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# Air Quality and Infant Mortality in Mexico: Evidence from Variation in Pollution levels caused by the usage of small-scale power plants

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**Air Quality and Infant Mortality in Mexico: Evidence from Variation in Pollution Levels Caused by the Usage of Small-Scale Power Plants**

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## Abstract

This paper exploits the discrete change in air pollutants induced by the installation of small-scale power plants throughout Mexico to measure the causal relationship between air pollution and infant mortality, and if this relationship varies by municipality's socio-economic conditions. The estimated elasticity for changes in infant mortality due to respiratory diseases with respect to changes in air pollution concentration ranges from 0.58 and 0.84 (more than ten times higher than the OLS estimate). The effect is significantly lower in municipalities with a high presence of primary health facilities but does not vary significantly by average income and education levels.

Lower income levels and lower access to health services in low and middle-income countries are likely to contribute to greater adverse effects of pollution on health outcomes. However, the unavailability of reliable measures of pollution concentrations has resulted in a lack of credible empirical studies carefully estimating this relationship for these contexts.

This paper is among the first to exploit an arguably exogenous source of variation in air pollution levels across the Mexican territory to measure the relationship between pollution and infant mortality. The empirical strategy exploits, on one hand, a unique data set that provides measures of pollution concentrations in the atmosphere at a detailed level for the whole Mexican territory from satellite imagery. On the other, it isolates changes in air quality from other confounding factors that could affect health outcomes by exploiting the discrete change in air pollutants induced by the installation of small-scale power plants by existing firms in Mexico. The estimated elasticity for changes in infant mortality due to respiratory diseases with respect to changes in air pollution concentration ranges from 0.58 and 0.84, more than ten times higher than the OLS estimate for the same context (Gutiérrez, 2010). The effect is significantly lower in municipalities with a high presence of primary health facilities, and weaker evidence suggests that it varies by average income and education levels.

The paper is organized as follows. The next section reviews the existing studies measuring the relationship between air pollution and health outcomes, stressing the need of a source of exogenous variation in pollution levels in order to identify the causal relationship between these variables. Section III describes the context and the nature of the instrumental variable exploited in this paper. Section IV describes the data used. Section V describes the empirical strategy. Section VI presents the results. The final section concludes.

## II. Related Studies

The evidence on the relationship between air pollution and health outcomes (especially infant mortality) for developed countries' settings is robust and growing. [1] The earlier studies document the positive relationship between air pollution and health outcomes (Pope et al. 1992; Schwartz 2000; Currie and Niedell 2004). More recent literature recognizes that the correlations between pollutant levels and health, due to measurement error and/or the omission of relevant controls may represent a biased estimate of the causal relationship between them.

For these reasons, Chay and Greenstone (2003) instrument variations in pollution levels in the United States with the implementation of the Clean Air Act and (in a different paper) the intensity of an economic recession to estimate the impact of air pollution on infant mortality. Their results suggest that Ordinary Least Squares estimates of the relationship between air quality and infant mortality are significantly biased towards zero.

Lower access to health services and lower nutrition are likely to be more prevalent in developing countries' settings. To the extent to which they constrain individuals' capacity to optimally respond to health shocks, the negative impacts of air pollution on health outcomes may be higher in these contexts, for which a smaller set of empirical studies exists.

The existing literature, perhaps due to data limitations, has generally focused on the relationship between air pollution and health outcomes in big cities (Saldiva et al. 1994, Bharadwaj et al. 2008, Arceo et al, 2012). Others do investigate the relationship between pollution levels and infant health outcomes over larger surfaces, although they have important limitations: some lack sources of arguably exogenous variation in air pollutant levels (Gutierrez, 2010), and others exploit sources of large variation in air quality induced by major events (Jayachandran, 2009 exploits Indonesian wildfires, Tanaka, 2010 changes in regulation in China).[2] The extent to which the events causing these large changes in pollution concentrations may have affected other

[1] See Glinianaia (2004) for a review of this literature.
[2] Foster et al (2009) also estimate the impact of firm's participation in a voluntary environmental certification program on infant mortality.

outcomes which can have a direct impact on infant health raises doubts about the consistency of the estimated impacts of pollution on infant mortality.

More recent studies for industrialized countries' settings have exploited sources of variation in pollutants that are less likely to be related to economic conditions (such as the introduction of EZ-pass in highways, Currie and Walker, 2011) in order to estimate pollutants' impact on infant mortality, finding large effects. This study also exploits a source of smaller exogenous variation in air quality, but throughout the territory of a developing country setting.

The first contribution of this paper to the existing literature is then that it estimates the relationship between air pollution concentrations and health outcomes across the Mexican territory exploiting a source of exogenous variation in pollution levels not likely to be correlated with local economic conditions o other factors which could bias the estimates. In addition, it provides evidence on which municipality-level socio-economic characteristics contribute to reduce or exacerbate pollution's adverse effects on health. The next section describes in detail the nature of the source of variation in pollution exploited in this paper.

## III. Context

Since 1994, the Commission for Energy Regulation (Comisión Reguladora de Energía, CRE) has authorized existing firms in Mexico to install small-scale power plants in their facilities for self consumption.  According to the national inventory of emissions (SEMARNAT & INE, 1999), power plants contribute with 2.89% of the total emissions of $PM_{10}$ and with 6.51% of the total emissions of $PM_{2.5}$ at the national level. They are responsible for a major part of $SO_X$ emissions, and they are the second source of $NO_X$ after the mobile sources. Between 2000 and 2006, 275 small-scale power plants entered in operation in 116 municipalities throughout the country. By 2009, these plants' electricity generation for self-consumption accounted to 9.4% of the electricity generated in Mexico. In addition to their relatively high contribution to electricity generation, these small power plants are generally characterized by low efficiency and high pollutant emissions (Tanaka, 2010).

