Effects of PM25 levels on Visits for Respiratory Tract Infection in Singapore

March 22, 2019

1 Introduction

This report analyses the effect of PM2.5 levels on visits to clinics for respiratory tract infection. PM2.5 are sufficiently small to penetrate and exacerbate respiratory tract symptoms, thus, directly related to short-term air quality changes. Respiratory infection occurs most and accounts for $\frac{4}{5}$ of total of 4 diseases. (Fig 1)

2 Equation

The effects are estimated by Two Stage Least Squares (2SLS) (Fig 3) :

$$RespVisits = \beta_0 + \beta_1 PM2.5 + \gamma W + \alpha I + e - (1)$$

$$PM2.5 = \delta_0 + \delta_1 Inversion + \delta_3 FRP + \rho W + \pi I + e - (2)$$

$RespVisits$= Number of clinic visits for Respiratory tract infection per day for the week

$PM2.5$= Particulate Matter with diameter less than 2.5mm

W= Control variables {School Holidays, Month, Year, Temperature, Wind Speed, Precipitation, Dew point, Humidity}

I = Interaction between variables {Month:Temperature, Month:Precipitation, Month:SchoolHoliday}

$Inversion$ (Instrument) = Proportion of days with atmospheric inversion

FRP (Instrument) = