of pollution over consecutive days would lead to increases in absenteeism. If negative health effects of pollution was the dominating mechanism driving workers' labor supply reductions on high pollution days, the impacts of PM 2.5 on labor supply would increase over consecutive days of high pollution.

To differentiate between these alternative explanations, we analyze the behavior of workers, both high-income and low-income, across different patterns of high pollution days. Specifically, we explore the contemporaneous response to high pollution in three different scenarios, namely (i) no hours of high pollution on either of the previous 2 days; (ii) one or more hours of high pollution on at least 1 of the 2 previous days; and (iii) one or more hours of high pollution on each of the previous 2 days.

Figure 4 illustrates our results. The contemporaneous responses to high pollution for top- and bottom-decile workers are stronger when there was no pollution on the previous two days. As pollution becomes persistent, the response decreases and becomes indistinguishable from zero on days in which both of the prior days had pollution above the IT1 threshold. In this case of persistent and constant pollution, observationally, it would appear that workers do not respond strongly to contemporaneous high pollution. However, the dynamic effects of pollution documented above suggest that the near zero change in labor supply may be the result of two opposing effects, the negative effect of contemporaneous high pollution and the positive compensatory effect of high pollution on prior days.

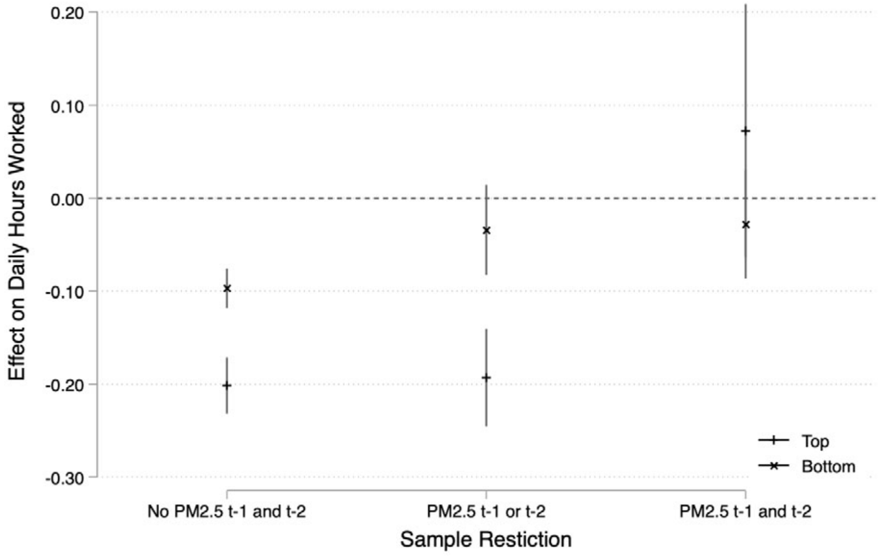

FIGURE 4.—Impact of Prior Days' PM 2.5 on Daily Hours Worked. Note: Coefficients and 90% confidence intervals are plotted from equation (2).

Figure 4 also illustrates that low-income workers seem to reduce their response quicker than high-income workers. In Table XII, we show that this pattern holds when looking at all workers together and within the bottom and the top deciles (columns (1)–(3)). These responses are more pronounced on weekdays (columns (7)–(9)) and especially during the peak pollution season (columns (4)–(6)); not only are the point estimates larger in magnitude, but the differential response between bottom decile and top decile workers is also larger. For example, in the full sample and on weekdays, workers in the bottom decile of the income distribution seemingly return to their usual work schedules after 1 day of high pollution (in columns (2) and (8), coefficients are significant in panel A and insignificant in panel B) whereas workers in the top decile of the income distribution return to their usual work schedules after 2 consecutive days of high pollution (in columns (3) and (9), coefficients are significant in panel B and insignificant in panel C). During the peak pollution season (columns (4)–(6)), both workers in the bottom decile and in the top decile continue to adjust their hours worked on the second day of high pollution. However, workers in the top decile reduce their labor supply by nearly four times as much as workers in the bottom decile.

