Discussion Paper Series
No. 1201
Jan 2012

# Does Air Pollution Matter for Low Birth Weight?

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Does Air Pollution Matter for Low Birth Weight?

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January 12, 2012

**ABSTRACTS**

There is growing concern that air pollution may impact the health of newborns. This study examines this issue by considering overtime variation generated by exogenous changes in the pollution level in Korea in early 2000, when some part of Korea experienced huge drop in air pollution. We matched the census of all births from 1998 to 2008 and air pollution data in mother's residence county level. For air pollutants, we considered carbon monoxide, nitrogen dioxide, particulate matter, sulfur dioxide, and ozone levels. The mother's exposure to one ozone level above 0.12 ppm per hour during the first trimester increased the probability of low birth weight by 0.4 percentage point (0.08% of the sample mean). On the other hand, the mother's exposure to carbon monoxide or sulfur dioxide during the third trimester led to a significant but modest increase in the probability of low birth weight. The results indicate that the effects of an air pollutant on the probability of low birth weight vary according to when the mother is exposed to the pollutant during the pregnancy.

Keywords: Air Pollution, Ozone, Carbon Monoxide, Sulfur Dioxide, Nitrogen Dioxide, Low Birth Weight

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## 1. INTRODUCTION

Currie (2011) suggested that air pollution is one of the main sources of health inequalities at birth. Less educated individuals are more likely to be exposed to air pollution, which in turn has considerable influence on their children's future outcomes such as educational attainment and future earnings. Previous studies have provided limited evidence of this causal relationship. Chay and Greenstone (2003) found that the Clean Air Act of 1970 and recessions led to sharp exogenous reductions in air pollution and that these reductions led to four to eight fewer infant deaths per 100,000 live births. However, air pollution may not have a linear relationship with health outcomes. That is, the effects of air pollution on health outcomes may vary according to the level of pollution. Korea experienced rapid economic growth over the last three decades, but at the same time, pollution has become a serious issue. Figure 1 provides a comparison of air pollution levels across major cities in Korea and the U.S. (World Bank, http://siteresources.worldbank.org/DATASTATISTICS/Resources/table3_13.pdf).[1] The level of particulate matter ($PM_{10}$) and that of sulfur dioxide ($SO_2$) in Korean cities were approximately two to four times higher than those in U.S. cities. However, the level of

[1] The U.S. and Korea use different measures of air pollution. The U.S. uses the following measures: (http://www.epa.gov/airtrends/interpret.html)
Carbon Monoxide Annual 2nd maximum 8-hour average
Nitrogen Dioxide Annual arithmetic average
Ozone (8-hour) Annual 4th maximum 8-hour average
PM10 Annual 2nd maximum 24-hour average
Sulfur Dioxide Annual arithmetic average
Korea measures air pollution every five minutes and calculates arithmetic averages for hourly, monthly, and annual statistics after excluding those days that do not record more than eight hours. Thus, it is difficult to make a direct comparison.

nitrogen dioxide ($NO_2$) was slightly higher in U.S. cities.[2] Most of the previous studies of air pollution have focused on the U.S.[3]

A comparison of air pollution levels between Korean cities and various cities in the U.K. and Australia is helpful because these countries employ the same measures of air pollution (Figure 2). The first chart compares the ozone ($O_3$) level across major cities in the three countries. The $O_3$ level was highest in cities in Australia. The $O_3$ level was higher in Australia because the ozone hole is near the South Pole (http://www.bbc.co.uk/news/science-environment-13161265). The other charts compare the annual levels of $NO_2$, $SO_2$, and $PM_{10}$. In terms of these air pollutants, Korean cities showed the highest levels of air pollution, followed by those in the U.K. and Australia except the level of carbon monoxide, which was higher in Australia than in the U.K.

Therefore, given the possibility of a nonlinear relationship between air pollution and health, it may be interesting to examine the causal relationship between air pollutants and health outcomes in high-pollution countries such as Korea. In addition, Korea has implemented several laws to improve air quality, particular in the last several years. The Air Quality Improvement Act of 2002 reduced the allowed level of pollution from diesel-powered public transit buses by half.[4] To meet the higher standards, local

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[2] Every air pollutant is measured in micrograms per cubic meter, which can be converted into concentrations in ppm through the following equation: PPM= ((micrograms per cubic meter concentration * 22.4136 * (temperature in °C + 273.15)* (760) / (molecular weight * 273.15 * atmospheric pressure in mmHg (use 760 if unsure) / 1000)).

[3] Among the 25 studies reviewed by Currie et al. (2009), 21 were for the U.S., 3 were for Canada, and 1 was for the U.K.