## IV. Data Description

The data used in this paper comes from four main sources: (1) from the publicly available list of permits granted by CRE to firms in Mexico to install small-scale power plants; (2) from daily satellite images containing measures of Aerosol Optic Depth (AOD), a measure of air quality, for the whole Mexican territory, for the period from January 1, 2001 to December 31, 2006; (3) from administrative records of registered infant deaths by municipality, month of occurrence and cause of death during the same time period; and (4) municipality-level socio-economic characteristics obtained from the 2000 Mexican Census, administered by the Mexican Statistics Institute (INEGI). The details on how the dataset used in the empirical analysis was constructed are described in what follows.

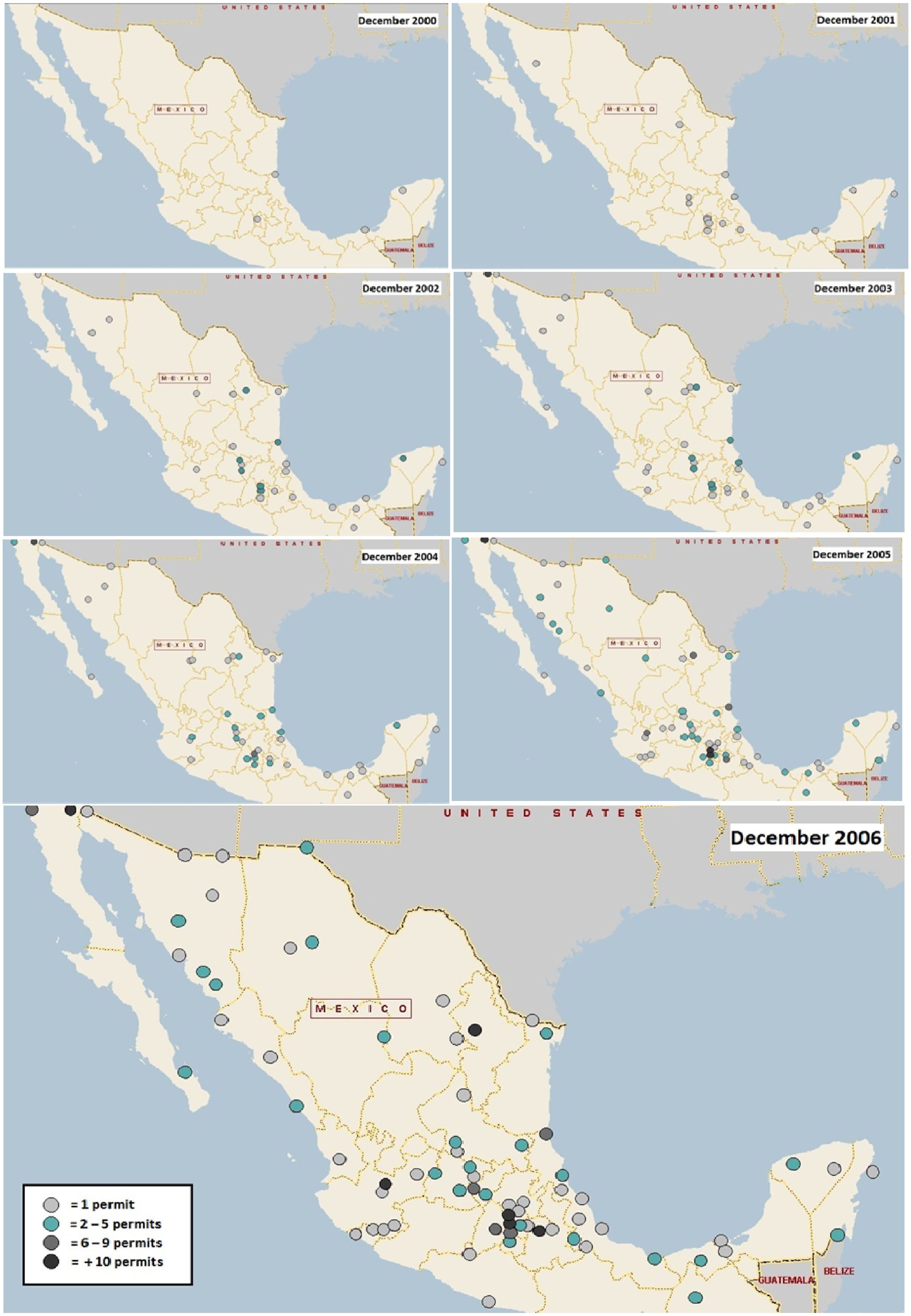
### IV.1. Power Plants

The publicly available list of permits granted to Mexican firms to install small-scale power plants was used to assign to each municipality (according to the address coded in the permit), a variable indicating the total number of power plants in operation in every period for the time frame analyzed in this paper (the permits specify the date at which plants started operating).

Figure 1 shows the distribution of these plants throughout the Mexican territory over time.

This study doesn't face the geographic limitations of the existing research for developing countries, as these power plants are spread across the whole Mexican territory. Because of this, exploiting the geographic variation in other socio-economic indicators, it will be then possible to estimate differential effects of pollution on mortality by municipality-level socio-economic conditions.