Finally, as additional evidence that the effects of air pollution on labor supply reflect avoidance behavior as opposed to short-term health impacts, we explore the possibility that the reduction in hours worked on high pollution days is driven by older workers who likely experience greater short-term health effects of air pollution (e.g., as in Anderson (2019), Deryugina et al. (2019)). Supplemental Appendix Table AVII reports the effects by age category and shows no discernible pattern across age groups, with similar point estimates for younger and older workers. Consistent with the results above this suggests that the reduction in hours worked on high pollution days at least partially reflects avoidance behavior. Further, because workers' age could be correlated with both earnings and health effects, these results suggest that the differential responses to high pollution that we observe across income levels is not due to different age compositions of workers across deciles of the income distribution.

TABLE XII

CONSECUTIVE DAYS OF HIGH POLLUTION.

	Full Sample			Peak Season			Weekdays		
	(1)	(2) Bottom 10%	(3) Top 10%	(4)	(5) Bottom 10%	(6) Top 10%	(7)	(8) Bottom 10%	(9) Top 10%
				Panel A: No Pollution on Prior 2 Days					
Hours Above PM2.5	−0.192	−0.097	−0.201	−0.338	−0.167	−0.341	−0.234	−0.124	−0.234
IT1 Threshold	(0.008)	(0.013)	(0.018)	(0.007)	(0.016)	(0.024)	(0.009)	(0.012)	(0.022)
N	2,017,330	136,068	126,410	116,133	7658	6768	1,450,598	97,839	90,870
R2	0.284	0.076	0.473	0.288	0.103	0.482	0.075	0.068	0.077
				Panel B: High Pollution on One of 2 Prior Days					
Hours Above PM2.5	−0.120	−0.034	−0.193	−0.248	−0.097	−0.368	−0.129	−0.027	−0.208
IT1 Threshold	(0.016)	(0.029)	(0.032)	(0.025)	(0.036)	(0.049)	(0.019)	(0.033)	(0.036)
N	170,940	12,189	10,111	31,579	2188	1757	115,676	8,287	6828
R2	0.296	0.114	0.522	0.266	0.126	0.488	0.092	0.113	0.169
				Panel C: High Pollution on Prior 2 Days					
Hours Above PM2.5	−0.018	−0.028	0.073	−0.050	0.015	−0.028	−0.047	−0.034	−0.009
IT1 Threshold	(0.022)	(0.035)	(0.081)	(0.062)	(0.102)	(0.226)	(0.027)	(0.030)	(0.055)
N	35,869	2895	1740	7360	566	354	21,599	1840	970
R2	0.316	0.184	0.589	0.305	0.225	0.569	0.094	0.198	0.274

Note: Standard errors clustered at the locality level. Results use the baseline specification as in column (1), Table III.

Our results suggest that workers reduce their hours worked on high pollution days as avoidance behavior. These results have important implications in terms of the limitations to avoidance as a sustainable adaptive behavior. If high pollution levels persist, workers eventually return to the workplace. This applies to both low-income and high-income workers, even if the latter seem to be able to avoid exposure a little longer. These results are consistent with the nonlinearity in responses that we reported in Section 4.1. If every day becomes a high pollution day, then workers eventually return to the workplace.

Additionally, our evidence suggests that, on average, a high-income worker is more likely to avoid exposure to harmful pollution by making larger reductions to the number of hours worked than a low-income worker. The difference is even starker in periods of persistently high pollution. This result is consistent with findings in the literature that the health effects of air pollution are worse for people with lower socioeconomic status (Jans, Johansson, and Nilsson (2018), Zhang, Zhang, and Chen (2017), Arceo, Hanna, and Oliva (2016)). While our results may partially explain these findings, other channels that we cannot fully explore (e.g., housing quality and indoor pollution levels, access to healthcare, etc.) likely also play a role.