[4] The allowed change in the level of particulate matter from 0.2 g/kW H to 0.1 g/kW/H was expected in 2000 but was delayed for two years.

governments have started to replace diesel buses with buses powered by natural gas. Motor vehicles, particularly diesel vehicles, are the main causes of high concentrations of respirable suspended particulates (RSPs) and nitrogen oxides (NOx) at the street level (http://www.epd.gov.hk/epd/english/environmentinhk/air/air_maincontent.html), The government created a new agency called the "Department of Metropolitan Air Quality" in 2005 to improve air quality in the Seoul metropolitan area. Some local governments have been more proactive than others. These situations have led to exogenous variations in the level of air pollution over time. Figure 3 shows different trends in air pollution level over time by region.

This study examines the health of newborns as an outcome, following previous research. The study contributes to the literature in the following ways: First, the study considers a large number of observations by using census data on all births in Korea for the 1998-2008 periods, which allows high precision. Second, Korea provides a unique opportunity for examining the relationship between air pollution and health. Korea is a highly polluted country, but the level of pollution has declined sharply in recent decades because of the implementation of various laws. Third, to minimize omitted-variable bias, which is a common issue in cross-sectional studies, this study employs a county fixed effects model that uses variations within a county over time.

The rest of this paper is organized as follows: Section 2 provides a literature review, and Section 3 discusses the data and the model. Section 4 presents the results, and Section 5 concludes.

## 2. LITERATURE REVIEW

The relationship between pollution and health has received considerable attention from the public since the Great Smog of 1952 in London. In February 1953, Lieutenant Colonel Lipton suggested at the House of Commons that the smog caused 6,000 deaths and that 25,000 claimed sickness benefits in London during that period. (http://hansard.millbanksystems.com/commons/1953/feb/16/nutty-slack). Since then, a number of studies have examined the relationship between pollution and health. However, most have considered cross-sectional variations to identify the model by comparing high-pollutant areas with low-pollutant ones (Bobak, 2000; Dejmek et al., 1999; Wang, Ding, Ryan & Xu, 1997; Alderman et al., 1987).

In the absence of randomized trials, however, it is difficult to analyze the causal relationship between pollution and health outcomes. There are two possible concerns regarding omitted-variable bias. Individuals tend to sort into the place they live. For example, those with a high level of income or strong preferences for clean air are likely to choose better living environments, and thus, clean air quality may be reflected in house prices, as indicated in Chay and Greenstone (2003). Thus, with this not controlled for, the effects of pollution may be overstated. Studies considering cross-sectional variations are likely to be affected by this problem. In addition, high-income individuals are likely to have better prenatal care and inputs for the fetus. On the other hand, pollution levels tend to be higher in urban areas, which are likely to have more educated individuals and better access to health care. Thus, this can lead to the underestimation of the true effects of pollution on health (Currie & Walker, 2011).

To overcome these limitations several studies of air pollution in the U.S. have used over time variation within geographic area by using fixed effect model to address this omitted-variable bias (Currie & Walker, 2011, Chay & Greenstone, 2003). However, it is not difficult to imagine a nonlinear relationship between the pollution level and adverse health outcomes. The level of pollution is substantially higher in Korea than in the U.S., and thus, it should be interesting to examine this relationship in Korea. Three studies considered the case of Korea, but all these studies employed cross-sectional variations using short sample periods (two to four years) (Ha et al., 2001; Lee et al., 2003; Cho et al., 2007). In this regard, the present study is the first to employ variations in the pollution level over time within a county in Korea. In addition, unlike previous studies considering Korea, which have typically focused only on Seoul, the present study considers the entire country. By doing so, this study has an advantage over previous studies in terms of considering more variations in the model and a larger sample size.[5]

Another issue in previous studies is that they have generally restricted the sample to full-term births (Ha et al., 2001; Lee et al., 2003). Air pollution, however, is likely to influence the gestation period. Therefore, restricting the sample to 37 weeks and over makes the data as selective sample. We also will restrict the sample but it is due to lower measurement error in the data.[6] For example, a gestation period exceeding 42 weeks is rare based on current practices, because pregnant women are not likely to wait more than two weeks after the due date (http://www.mayoclinic.com/health/inducing-labor/PR00117). The existence of gestation longer than 42 weeks are measurement errors since it is computed later based on the last period. In addition, a gestation period less than 20 weeks is not likely, and thus, this study excludes such observations.[7]

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[5] In cross-sectional studies with selective sorting, heterogeneity may be a concern, but the identification of the present study's model of county fixed effects does not depend on this variation.

[6] The results are robust to this restriction.

[7] These observations accounted for less than 0.3% of the sample.

## 3. DATA

The number of monitoring stations in Korea, which monitor air pollution every five minutes, increased over the sample period.[8] The National Ambient Air Information System collects the data, and the National Institute of Environmental Research (NIER) compiles and stores them in a database. In this study, we employed monthly data from each monitoring station and aggregated them at the county (gu in Korean) level.[9] Thus, we considered a total of about 230 counties in Korea.