**Figure 1. Number of small-scale power plants in operation by year**



## IV.2. Air Quality

Daily measures of Aerosol Optical Depth (AOD) for the entire land area of Mexico at a 5km spatial resolution for cloud-free images over the 2001-2006 time period were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS onboard the Terra Satellite), of NASA's Goddard Space Flight Center Earth Sciences Distributed Active Archive Center (DAAC).[3]

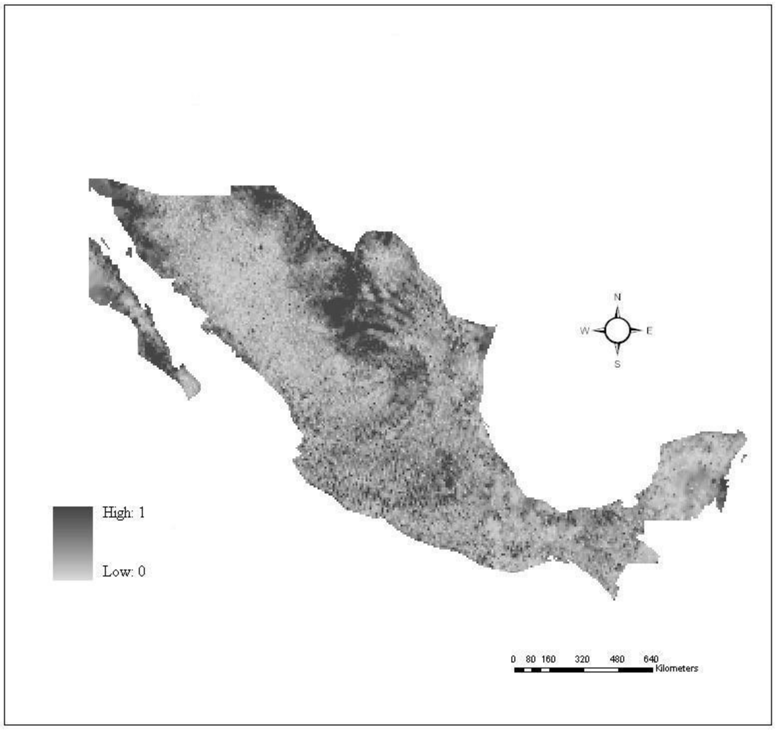
AOD can be described as the extinction of beam power caused by the presence solid and liquid particles in the atmosphere. Existing evidence (Kumar et al., 2007; Chu et al., 2003; Gupta et al., 2006) suggest that AOD is a good predictor of the traditional ground measures of suspended particles (PM2.5 and PM10). Nonetheless, it does not allow for a precise distinction between pollutants.

Using GIS, the daily measures of AOD from the satellite images were overlapped with each municipality's capital geographic coordinates. The estimated AOD daily value for each municipality was averaged for each month in the sample.

Figure 2 shows a map with the calculated levels of AOD for Mexico in October, 2006. Geography and weather conditions may have a direct effect on the AOD measure regardless of the concentrations of particulate matter. Although comparisons of AOD levels across space are thus hard to make, AOD levels are higher around metropolitan areas (i.e., Mexico City, Guadalajara and Monterrey).

[3] For the Mexican context, these data have already made it possible to better evaluate pollution abatement policies (Foster and Gutierrez, 2008), and their potential relationship with health outcomes (Foster, et al., 2009).

**Figure 2. Mexico. AOD levels. October 2006.**

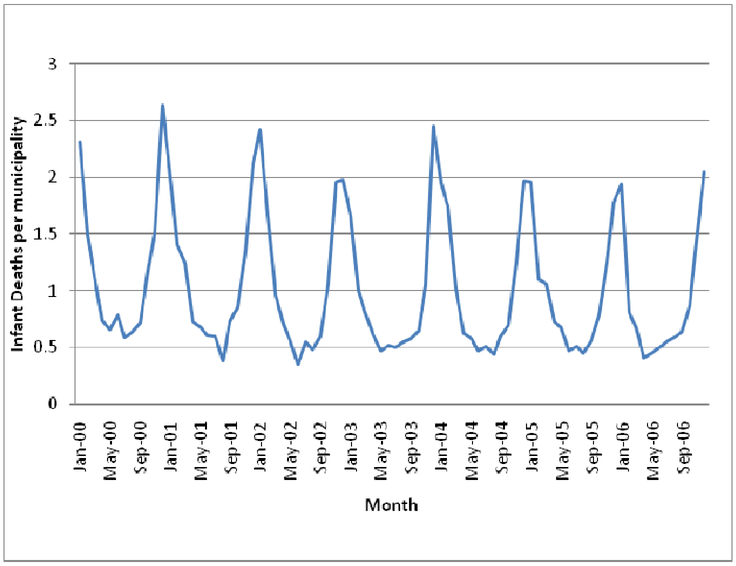



IV.3. Infant Mortality

The data on infant mortality is constructed from death certificate records over the period of January 1, 2001 through December 31, 2006 (the same period for which the satellite imagery data is available) held by the Mexican Statistics and Geography National Institute (Instituto Nacional de Estadística, Geografía en Informática, INEGI). It includes, for each municipality, all registered monthly deaths of children aged less than one, by cause of death. For this paper, the total numbers of deaths due to respiratory diseases and to external causes in each municipality in each month during the study's time frame were collected. As air quality is likely to have no effect on mortality due to external causes, the estimated coefficient of the impact of air pollution on this outcome is then expected to be close to zero.

Figure 3 shows the average number of registered infant deaths due to respiratory diseases per municipality in Mexico over the time period analyzed in this study. Perhaps not surprisingly, infant mortality levels due to respiratory diseases tend to increase during the winter.

**Figure 3. Infant Mortality due to Respiratory Diseases in Mexico.**




IV.4. Weather conditions

Weather conditions are likely to be correlated with air quality, but also have a direct impact on health outcomes. This is one of the potential explanations for the observed seasonality in infant mortality shown in Figure 3.

Weather data was obtained from the US National Climatic Data Center, which publishes the Global Surface Summary of Day Data. This database provides daily information from over 100 weather stations throughout Mexico. Monthly measures of the average temperature and dew point (in degrees Fahrenheit) were calculated for each of the weather stations. The mean monthly temperature and dew point assigned to each municipality are the estimated values from the interpolated data at each municipality's capital.

IV.5. Socio-Economic Characteristics

Given that power plants were installed throughout the Mexican territory, it will be possible to explore if baseline socio-economic conditions at the municipality level are correlated with higher or lower impacts of pollution on mortality. Information on the total population of individuals aged less than four, the percentage of the household heads participating in the labor force, the percentage of illiterate household heads, and the percentage of household heads earning less than one minimum wage as well a measure of the availability of primary health care facilities at the municipality level (the number of primary health facilities per 10,000 inhabitants) were obtained from the 2000 Mexican Census, administered by INEGI.