7. CONCLUSION

In this paper, we provide evidence that workers reduce their labor supply on days with high pollution levels and compensate on subsequent days. These responses are stronger for high-income workers and are consistent with avoidance behavior. Unequal responses along other dimensions (job quality, flexibility, gender) matter, but less than income, leading us to conclude that low-income workers are subject to a stronger income-health tradeoff than high-income workers.

The general characteristics of the environment and labor markets of Mexico City are particularly relevant as they allow our results to speak more broadly to developing countries. Similar to many other large cities in the region (such as Santiago, Lima, and Bogota) and in other developing countries (such as India, China, and Pakistan), Mexico City experiences high levels of fine particulate matter and has a segmented labor market, largely unequal in terms of income and productivity and with high levels of informality and self-employment (IQAir (2019), World Bank Development Indicators (2021)).

Our results have three key policy implications. First, the strong nonlinear relationship of PM 2.5 with labor supply indicates that policies should focus on decreasing peak levels of particulate matter.

Second, our results suggest that workers' ability to adjust labor supply as avoidance behavior differs across the income distribution, implying that the costs of air pollution are unequally distributed across workers. Low-income workers' relatively inflexible labor supply may be one channel through which they are more exposed to air pollution than richer workers, which could contribute to some of the health inequalities associated with air pollution documented in the literature. Our results imply that even if access and use of health services were equal, the income effect through the labor supply channel could cause unequal health impacts of air pollution. Low-income workers may not have access to public paid sick leave and are unlikely to have paid sick leave from their employers. Social programs that support low-income workers on high pollution days could allow them to avoid steep drops in income while engaging in avoidance behavior that could reduce the risk of negative health outcomes.

Finally, our results have implications for how workers will respond to higher pollution environments. Higher average pollution could be due to either larger pollution shocks or an increase in persistent levels of pollution. The larger labor supply reductions that we document in the peak pollution season suggest that workers will respond to larger pollution shocks with larger decreases in labor supply. The dynamic responses and the effects on consecutive days of high pollution hint that there are limits to avoidance as an adaptive behavior. If high pollution persists, workers eventually return to the workplace. Further, if pollution were to increase so that currently extreme levels of pollution were to become more frequent, our nonlinear results suggest that workers may shift their responses to a new, higher threshold, and work their normal hours in the new, more polluted environment. The heterogeneity that we observe across income levels in the response to contemporaneous pollution after consecutive days of high pollution implies that low-income workers have more limitations to avoidance behavior and will be less able to adapt to a more polluted environment than high-income workers.

REFERENCES

AGUILAR-GOMEZ, SANDRA (2020): "Adaptation and Mitigation of Pollution: Evidence From Air Quality Warnings," Report. [1086,1088]

ANDERSON, JONATHAN, JOSEF THUNDIYIL, AND ANDREW STOLBACH (2011): "Clearing the Air: A Review of the Effects of Particulate Matter Air Pollution on Human Health," *Journal of medical toxicology: official journal of the American College of Medical Toxicology*, 8, 166–175. [1068]

ANDERSON, MICHAEL L. (2019): "As the Wind Blows: The Effects of Long-Term Exposure to Air Pollution on Mortality," *Journal of the European Economic Association*, 18 (4), 1886–1927. [1063,1090]

ARAGÓN, FERNANDO M., AND JUAN PABLO RUD (2016): "Polluting Industries and Agricultural Productivity: Evidence From Mining in Ghana," *The Economic Journal*, 126 (597), 1980–2011. [1072]

ARAGÓN, FERNANDO M., JUAN JOSE MIRANDA, AND PAULINA OLIVA (2017): "Particulate Matter and Labor Supply: The Role of Caregiving and Non-Linearities," *Journal of Environmental Economics and Management*, 86, 295–309. Special issue on environmental economics in developing countries. [1064,1066,1084]

ARAGÓN, FERNANDO M., FRANCISCO OTEIZA, AND JUAN PABLO RUD (2021): "Climate Change and Agriculture: Subsistence Farmers' Response to Extreme Heat," *American Economic Journal: Economic Policy*, 13 (1), 1–35. [1072]