The other major source of data was the Natality Detail File in Korea from 1997 to 2008, which included census data on all births in Korea. The Natality Detail File (individual-level data) is maintained to issue birth certificates and has the most complete and detail information on all births in Korea. In addition, it provides the demographic characteristics of the mother (i.e., age, the education level—no education, elementary school, middle school, high school, college, and graduate school and over—and the county of residence), information on newborns (i.e., gender, the gestation period, and the birth order, and singleton). We merged the data from monitoring stations with the data from the Natality Detail File at the county level. We excluded Korean newborns born outside Korea because they were not exposed to pollution in Korea.[10]

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[8] The number of stations increased from 128 in 1998 to 230 in 2008. This increase was not random, and less populated areas were included in later years. However, the results are robust to this increase.

[9] In general, there was one monitoring station in every county. A few counties had two or three stations. In such a case, we employed the average pollution level for the county's multiple stations.

[10] The natality data contained the mother's place of residence. Because an individual's actual exposure to air pollution may depend on the location where the individual spends the greatest amount of time, we employed the place of residence as the proxy for the location of pollution exposure.

### 3.1. NEWBORNS' EXPOSURE TO AIR POLLUTION

We measured newborns' exposure to air pollution as follows: We identified the month and year of each birth in the Natality data.[11] Following previous research, we measured pollution exposure during four periods: during the last month of pregnancy, during the third trimester, during the first trimester, and during the first month of pregnancy. The average gestation period was 39 weeks (Table 1), and thus, for a baby born in October 2000, for example, we measured its exposure to air pollution by calculating the amount of air pollution for September (the last month) as well as for July, August, and September (the third trimester). Based on the average gestation period of 39 weeks, we estimated that the newborn was conceived in January. As a result, January, February, and March represented the first trimester, and January was the first month of pregnancy.

### 3.2. INDEPENDENT VARIABLES

We considered five air pollutants widely considered in previous studies: CO, $NO_2$, $PM_{10}$, $SO_2$, and $O_3$. For $O_3$, the Environmental Protection Agency warned that inhaling ground-level $O_3$ can result in the induction of respiratory symptoms, decrements in lung functions, and inflammation in the airway (http://www.epa.gov/apti/ozonehealth/population.html). The health outcome of the newborn may be influenced by these pollutants. We measured $O_3$ as its concentration per hour.[12] We constructed a binary variable coded as 1 if the $O_3$ level exceeded 0.12

[11] The natality data did not provide exact dates of birth.

[12] Korea had no public warning system until 2008. Therefore, behavioral responses to warnings were not a concern in the analysis. Current public warning has three levels.

ppm per hour. Therefore, we employed this measure of $O_3$ to determine how many days the $O_3$ level exceeded 0.12ppm per hour during a particular period (the last month of pregnancy, the third trimester, the first trimester, or the first month of pregnancy).

The other independent variables were the demographic characteristics of the mother (i.e., age, the education level, and the county of residence), the characteristics of pregnancy (i.e., gender, singleton, and the birth order), and the seasonal effect.

### 3.3. DEPENDENT VARIABLES

We considered low birth weight (defined as birth weight less than or equal to 2,500 grams at birth) as the main outcome variable. Low birth weight has been widely used for the evaluation of public policies, and a number of studies have employed it as an outcome variable (Currie & Cole, 1993). Because an early delivery may be an outcome of pollution exposure, we also considered the gestation period as another dependent variable.

### 3.3. ECONOMETRIC MODEL

We considered the following econometric model:

$$Y_{ijt}=\beta_0+\beta_1 * \text{ airpollutant}_{jt}+\beta 2 * X_{ijt}+r_{ijt} \quad (1)$$

where Y indicates low birth weight for baby i residing in county j and born at time t (measured by the delivery month); airpollutant is pollution exposure; and X captures demographic characteristics, pregnancy characteristics, and seasonal effects. This model uses cross-sectional variations as well as variations over time. However, health

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The lowest level is “advisory,” which is announced when the ozone level above 0.12 ppm. The next level is “warning” (an ozone level above 0.3 ppm), and the highest level is “severe warning” (an ozone level above 0.5 ppm).

outcomes may be influenced by unobserved time-invariant characteristics for each county. For example, the stress level in a metropolitan county may be very different from that in a rural county. In addition, healthcare facilities may vary widely across counties, although they may not change much over time. To address this unobserved factors we employed the following fixed effects model:

$$Y_{ijt}=\beta_0+\beta_1 * \text{airpollutant}_{jt}+\beta 2 * X_{ijt}+\alpha_j+ r_{ijt} \qquad (2)$$

The county fixed effect of $\alpha_j$ is added in Model 2.