Descriptive statistics for the whole set of variables constructed for the analysis performed in this paper for the sample of municipalities in which at least one power plant was installed during the period analyzed are presented in Table 1.

**Table 1**

**Municipality Descriptive Statistics**

| | N | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Monthly Infant Deaths due to Respiratory Diseases (2000) | 102 | 1.24 | 1.85 | 0.00 | 9.67 |
| Monthly Infant Deaths due to External Causes (2000) | 102 | 0.58 | 0.72 | 0.00 | 4.58 |
| AOD in 2000 | 102 | 0.33 | 0.15 | 0.10 | 0.79 |
| Maximum Number of Power Plants (2006) | 102 | 2.26 | 2.19 | 1.00 | 10.00 |
| Average Temperature (in 2000) | 102 | 69.24 | 7.15 | 54.64 | 81.85 |
| Average Dew Point (2000) | 102 | 52.76 | 10.65 | 39.94 | 73.68 |
| Log of population with aged 4 or less (2000) | 102 | 9.97 | 1.19 | 6.86 | 12.08 |
| Primary Health Facilities per 10,000 inhabitants in (2000) | 102 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fraction of Household Heads that are unemployed (2000) | 102 | 0.00 | 0.00 | 0.00 | 0.02 |
| Fraction of Household Heads that are illiterate (2000) | 102 | 0.09 | 0.06 | 0.01 | 0.37 |
| Fraction of Household Heads earning < 1 minimum wage (2000) | 102 | 0.01 | 0.01 | 0.00 | 0.07 |

As can be seen, on average, there are 1.24 monthly infant deaths due to respiratory diseases in each municipality in our sample, and 0.58 deaths due to external causes. The average AOD level is 0.33, but varies considerably across municipalities, ranging from 0.10 to 0.79. On average, there is one primary health facility for every 10,000 inhabitants (this number varies greatly from 0.15 to 11per 10,000) , less than 0.5 percent of household heads do not participate in the labor force, 9 percent is illiterate and one percent earns less than one minimum wage. While our subsample of municipalities is surely not a random sample of all Mexican municipalities, it does show great variation in the observable baseline characteristics collected from the 2000 Mexican Census.

## V. Empirical Strategy

V.1.The installation of power plants and air pollution concentrations

The first objective of this paper is to estimate the impact that the installation of small-scale power plants had on local air quality. The empirical strategy employed to test for this relationship is close to a difference-in-differences approach, taking into account that: (1) power plants were installed at different points in time in different municipalities; and (2), in some municipalities, more than one power plant was installed during the time period analyzed. Assuming that the marginal effect that each power plant has on local air quality is constant on average, the effect of the installation of power plants on air quality is estimated by running the following regression:

$$poll_{it} = \alpha_i + \sum_t \gamma_t D_t + \beta(PP_{it}) + \sum_t \sum_j \partial_{jt} X_{ji} * D_t + \varepsilon_{it} \quad (1)$$

Where

$poll_{it}$ is the log of AOD for municipality $i$ in month $t$;

$\alpha_i$ are municipality fixed effects, included to control for the differences in levels of pollution across municipalities;

$D_t$ are $T$ month dummies. The $\gamma_t$ will then capture differences in the level of pollution across time;

$X_{ji}$ are a set of $J$ socioeconomic variables at the municipality level.[4] The $\partial_{jt}s$ will then control for differences in pollution levels across time in municipalities with different baseline socio-economic indicators;

[4] A dummy variable indicating if less than 30 percent of the population has access to formal health insurance, the log of total population in 1999, and the log of total infant deaths between 1990 and 1999.

$PP_{it}$ is a variable that measures the number power plants in operation in municipality *i* at time *t*;

$\varepsilon_{it}$ is an error term.

$\hat{\beta}$ is the main coefficient of interest, as it captures the relationship between the number of power plants operating in municipality $i$ in year $t$ and air quality. If positive, it should be interpreted as the increase in pollution levels in municipality *i* at the time when a small-scale power plant was installed.

An important underlying assumption for this identification strategy to be valid is that trends in pollution levels would not differ in the absence of the installation of these power plants between municipalities with and without power plants.  In order to explore if this assumption is plausible, we will present evidence of how sensitive this estimator is to the inclusion of the interaction between the month dummies and potentially relevant controls that could be related to differential trends in air pollution levels (and infant mortality) across municipalities.

In addition, this paper will estimate if the discrete increase in pollution levels effectively occurs at the time of the installation of power plants, by running a regression of the following form:

$$poll_{it} = \alpha_i + \sum_t \gamma_t D_t + \beta_1(PP_{it}) + \sum_{\tau=-2}^{2} \gamma_\tau \,(PP_{it+\tau}) + \sum_t \sum_j \partial_{jt} X_{ji} * D_t + \varepsilon_{it} \qquad (2)$$

Where

$PP_{it+\tau}$ are variables measuring the number power plants in operation in municipality *i* at time $t+\tau$.