ARCEO, EVA, REMA HANNA, AND PAULINA OLIVA (2016): "Does the Effect of Pollution on Infant Mortality Differ Between Developing and Developed Countries? Evidence From Mexico City," *The Economic Journal*, 126 (591), 257–280. [1063,1067,1092]

BANDIERA, ORIANA, RENATA LEMOS, ANDREA PRAT, AND RAFFAELLA SADUN (2018): "Managing the Family Firm: Evidence From CEOs at Work," *Review of Financial Studies*, 31 (5), 1605–1653. [1065,1082]

BECKETT, K. PAUL, P. H. FREER-SMITH, AND GAIL TAYLOR (2000): "Particulate Pollution Capture by Urban Trees: Effect of Species and Windspeed," *Global Change Biology*, 6 (8), 995–1003. [1068]

BELL, MICHELLE, JONATHAN SAMET, AND FRANCESCA DOMINICI (2004): "Time-Series Studies of Particulate Matter," *Annual review of public health*, 25 (1), 247–280. [1068]

BHARADWAJ, PRASHANT, MATTHEW GIBSON, JOSHUA GRAFF ZIVIN, AND CHRISTOPHER NEILSON (2017): "Gray Matters: Fetal Pollution Exposure and Human Capital Formation," *Journal of the Association of Environmental and Resource Economists*, 4 (2), 505–542. [1066]

BONDY, MALVINA, SEFI ROTH, AND LUTZ SAGER (2020): "Crime Is in the Air: The Contemporaneous Relationship Between Air Pollution and Crime," *Journal of the Association of Environmental and Resource Economists*, 7 (3), 555–585. [1072]

BORGSCHULTE, MARK, DAVID MOLITOR, AND ERIC ZOU (2022): "Air Pollution and the Labor Market: Evidence From Wildfire Smoke," Review of Economics and Statistics Advance online publication. [1066]

CAMERER, COLIN, LINDA BABCOCK, GEORGE LOEWENSTEIN, AND RICHARD THALER (1997): "Labor Supply of New York City Cabdrivers: One Day at a Time," *The Quarterly Journal of Economics*, 112 (2), 407–441. [1071,1072]

CARB (2021): "Inhalable Particulate Matter and Health (PM 2.5 and PM 10)." [1068]

CESARONI, GIULIA, FRANCESCO FORASTIERE, MASSIMO STAFOGGIA, ZORANA J. ANDERSEN, CHIARA BADALONI, ROB BEELEN, BARBARA CARACCIOLO, ULF DE FAIRE, RAIMUND ERBEL, KIRSTEN T. ERIKSEN et al. (2014): "Long Term Exposure to Ambient Air Pollution and Incidence of Acute Coronary Events: Prospective Cohort Study and Meta-Analysis in 11 European Cohorts From the ESCAPE Project," *BMJ (Clinical research ed.)*, 348, f7412. [1068]

CHAN, H. RON, MARTINO PELLI, AND VERONICA VIENNE ARANCIBIA (2023): "Air Pollution, Smoky Days and Hours Worked," Report. [1066]

CHANG, TOM, JOSHUA GRAFF ZIVIN, TAL GROSS, AND MATTHEW NEIDELL (2016): "Particulate Pollution and the Productivity of Pear Packers," *American Economic Journal: Economic Policy*, 8 (3), 141–169. [1066, 1072]

CHANG, TOM Y., JOSHUA GRAFF ZIVIN, TAL GROSS, AND MATTHEW NEIDELL (2019): "The Effect of Pollution on Worker Productivity: Evidence From Call Center Workers in China," *American Economic Journal: Applied Economics*, 11 (1), 151–172. [1066,1072]

CHAY, KENNETH Y., AND MICHAEL GREENSTONE (2003): "The Impact of Air Pollution on Infant Mortality: Evidence From Geographic Variation in Pollution Shocks Induced by a Recession*," *The Quarterly Journal of Economics*, 118 (3), 1121–1167. [1063]