In the model, we considered variations within counties and over time. Figure 2 shows substantial variations in the pollution level over time and within the same state, which was aggregated from county to ensure enough variations for the model.[13]

**4. RESULTS**

As shown in Table 1, 5% of newborns had low birth weight. The average level of carbon monoxide was 0.73 ppm and mean $NO_2$ and $SO_2$ levels were 29 ppb and 6 ppb, respectively. The average level of $PM_{10}$ was 60 ug/L. On average, the number of times per month the $O_3$ level exceeded 0.12 ppm per hour was 0.08.

Table 2 shows the effects of exposure to air pollution during the first trimester on low birth weight. There were approximately 2.4 million births during the sample period (11 years). The first column shows the estimation of Model 1 and the effects of the $O_3$ level (the number of times per month the $O_3$ level exceeded 0.12 ppm per hour during first trimester) on low birth weight. We considered a linear probability model. Because the estimates came out at the fourth or fifth decimal place, we adjusted the

[13] The aggregation might average out the variations, but we show the state-level results for presentation purposes.

scale by multiplying the coefficient and the standard error by 1,000. The results indicate that additional exposure to the $O_3$ level above 0.12 ppm per hour reduced the probability of low birth weight by 0.4 percentage point. The second column considers the county fixed effects (Model 2). There were slight increases in the estimates, and every additional exposure to the $O_3$ level above 0.12 ppm per hour reduced the probability of low birth weight by 0.5 percentage point, which was 6.7% of the sample mean (0.05). Considering only the variations over time increased the effects of pollutants by approximately 33%, which was not a small increase. The third column considers the county fixed effects model with standard errors clustered at the county level. Individual errors within a county may remain correlated even after taking into account county fixed effects because of unobserved common factors. To address this issue, we clustered standard errors at the county level. As a result, the standard errors increased by 65%, but it remained significance.

Air pollutants may be correlated with one another, that is, various air pollutants may coexist in the air in one location. Thus, we included all the air pollutants in the model. As shown in Table 3, we estimated the effects of each air pollutant separately except the last column that shows the results from including all the air pollutants in the same model. The last column results indicate no substantial changes in the estimates except for $SO_2$ compared to considering each pollutant separately. However, $SO_2$ was insignificant in both the one-pollutant model (4) and the all-pollutant model (6). The $O_3$ level above 0.12 ppm per hour had significant negative effects on low birth weight across different specifications. However, $NO_2$ provided counter-intuitive results: Every one standard deviation increase in the $NO_2$ level reduced the probability of low birth weight by 0.21 percentage point, which was 4.1% of the sample mean (0.049). The other pollutants ($PM_{10,}$ $SO_2$, and CO) had no significant effects on low birth weight.

Previous studies have produced mixed results for the effects of air pollution on the health of newborns depending on the time of exposure. In this study, we measured the mother's exposure to air pollution during four periods (during the last month of pregnancy, during the third trimester, during the first trimester, and during the first month of pregnancy). Table 4 shows the results for a model with all air pollutants and standard errors clustered at the county level. The first column shows the results for exposure during the first trimester, which correspond to the results in Table 3. The second column shows the results for exposure during the first month, and the third and fourth columns show the results for exposure during the third trimester and the last month, respectively.

As shown in the first column, additional increase in the $O_3$ level above 0.12 ppm per hour increased the probability of low birth weight by 0.4 percentage point. However, every one standard deviation increase in the $NO_2$ level reduced the probability of low birth weight by 0.02 percentage point, which was negligible in magnitude. The other pollutants had no significant effects on low birth weight. The mother's exposure to air pollution during the first month was lower than that during the first trimester except for $SO_2$.

The results for the third trimester and the last month show different patterns to the first trimester. $O_3$ and $NO_2$ had no significant effects on low birth weight, but $SO_2$ and CO did. Every one standard deviation increase in the CO and $SO_2$ levels increased the probability of low birth weight by 0.06 percentage point and 0.09 percentage point, respectively. $PM_{10}$ provided counter-intuitive results, but its effects were slightly weaker. Every one standard deviation increase in the $PM_{10}$ level reduced the probability of low birth weight by 0.08 percentage point for the third trimester and 0.03 percentage point for the last month.

Table 5 shows the results based on the gestation period as an outcome. One mechanism underlying changes in birth weight may work through the gestation period because a baby needs time to grow in the uterus. Every one standard deviation increase in the $SO_2$ and CO levels during the first trimester increased the gestation period by 0.021 week and 0.069 week, respectively, which is less than a day (i.e., a small increase). Every one standard deviation increase in the $O_3$ level above 0.12 ppm per hour during the first trimester reduced the gestation period by 0.017 week. The third and fourth columns show the results for the mother's exposure to air pollution during the last trimester and the last month, respectively. These results generally show similar patterns, but the estimates for the last month were smaller than those for the last trimester.