If the increase in pollution levels can be effectively attributed to the date at which these power plants were installed, we expect to only observe a discrete difference in pollution levels at the time of their introduction. As the variable $PP_{it}$ measures the total number of power plants *in operation* in municipality *i* at time *t*, $\widehat{\gamma_2}$ will measure if the air pollution concentration levels changed significantly in municipalities where a power plant was installed between the third and second month prior to the installation of the plant; $\sum_{t=-t^*}^{2} \widehat{\gamma_t}$ will indicate if the change in pollution levels between three months and the $t^{th}$ month around the installation of the plant was different for those municipalities where the plant was installed. If the installation of the power plants implied a discrete increase in pollution concentrations, we would then expect $\widehat{\gamma_2}$ and $\widehat{\gamma_2} + \widehat{\gamma_1}$ to be not statistically different from zero, while $\widehat{\gamma_2} + \widehat{\gamma_1} + \widehat{\gamma_0}$, $\widehat{\gamma_2} + \widehat{\gamma_1} + \widehat{\gamma_0} + \widehat{\gamma_{-1}}$, $\widehat{\gamma_2} + \widehat{\gamma_1} + \widehat{\gamma_0} + \widehat{\gamma_{-1}} + \widehat{\gamma_{-2}}$ to be significantly different from zero and similar in magnitude to the estimated $\hat{\beta}$ in specification (1).

V.2. Heterogeneous impacts of the installation of power plants on air pollution.

Finally, in order to test for differential effects of air pollution in municipalities with different baseline socio-economic characteristics, it is first important to explore if the impact that the installation of the power plants have on air quality differs depending on these characteristics. For this purpose, we will run regressions of the following form:

$$poll_{it} = \alpha_i + \sum_t \gamma_t D_t + \beta_1(PP_{it}) + \beta_2(PP_{it}) * x_i + \sum_t \sum_j \partial_{jt} X_{ji} * D_t + \varepsilon_{it} \qquad (3)$$

Where the $x_i$'s are a set of baseline municipality-level characteristics. Our coefficients of interest in this case are $\widehat{\beta_1}$ and $\widehat{\beta_2}$. If the installation of power plants had a different effect on air quality for municipalities with different $x_i$, $\widehat{\beta_2}$ should be statistically different from zero. If not, this coefficient should be close to zero and $\widehat{\beta_1}$ should be similar in magnitude to the estimated $\hat{\beta}$ in specification (1).

V.3. Instrumental variables estimation.

Once having established the relationship between the installation of power plants and air quality, we will proceed to estimate the impact of air quality on infant mortality through an instrumental variables strategy. The general form of the estimated regression in this case is:

$$Mort_{it} = \alpha_i + \sum_t \theta_t D_t + \varphi(poll_{it}) + \sum_t \sum_j \pi_{jt} X_{ji} * D_t + \varepsilon_{it} \tag{4}$$

Where all variables are defined as previously and $Mort_{it}$ is the log of one plus the total number of registered infant deaths in municipality *i* in month $t$. $(poll_{it})$, as stated, will be instrumented with $(PP_{it})$, defined in section V.1. The estimated $\hat{\varphi}$ will measure the causal relationship between pollution levels and infant mortality in the setting analyzed.

When exploring if the effects of air quality on infant mortality are different for municipalities with different baseline characteristics, we will run the following specification, again, instrumenting $(poll_{it})$ with $(PP_{it})$.

$$Mort_{it} = \alpha_i + \sum_t \theta_t D_t + \varphi_1(poll_{it}) + \varphi_2(poll_{it}) * x_i + \sum_t \sum_j \pi_{jt} X_{ji} * D_t + \varepsilon_{it} \tag{5}$$

The coefficients of interest in this case will be $\hat{\varphi}_1$ and $\hat{\varphi}_2$. If the effect of air quality on infant mortality is different in municipalities with different $x_i$, $\hat{\varphi}_2$ should be statistically different from zero. If not, it should be close to zero and $\hat{\varphi}_1$ should be similar in magnitude to the coefficient $\hat{\varphi}$ for the estimation in equation (3).

## VI. Results

VI.1.The impact of power plants on air quality

Table 2 presents the results of the first stage equations (specification 1). Column 1 shows the result when only including time and municipality fixed effects. Column 2 includes weather controls; Column 3 adds the log of total population aged 4 or younger according to the 2000 Census interacted with month dummies  as controls. Column 4 additionally includes a variable indicating the number of primary health facilities per 10,000 inhabitants interacted with month dummies. Columns 5, 6 and 7, additionally control for the fraction of unemployed household heads, the fraction of illiterate household heads and the fraction of household heads earning less than 0.5 minimum wages interacted with month dummies, respectively.

Because the dependent variable in all specifications is the log of our measure of air quality, the estimated coefficients of the impact of the installation of a power plant can be interpreted as semi-elasticities. The installation of a power plant increases our measure of local air particulate matter concentrations in 1.8 to 2.1 percent. The little variation across specifications suggests that the impact is robust to the inclusion of relevant controls that may have a direct relationship with the observed trends in air quality within municipalities, regardless of the installation of power plants. Appendix Table 1 shows that the found relationship is robust to the inclusion of municipality-specific time trends.

**Table 2: Relationship between Installation of Power Plants and Pollution Levels**

**Dependent Variable: Log AOD**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Number of Power plants | 0.0214*** | 0.0210*** | 0.0187*** | 0.0180*** | 0.0180*** | 0.0179*** | 0.0176*** |
| | [0.00447] | [0.00449] | [0.00525] | [0.00532] | [0.00537] | [0.00566] | [0.00556] |
| Constant | -0.338*** | -2.252*** | -5.030*** | -3.773*** | -5.536*** | -5.418*** | -4.699*** |
| | [0.0469] | [0.255] | [0.548] | [0.929] | [1.067] | [1.197] | [1.628] |
| Municipality Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Weather Controls | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population aged 4 and younger | No | No | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with access to primary health facilities | No | No | No | Yes | Yes | Yes | Yes |
| Differential trends by unemployed Household Heads | No | No | No | No | Yes | Yes | Yes |
| Differential trends by illiterate Household Heads | No | No | No | No | No | Yes | Yes |
| Differential trends by Household Heads earning less than 0.5 MW | No | No | No | No | No | No | Yes |
| Observations | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 |
| R squared | 0.694 | 0.709 | 0.714 | 0.721 | 0.725 | 0.733 | 0.745 |