CURRIE, JANET, AND MATTHEW NEIDELL (2005): "Air Pollution and Infant Health: What Can We Learn From California's Recent Experience?*," *The Quarterly Journal of Economics*, 120 (3), 1003–1030. [1063]

CURRIE, JANET, ERIC A. HANUSHEK, E. MEGAN KAHN, MATTHEW NEIDELL, AND STEVEN G. RIVKIN (2009): "Does Pollution Increase School Absences?" *The Review of Economics and Statistics*, 91 (4), 682–694. [1066]

CYGAN-REHM, KAMILA, AND CHRISTOPH WUNDER (2018): "Do Working Hours Affect Health? Evidence From Statutory Workweek Regulations in Germany," *Labour Economics*, 53, 162–171. [1072]

DERYUGINA, TATYANA, GARTH HEUTEL, NOLAN H. MILLER, DAVID MOLITOR, AND JULIAN REIF (2019): "The Mortality and Medical Costs of Air Pollution: Evidence From Changes in Wind Direction," *American Economic Review*, 109 (12), 4178–4219. [1063,1090]

EBENSTEIN, AVRAHAM, VICTOR LAVY, AND SEFI ROTH (2016): "The Long-Run Economic Consequences of High-Stakes Examinations: Evidence From Transitory Variation in Pollution," *American Economic Journal: Applied Economics*, 8 (4), 36–65. [1066]

EPA (2009): "Integrated Science Assessment for Particulate Matter," Tech. rep, United States Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F National Center for Environmental Assessment-RTP Division. [1067]

EPA (2010): "Particle Pollution and Your Health," Tech. rep, United States Environmental Protection Agency. [1068]

FUNK, CHRIS C., PETE J. PETERSON, MARTIN F. LANDSFELD, DIEGO H. PEDREROS, JAMES P. VERDIN, JAMES D. ROWLAND, BO E. ROMERO, GREGORY J. HUSAK, JOEL C. MICHAELSEN, AND ANDREW P. VERDIN (2014): "A Quasi-Global Precipitation Time Series for Drought Monitoring," *U.S. Geological Survey Data Series*, 832, 4, http://pubs.usgs.gov/ds/832/. [1069]

GRAFF ZIVIN, JOSHUA, AND MATTHEW NEIDELL (2012): "The Impact of Pollution on Worker Productivity," *American Economic Review*, 102 (7), 3652–3673. [1066,1071]

——— (2013): "Environment, Health, and Human Capital," *Journal of Economic Literature*, 51 (3), 689–730. [1063]

GUARNIERI, MICHAEL, AND JOHN R. BALMES (2014): "Outdoor Air Pollution and Asthma," *The Lancet*, 383 (9928), 1581–1592. [1063]

GUTIÉRREZ, JUAN PABLO, JUAN ÁNGEL RIVERA-DOMMARCO, TERESA SHAMAH-LEVY, SALVADOR VILLALPANDO-HERNÁNDEZ, AURORA FRANCO, LUCÍA CUEVAS-NASU, MARTÍN ROMERO-MARTÍNEZ, AND MAURICIO HERNÁNDEZ-ÁVILA (2013): *Encuesta Nacional de Salud y Nutrición 2012. Resultados Nacionales. 2a. ed*. Cuernavaca, México: Instituto Nacional, de Salud Pública (MX). Tech. rep. [1068]

HANNA, REMA, AND PAULINA OLIVA (2015): "The Effect of Pollution on Labor Supply: Evidence From a Natural Experiment in Mexico City," *Journal of Public Economics*, 122, 68–79. [1064,1066]

HANNA, REMA, BRIDGET HOFFMANN, PAULINA OLIVA, AND JACOB SCHNEIDER (2021): "The Power of Perception: Limitations of Information in Reducing Air Pollution Exposure," IDB Working Paper IDB-WP-1260. [1067]