We use birth weight (measured in grams) as a dependent variable to examine the effects of air pollution on the overall birth weight distribution and found somewhat inconsistent results. CO showed the largest changes. The CO level had significant positive effects on birth weight regardless of the time of exposure. Previous studies have provided similar counter-intuitive findings but provided no explanations (Lee et al., 2003).

## 5. CONCLUSION

There is growing concern about adverse effects of air pollution on health outcomes. However, previous studies have provided limited evidence of such effects.

In addition, there may be a nonlinear relationship between the level of air pollution and health outcomes. The level of air pollution in Korea is generally higher than that in other developed countries typically considered in previous studies. However, there have been dramatic changes in the level of air pollution in Korea since early 2000, when Korea implemented various laws to reduce air pollution. By using these drop in some area, we examined the relationship between air pollution and the health of newborns in Korea. For this, we employed census data on all births in Korea from 1998 to 2008.

The results indicate that the effects of various air pollutants on the health of newborns varied according to the time of exposure. Exposure to an $O_3$ level above 0.12 ppm per hour during the first trimester or the first month increased the probability of low birth weight substantially. On the other hand, exposure to $SO_2$ or CO during the third trimester or the last month increased the probability of low birth weight moderately. These results for CO and $SO_2$ are consistent with the findings of previous studies (Bobak, 2000; Maisonet et al., 2001; Currie & Neidell, 2005). The results of the $O_3$ level above 0.12 ppm are noteworthy because few studies have examined the effects of $O_3$ on low birth weight (Salam et al., 2005).

This study's results are inconsistent with the findings of previous studies in terms of the relationship between the time of exposure to air pollution and health outcomes. A number of studies have found significant effects of CO exposure during the first trimester on low birth weight, but we found no such effects (Lee et al., 2003; Ha et al., 2001; Maisonet et al., 2001). Salam et al. (2005) found significant effects of $O_3$ exposure during the second and third trimesters on low birth weight, but we found significant effects of $O_3$ exposure during the first trimester, although there were differences in $O_3$ measures. These differences may be due to some unknown mechanisms underlying the effects of air pollution on health outcomes and future research is needed (Gabrielli et al., 1995).

One limitation of this study is that determining the true causal relationship between air pollution and health outcome may not be possible if individuals are aware of the pollution level and change their behavior accordingly. For example, if individuals decide not to go outside when there is an $O_3$ advisory, then the estimate may be underestimated because avoidance behaviors. However, this limitation is not serious because Korea had no $O_3$ advisory system until 2008 and advisories about other pollutants are not made every day.

**Acknowledgements**

This work was supported by the National Research Foundation of Korea Grant, funded by the Korean Government (NRF-2010-411-B00028), and the Korea University Grant.