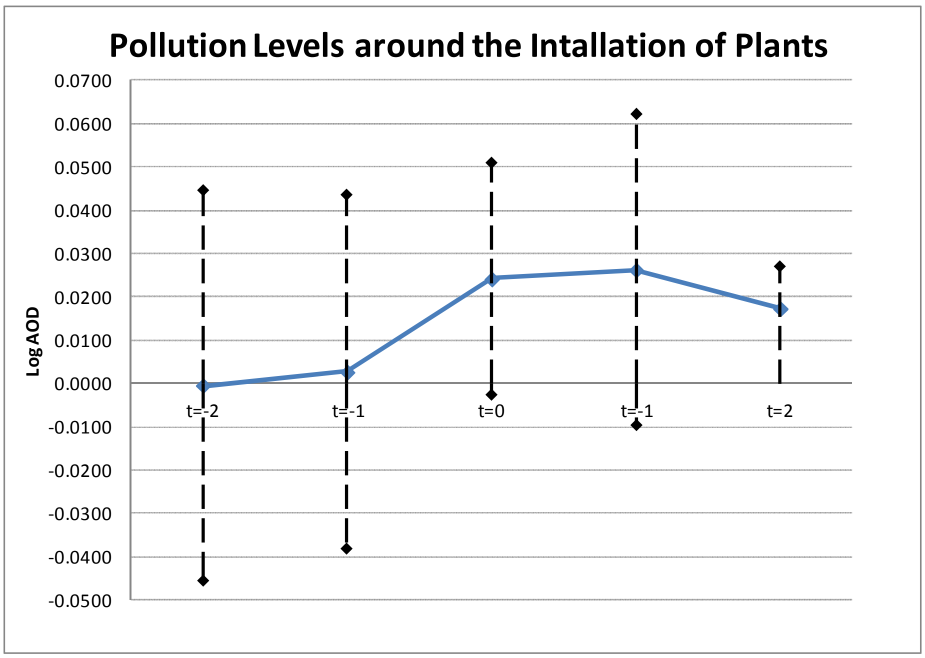
Robust standard errors clustered at the municipality level in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

VI.2. Timing of the Change in Air Quality

Figure 4 presents the estimated sum of coefficients for the regression specified in equation (2), including all the controls in Table 2, Column 7. The first plotted coefficient should be interpreted as the difference in log AOD levels between three and two months prior to the introduction of a power plant; the second as the difference in log AOD between three and one month prior to the installation of the plant. The third is the change in log AOD at the time of the installation of the power plant (with respect to three months before its installation); while the next two coefficients measure the difference in pollution levels between three months prior and one and two months after the installation of a power plant, respectively.

**Figure 4**




The blue dots measure the sum of the γ coefficients in equation (2) up to period t.
90% Confidence intervals are also reported.

As can be seen, no differential significant changes in log AOD levels are observed for municipalities where the power plants were installed one or two months before the installation of the plants. In contrast, the estimated increase in log AOD at the date at which the power plants were installed remains positive and similar in magnitude for the two months after the installation of the plant. This result suggests that the increase in particulate matter concentrations indeed occurred at the time of the installation of the power plants.

VI.3. Impact on infant mortality

Table 3 presents the two stages least squares instrumental variables estimates of the impact of air quality on infant mortality due to respiratory diseases. Each Column includes the controls in the corresponding Columns in Table 2. The dependent variable is equal to the log of one plus the total number of infant deaths due to respiratory diseases in each municipality. We can then roughly interpret the estimated coefficients as the elasticity of infant mortality due to respiratory diseases with respect to changes in local air quality. As can be seen, the estimated coefficient ranges from 0.58 to 0.84. This suggests that an increase in our measure of air quality in one percent implies an increase of  0.58-0.84 percent in infant deaths due to respiratory diseases. Column 8 shows the OLS estimate of the relationship between the log of AOD the same outcome, showing that, when using instrumental variable techniques, the impact of air quality on infant mortality is significantly higher than the traditional OLS estimates presented here and in other studies (Gutierrez, 2010).

Our estimates are consistent with other studies' findings for different contexts. Chay and Greenstone (2003), for example, found that a 1% percent decline in TSP measures translates into 0.5% decline in infant mortality rate in the United States; Tanaka found that a 1% decline in TSP reduced infant mortality rates in 0.95% (2010) for the Chinese context.

Finally, as a specification test, the relationship between air pollution levels and infant mortality due to external causes is presented in Table 4. All Columns include the same controls as the corresponding Column in Table 3. The estimated coefficient varies greatly and is insignificantly different from zero across specifications. As expected no significant relationship is found between AOD levels and infant deaths due to external causes.

**Table 3: Relationship between Log AOD and Infant Mortality**
**Dependent variable: Log Infant Mortality by Respiratory Diseases**

| | Respiratory Diseases | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IV | IV | IV | IV | IV | IV | IV | OLS |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Log AOD | 0.581** | 0.539** | 0.830** | 0.844** | 0.842** | 0.763* | 0.784* | 0.0394** |
| | [0.288] | [0.297] | [0.379] | [0.405] | [0.414] | [0.406] | [0.415] | [0.0180] |
| Constant | 2.157** | 2.916** | 3.907** | 4.191** | 4.203** | 3.753* | 3.887* | 0.440 |
| | [0.898] | [1.434] | [1.818] | [2.052] | [2.130] | [2.095] | [2.184] | [1.383] |
| Municipality Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Weather Controls | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population aged 4 and younger | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with access to primary health facilities | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Differential trends by unemployed Household Heads | No | No | No | No | Yes | Yes | Yes | Yes |
| Differential trends by illiterate Household Heads | No | No | No | No | No | Yes | Yes | Yes |
| Differential trends by Household Heads earning less than 0.5 MW | No | No | No | No | No | No | Yes | Yes |
| Observations | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 |
| R-squared | 0.503 | 0.504 | 0.424 | 0.423 | 0.431 | 0.475 | 0.477 | 0.632 |