HE, JIAXIU, HAOMING LIU, AND ALBERTO SALVO (2019): "Severe Air Pollution and Labor Productivity: Evidence From Industrial Towns in China," *American Economic Journal: Applied Economics*, 11 (1), 173–201. [1072]

HIEN, P. D., V. T. BAC, H. C. THAM, D. D. NHAM, AND L. D. VINH (2002): "Influence of Meteorological Conditions on PM 2.5 and PM 2.5-10 Concentrations During the Monsoon Season in Hanoi, Vietnam," *Atmospheric Environment*, 36 (21), 3473–3484. [1068]

HOFFMANN, BRIDGET, AND JUAN PABLO RUD (2024): "Supplement to 'The Unequal Effects of Pollution on Labor Supply'," *Econometrica Supplemental Material*, 92, https://doi.org/10.3982/ECTA20484. [1069]

HOLUB, FELIX, AND BEATE THIES (2023): "Air Quality, High-Skilled Worker Productivity and Adaptation: Evidence From Github," Report. [1082]

INEGI (2005–2016): "Encuesta Nacional de Ocupación y Empleo ENOE," Retrieved from: https://en.www.inegi.org.mx/programas/enoe/15ymas/#microdata. [1068]

IQAIR (2019): "2019 World Air Quality Report: Region & City PM 2.5 Ranking." [1092]

JANHÄLL, SARA (2015): "Review on Urban Vegetation and Particle Air Pollution—Deposition and Dispersion," *Atmospheric Environment*, 105, 130–137. [1068]

JANS, JENNY, PER JOHANSSON, AND J. PETER NILSSON (2018): "Economic Status, Air Quality, and Child Health: Evidence From Inversion Episodes," *Journal of Health Economics*, 61, 220–232. [1067,1092]

JAYACHANDRAN, SEEMA (2006): "Selling Labor Low: Wage Responses to Productivity Shocks in Developing Countries," *Journal of Political Economy*, 114 (3), 538–575. [1065,1082]

KIM, YOUNOH, JAMES MANLEY, AND VLAD RADOIAS (2017): "Medium- and Long-Term Consequences of Pollution on Labor Supply: Evidence From Indonesia," *IZA Journal of Labor Economics*, 6 (1), 5. [1066]

LEPINTEUR, ANTHONY (2019): "The Shorter Workweek and Worker Wellbeing: Evidence From Portugal and France," *Labour Economics*, 58, 204–220. [1072]

LIN, MEI, YUE CHEN, RICHARD T. BURNETT, PAUL J. VILLENEUVE, AND DANIEL KREWSKI (2002): "The Influence of Ambient Coarse Particulate Matter on Asthma Hospitalization in Children: Case-Crossover and Time-Series Analyses," *Environmental health perspectives*, 110 (6), 575–581. [1068]

MANCERA, MIGUEL A., TANYA MULLER, ANTONIO MEDIAVILLA, AND DIANA GUZMÁN (2014): "Inventario de Emisiones de la CDMX." [1067]

MEGHIR, COSTAS, RENATA NARITA, AND JEAN-MARC ROBIN (2015): "Wages and Informality in Developing Countries," *American Economic Review*, 105 (4), 1509–1546. [1078]

MOLINA, L. T., SASHA MADRONICH, J. GAFFNEY, ERIC APEL, BENJAMIN DE FOY, J. FAST, R. FERRARE, SCOTT HERNDON, J. JIMENEZ, BRIAN LAMB, ALVARO R. OSORNIO-VARGAS, PHIL RUSSELL, J. SCHAUER, PHILIP STEVENS, R. VOLKAMER, AND M. ZAVALA (2010): "An Overview of the MILAGRO 2006 Campaign: Mexico City Emissions and Their Transport and Transformation," *Atmospheric Chemistry and Physics Discussions*, 10, 8697–8760. [1067]