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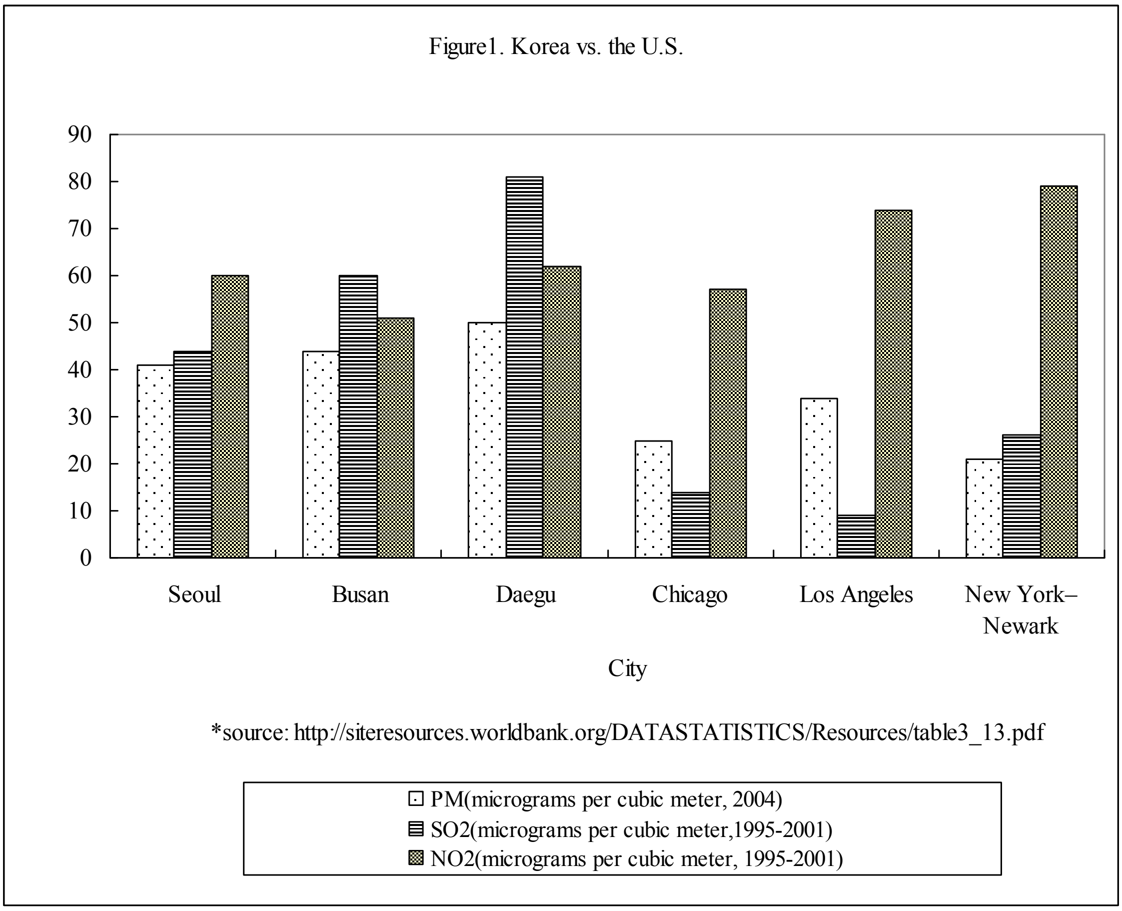
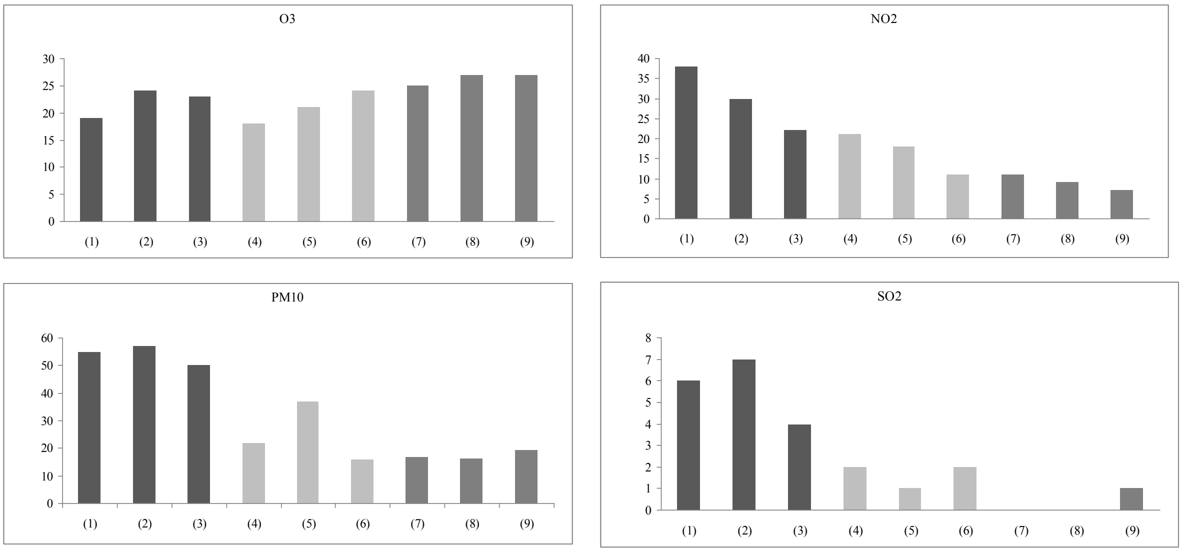
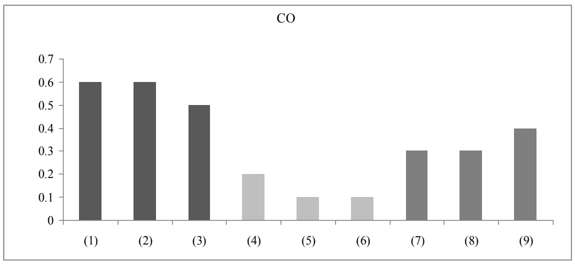


Figure1. Korea vs. the U.S.
90
80
70
60
50
40
30
20
10
0
Seoul
Busan
Daegu
Chicago
Los Angeles
New York–Newark
City
*source: http://siteresources.worldbank.org/DATASTATISTICS/Resources/table3_13.pdf
PM(micrograms per cubic meter, 2004)
SO2(micrograms per cubic meter,1995-2001)
NO2(micrograms per cubic meter, 1995-2001)