Robust standard errors clustered at the municipality level in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

**Table 4: Relationship between Log AOD and Infant Mortality**
**Dependent variable: Log Infant Mortality due to External Causes**

| | External Causes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IV | IV | IV | IV | IV | IV | IV | OLS |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Log AOD | -1.003 | -0.939 | -0.585 | -0.224 | -0.4 | -0.19 | -0.175 | 0.0794*** |
| | [1.022] | [0.938] | [0.820] | [0.242] | [0.493] | [0.534] | [0.404] | [0.0284] |
| Constant | -2.705 | -3.111 | -1.089 | -0.848 | -0.778 | 0.775 | -0.242 | -5.182 |
| | [2.710] | [3.871] | [3.418] | [1.136] | [1.674] | [2.481] | [2.284] | [6.031] |
| Municipality Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Weather Controls | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population aged 4 and younger | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with access to primary health facilities | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Differential trends by unemployed Household Heads | No | No | No | No | Yes | Yes | Yes | Yes |
| Differential trends by illiterate Household Heads | No | No | No | No | No | Yes | Yes | Yes |
| Differential trends by Household Heads earning less than 0.5 MW | No | No | No | No | No | No | Yes | Yes |
| Observations | 2,319 | 2,319 | 2,319 | 2,319 | 2,319 | 2,319 | 2,319 | 2,319 |
| R-squared | . | . | 0.13 | 0.309 | 0.277 | 0.364 | 0.402 | 0.426 |

Robust standard errors clustered at the municipality level in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

### VI.4. Heterogeneous Effects

The nature of the source of exogenous variation in air particulate matter concentrations exploited in this paper allows us to test for heterogeneous effects of air quality related to different base-line socio-economic conditions at the municipality level. As shown in Table 1, socio-economic characteristics vary greatly across the municipalities where the power plants were installed.

As it seems particularly relevant to explore if the adverse effects of air quality may be mitigated by the presence of primary health care facilities, or exacerbated by lower income and education levels, this section explores these possibilities. It is perhaps worth noting that, for this analysis, while we exploit a source of exogenous variation in air quality, we are not exploiting exogenous variation in socio-economic characteristics. The extent to which these characteristics may be correlated with other municipality-level characteristics does not allow us to interpret the calculated impacts as the causal effect of these indicators on the impact of air quality.

The results presented in this sub-section should then be taken only as suggestive evidence of the potential impacts that these baseline socio-economic characteristics may have on the impact of air quality on infant health.

For ease of interpretation of the estimates presented in this section, we define a binary classification for municipalities based on the different socio-economic characteristics for which we collected information. In particular, we construct four dummy variables taking value of one if the number of primary health care facilities per 10,000 inhabitants, the fraction of household heads not participating in the labor force, the fraction of illiterate household heads, and the fraction of household heads earning less than one minimum wage in each municipality is higher than the median for the municipalities in our sample, and interact them with the variable indicating the number of power plants in operation in each municipality in each time period (equation 3), and with the AOD measure (equation 5).

In specification (3), the interaction between each of these dummy variables and the variable indicating the number of power plants in operation in each municipality at time t will measure if the effect of the installation of these plants differ significantly in municipalities where these variables take value of one with respect to those where it takes value of zero. This analysis will, on one hand, provide evidence on the effect of the installation of power plants varies across municipalities in our sample. On the other, it will test if an instrumental variables analysis is possible to estimate the relationship between air pollution and health outcomes for municipalities that differ in these characteristics. In particular, the instrumental variables estimators will only be valid if the number of power plants installed in each municipality predicts air pollution levels both in municipalities where these variables take value of zero and in those where it takes value of one.

The results for the specification described in equation 3, measuring if the impact of the installation of these small scale power plants has a differential impact on air quality in municipalities where these dummy variables take value of one are presented in Table 5. All Columns include all controls specified in Table 2, Column 7. Column 1 includes the interaction between the variable indicating the number of power plants in operation and the dummy variable taking value of one if the number of primary health care facilities per 10,000 inhabitants is higher than the median for our sample; Column 2 includes the interaction of the number of power plants with the dummy indicating if the fraction of household heads not participating in the labor force is higher than the sample median; Column 3 interacts the number of power plants with the variable that indicates if the fraction of illiterate household heads exceeds the sample median; Column four shows the interaction of the number of power plants and the dummy indicating if the fraction of household heads earning less than1 minimum wage is higher than the sample median; and, finally, Column 5 includes all interactions in the same regression.

As can be seen, no differential effects of the installation of the power plants on air quality are observed in municipalities with different socio-economic characteristics, as defined previously (the coefficients for all interactions throughout specifications are close to zero and insignificant). These results allow us to the estimate equation 5, and explore if the impacts of particulate matter concentrations differ significantly for municipalities with different baseline socio-economic characteristics.

**Table 5: Relationship between Installation of Power Plants and Pollution Levels including Interactions**
**Dependent variable: Log AOD**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Number of Power plants | 0.0184*** | 0.0172*** | 0.0194*** | 0.0201*** | 0.0203*** |
| | [0.00639] | [0.00543] | [0.00559] | [0.00598] | [0.00632] |
| Number of Power plants*Access to clinics | -0.0021 | | | | 0.00081 |
| | [0.00706] | | | | [0.00702] |
| Number of Power plants*HH No Labor Force Participation | | 0.00248 | | | 0.00258 |
| | | [0.00892] | | | [0.00895] |
| Number of Power plants*HH No Education | | | -0.0121 | | -0.0118 |
| | | | [0.0106] | | [0.0102] |
| Number of Power plants*HH's income < 0.5 M.W. (Minimum Wage) | | | | -0.00496 | -0.0034 |
| | | | | [0.00740] | [0.00758] |
| Constant | -4.701*** | -4.709*** | -4.681*** | -4.698*** | -4.691*** |
| | [1.626] | [1.626] | [1.626] | [1.627] | [1.621] |
| Municipality Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Month Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Weather Controls | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with 4 years or less | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with access to clinics | Yes | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH has no job | Yes | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH has no education | Yes | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH earns < 0.5 M.W. | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 |
| R-squared | 0.745 | 0.745 | 0.746 | 0.745 | 0.746 |

Robust standard errors clustered at the municipality level in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

The results of the instrumental variable analysis for the impact of air particulate matter on infant mortality due to respiratory diseases, exploring if the effect differs by municipality's socio-economic characteristics are presented in Table 6. All regressions include all controls as those presented in Table 2, Column 7. Each Column interacts the measure of AOD with the dummy variable with which the measure of the number of installed power plants is interacted in the corresponding Column in Table 5.