MORETTI, ENRICO, AND MATTHEW NEIDELL (2011): "Pollution, Health, and Avoidance Behavior: Evidence From the Ports of los Angeles," *Journal of Human Resources*, 46 (1), 154–175. [1063]

MUGICA, V., E. ORTIZ, L. MOLINA, A. DE VIZCAYA-RUIZ, A. NEBOT, R. QUINTANA, J. AGUILAR, AND E. ALCÁNTARA (2009): "PM Composition and Source Reconciliation in Mexico City," *Atmospheric Environment*, 43 (32), 5068–5074. [1067]

NEIDELL, MATTHEW J. (2004): "Air Pollution, Health, and Socio-Economic Status: The Effect of Outdoor Air Quality on Childhood Asthma," *Journal of Health Economics*, 23 (6), 1209–1236. [1066]

POPE, C. ARDEN, AND DOUGLAS W. DOCKERY (2006): "Health Effects of Fine Particulate Air Pollution: Lines That Connect," *Journal of the Air & Waste Management Association*, 56, 709–742. [1068]

ROTH, SEFI (2018): "The Effect of Indoor Air Pollution on Cognitive Performance: Evidence From the UK," Report. [1066]

SAGER, LUTZ (2019): "Estimating the Effect of Air Pollution on Road Safety Using Atmospheric Temperature Inversions," *Journal of Environmental Economics and Management*, 98, 102250. [1072]

SCHLENKER, WOLFRAM, AND W. REED WALKER (2016): "Airports, Air Pollution, and Contemporaneous Health," *The Review of Economic Studies*, 83 (2), 768–809. [1063]

SECRETARIA DEL MEDIO AMBIENTE (2005): "Informe Climatologico Ambiental del Valle de Mexico," Tech. rep, Mexico: Gobierno del Distrito Federal. [1068]

SEDEMA (2005–2016): "Estadisticas de calidad del aire del Sistema de Monitoreo Atmosférico (SIMAT)," Retrieved from: http://www.aire.df.gob.mx. [1069]

SHIHE, FU, BRIAN VIARD, AND PENG ZHANG (2017): "Air Quality and Manufacturing Firm Productivity: Comprehensive Evidence From China," Tech. rep. [1072]

STAFFORD, TESS M. (2015): "Indoor Air Quality and Academic Performance," *Journal of Environmental Economics and Management*, 70, 34–50. [1066]

TERTRE, ALAIN LE, SYLVIA MEDINA, EVI SAMOLI, BERTIL FORSBERG, P. MICHELOZZI, A. BOUMGHAR, JUDITH VONK, A. BELLINI, R. ATKINSON, JON AYRES, J. SUNYER, JOEL SCHWARTZ, AND K. KATSOUYANNI (2002): "Short-Term Effects of Particulate Air Pollution on Cardiovascular Diseases in Eight European Cities," *Journal of epidemiology and community health*, 56, 773–779. [1068]

ULYSSEA, GABRIEL (2018): "Firms, Informality, and Development: Theory and Evidence From Brazil," *American Economic Review*, 108 (8), 2015–2047. [1078]

WHO (2005): "WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide. Global Update 2005. Summary of Risk Assessment," Tech. rep, World Health Organization. [1069, 1070]

——— (2016): *Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease*. [1063]

WORLD BANK DEVELOPMENT INDICATORS (2021): "Self-Employed Total (% of Total Employment) (Modeled ILO Estimate)—Colombia, Mexico, Brazil, Peru, Argentina, Chile, Bolivia." [1092]

ZHANG, XIN, XI CHEN, AND XIAOBO ZHANG (2018): "The Impact of Exposure to Air Pollution on Cognitive Performance," *Proceedings of the National Academy of Sciences*, 115 (37), 9193–9197. [1066,1067]

ZHANG, XIN, XIAOBO ZHANG, AND XI CHEN (2017): "Happiness in the Air: How Does a Dirty Sky Affect Mental Health and Subjective Well-Being?" *Journal of Environmental Economics and Management*, 85, 81–94. [1063,1092]

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