Figure 2. Air Pollution in Korea, the U.K. and Australia (2008)




*source
the U.K.: http://www.airquality.co.uk/annualreport/annualreport2008.php
Australia: http://www.ephc.gov.au/taxonomy/term/34

*note
Korea: (1) Seoul, (2) Incheon, (3) Gwangju
the U.K.: (4) London Westminster, (5) Newcastle Center
(6) Liverpool Speke
Australia: (7) Sydney Rozelle, (8) Illawarra Wollongong
(9) Lower Hunter Newcastle
unit: O3 (ppb), NO2 (ppb), PM10 (㎍/m3), SO2(ppb), CO(ppm)

Figure 3. Mean Annual Air Pollution in Korea (2008)

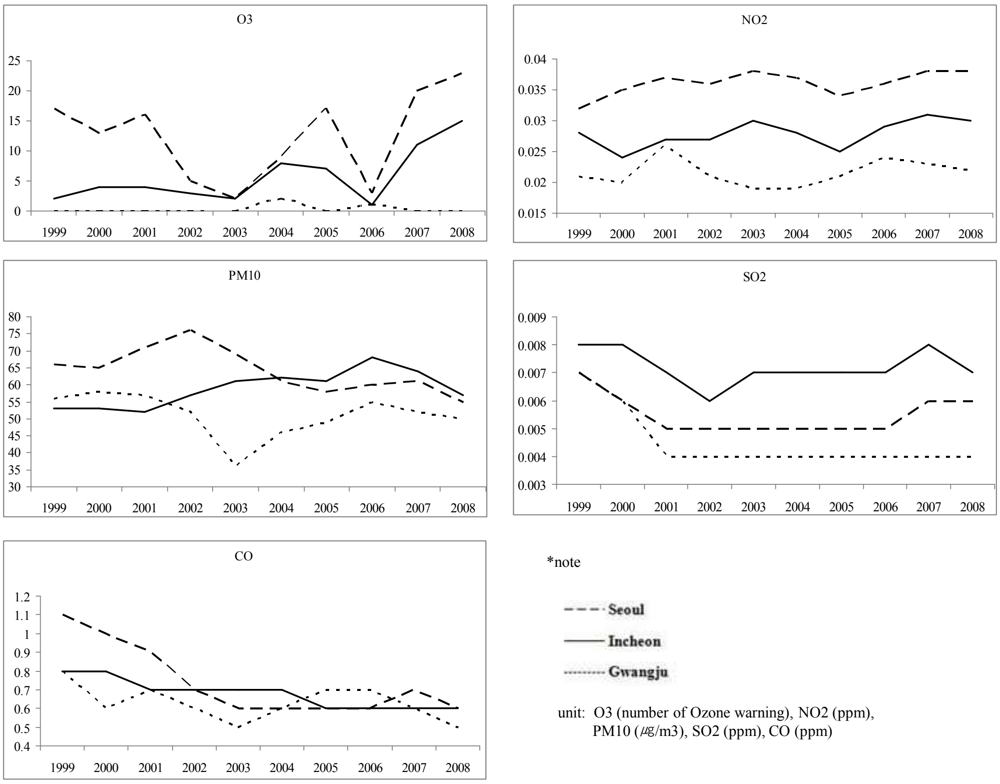


Table1. Descriptive Statistics

| Variables | Mean | Standard Deviation |
|---|---|---|
| Weight (g) | 3250.49 | 454.73 |
| Low birth weight* | 0.0498 | 0.2176 |
| **Pollutants** | | |
| CO (ppm) | 0.7254 | 0.3051 |
| NO2 (ppb) | 28.5148 | 9.8045 |
| O3 level above 0.12 ppm | 0.0756 | 0.2427 |
| PM10 (㎍/㎥) | 60.2306 | 16.5259 |
| SO2 (ppb) | 6.4908 | 3.1250 |
| **Demographic Characteristics** | | |
| Age of the mother | 29.6050 | 3.8847 |
| Male | 0.5185 | 0.4997 |
| Length of pregnancy (week) | 39.0178 | 1.5870 |
| Singleton | 0.9775 | 0.1482 |
| First child | 0.5175 | 0.4997 |
| Second child | 0.3947 | 0.4888 |
| Third child | 0.0791 | 0.2699 |
| Fourth or above | 0.0077 | 0.0873 |
| Season (spring) | 0.2509 | 0.4335 |
| Season (summer) | 0.2249 | 0.4175 |
| Season (fall) | 0.2687 | 0.4433 |
| Season (winter) | 0.2555 | 0.4361 |
| No education | 0.0004 | 0.0203 |
| Elementary school | 0.0038 | 0.0613 |
| Middle school | 0.0198 | 0.1394 |
| High school | 0.4369 | 0.4960 |
| University | 0.0834 | 0.2764 |
| Graduate school (≥16) | 0.0077 | 0.0872 |

| | | |
|---|---|---|
| College or higher (>12) | 0.4458 | 0.4971 |
| *obs* | 2,397,779 | |

Note: We used the census of all births in Korea from 1998 to 2008.

Low birth weight means birth weight less than or equal to 2,500 grams.

Table 2. Effects of Air Pollutants on Low Birth Weight: Individual Pollutants

| | Pollution exposure measured during the first trimester | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | Coefficients and standard errors are multiplied by 1,000 | | |
| O3 level above 0.12 ppm | 3.6500 | 4.8642 | 4.8642 |
| | (0.5684) | (0.5924) | (0.8707) |
| County fixed effect | N | Y | Y |
| Clustered standard error | N | N | Y |
| *obs* | | 2,395,110 | |

Note: We used the census of all births in Korea from 1998 to 2008. We obtained the data on average monthly air pollution from annual reports on air quality in Korea from 1998 to 2008. The independent variables were the demographic characteristics of the mother (age and the education level—no school, elementary school, middle school, high school, college, and graduate school), the characteristics of pregnancy (gender, singleton, and the birth order), and the seasonal effect.

Table 3. Effects of Air Pollutants on Low Birth Weight: All Pollutants Simultaneously

| | Pollution exposure measured during the first trimester | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | Coefficients and standard errors are multiplied by 1,000 | | | | | |
| O3 level | 4.8642 | | | | | 4.3948 |
| above 0.12 ppm | (0.9) | | | | | (0.8522) |
| NO2 | | -0.2305 | | | | -0.2082 |
| (ppb) | | (0.0339) | | | | (0.0359) |
| PM10 | | | -0.0593 | | | -0.0348 |
| ($\mu g/m^3$) | | | (0.0183) | | | (0.0188) |
| SO2 | | | | -0.0534 | | 0.0840 |
| (ppb) | | | | (0.0752) | | (0.0772) |
| CO | | | | | -1.4383 | -1.1414 |
| (ppm) | | | | | (0.9502) | (0.8171) |
| *obs* | | | 2,395,110 | | | |

See the note in Table 2. We employed county fixed effects. Standard errors clustered at the county level are in parentheses.

Table 4. Effects of Air Pollutants on Low Birth Weight

| | Pollution exposure measured during | | | |
|---|---|---|---|---|
| | first trimester | first month | third trimester | last month |
| | Coefficients and standard errors are multiplied by 1,000 | | | |
| O3 level above | 4.3948 | 1.5354 | -0.3569 | -0.1633 |
| 0.12 ppm | (0.8522) | (0.487) | (0.6427) | (0.3762) |
| NO2 | -0.2082 | -0.0944 | -0.0537 | -0.0280 |
| (ppb) | (0.0358) | (0.0278) | (0.0376) | (0.0271) |
| PM10 | -0.0348 | 0.0086 | -0.0516 | -0.0271 |
| ($\mu g/m^3$) | (0.0188) | (0.0128) | (0.0193) | (0.0123) |
| SO2 | 0.0840 | 0.1472 | 0.2847 | 0.2444 |
| (ppb) | (0.0772) | (0.0611) | (0.1088) | (0.0806) |
| CO | -1.1414 | -0.3065 | 1.8196 | 1.8292 |
| (ppm) | (0.8171) | (0.6883) | (0.8183) | (0.6659) |
| *obs* | 2,395,110 | | | |

See the note in Table 3.

Table 5. Effects of Air Pollutants on Gestation

| | Pollution exposure measured during | | | |
|---|---|---|---|---|
| | first trimester | first month | third trimester | last month |
| | Coefficients and standard errors are multiplied by 1,000 | | | |
| O3 level above | -0.0698 | -0.0249 | -0.0419 | -0.0133 |
| 0.12 ppm | (0.0159) | (0.0073) | (0.0078) | (0.0042) |
| NO2 | -0.0006 | -0.0015 | -0.0019 | -0.0013 |
| (ppb) | (0.0007) | (0.0005) | (0.0006) | (0.0004) |
| PM10 | 0.0006 | -0.0001 | 0.0006 | 0.0007 |
| ($\mu g/m^3$) | (0.0003) | (0.0002) | (0.0004) | (0.0002) |
| SO2 | 0.0066 | 0.0052 | 0.0023 | 0.0031 |
| (ppb) | (0.002) | (0.0016) | (0.0023) | (0.0017) |
| CO | 0.2265 | 0.1743 | 0.2051 | 0.1644 |
| (ppm) | (0.0221) | (0.0162) | (0.0221) | (0.0155) |
| *obs* | 2,395,110 | | | |

See the note in Table 3.