**Table 6: Relationship between Log AOD and Infant Mortality including Interactions**
**Dependent variable: Log Infant Mortality by Respiratory Diseases**

| | Respiratory Diseases | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Log AOD | 0.984** | 0.870* | 0.661 | 0.833* | 1.205* |
| | [0.426] | [0.453] | [0.481] | [0.428] | [0.656] |
| Log AOD*Access to clinics | -0.656** | | | | -0.815** |
| | [0.330] | | | | [0.399] |
| Log AOD*HH No Labor Force Participation | | -0.130 | | | -0.333 |
| | | [0.292] | | | [0.403] |
| Log AOD*HH No Education | | | 0.482 | | 0.346 |
| | | | [0.316] | | [0.271] |
| Log AOD*HH's income < 0.5 M.W. (Minimum Wage) | | | | -0.113 | -0.0941 |
| | | | | [0.257] | [0.276] |
| Constant | 2.501 | 4.157* | 5.072** | 3.773* | 3.612 |
| | [2.682] | [2.240] | [2.184] | [2.200] | [2.822] |
| Municipality Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Month Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Weather Controls | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with 4 years or less | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with access to clinics | Yes | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH has no job | Yes | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH has no education | Yes | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH earns < 0.5 M.W. | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 |
| R-squared | 0.458 | 0.465 | 0.404 | 0.482 | 0.384 |

Robust standard errors clustered at the municipality level in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

Column 1 suggest that the adverse effects of air pollution on infant mortality due to respiratory diseases are highly concentrated in municipalities with low access to primary health facilities. Columns 2 and 4 suggests that the adverse effects of air particulate matter on infant health are lower in municipalities where more household heads participate in the labor force and fewer household heads earn less than one minimum wage, although the coefficients on the interactions are not statistically different from zero. Column 3 suggests that the impact of air pollution is higher in municipalities with a higher fraction of illiterate household heads, although, again, the coefficient on the interaction is not significantly different from zero (the sum of the coefficient associated with Log AOD and its interaction with the dummy indication if the fraction of illiterate household heads is higher than the median is significantly different from zero). Finally, Column 5 suggests that all these relationships hold when including all interactions in the same specification.

Strong evidence is the found suggesting that the presence of primary health facilities is related to lower impacts of air pollution concentrations. While the sign of the rest of the coefficients is consistent with the hypothesis that lower income and education levels are likely to contribute to exacerbate the effects of pollution on health, their impact is not as high or has the statistical significance that the presence of primary health care facilities seems to have on the mitigation of these effects. While preliminary, these results suggest that the expansion of basic health services in developing countries' settings may have strong positive impacts on their population's health status.

## VII. Conclusions

This paper is among the first to exploit an arguably exogenous source of variation in air pollution levels -the installation of small-scale power plants- to measure the relationship between pollution and infant mortality across the Mexican territory. The relevance of the study relies on the fact that, for middle-income countries, lower income, nutrition levels and lower access to health services may exacerbate the negative impacts of pollution on health. Using a unique dataset including detailed measures of pollution concentrations in the atmosphere, the paper exploits the discrete change in pollutant concentrations induced by the installation of power plants to isolate the causal impact of pollution on infant mortality. The estimated elasticity for changes in air pollution measured from satellite imagery and infant mortality due to respiratory diseases ranges from 0.58 and 0.84, more than ten times higher than the OLS estimate. The effect is significantly lower in municipalities with a high presence of primary health facilities, and does not vary significantly by average income and education levels. While preliminary, these results suggest that the expansion of basic health services in developing countries' settings may have strong positive impacts on their population's health status. No significant relationship is found between pollution levels and mortality due to external causes.

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## Appendix Table 1

**Appendix Table 1: Relationship between Installation of Power Plants and Pollution Levels**

**Dependent Variable: Log AOD**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Number of Power plants | 0.0189** | 0.0209*** | 0.0175** | 0.0169** | 0.0183** | 0.0165* | 0.0158* |
| | [0.00757] | [0.00747] | [0.00823] | [0.00808] | [0.00782] | [0.00840] | [0.00808] |
| Constant | -1.133*** | -2.862*** | -3.849*** | -5.410*** | -5.373*** | -5.593*** | -5.632*** |
| | [0.0975] | [0.271] | [0.865] | [0.848] | [0.894] | [0.642] | [0.493] |
| | | | | | | | |
| Municipality Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipality Specific Linear Time Trends | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Weather Controls | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with 4 years or less | No | No | Yes | Yes | Yes | Yes | Yes |
| Differential trends by population with access to clinics | No | No | No | Yes | Yes | Yes | Yes |
| Differential trends by homes where HH has no job | No | No | No | No | Yes | Yes | Yes |
| Differential trends by homes where HH has no education | No | No | No | No | No | Yes | Yes |
| Differential trends by homes where HH earns < 1 M.W. | No | No | No | No | No | No | Yes |
| | | | | | | | |
| Observations | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 | 8,010 |
| R-squared | 0.7 | 0.715 | 0.719 | 0.727 | 0.731 | 0.738 | 0.75 |

Robust standard errors clustered at the municipality level in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%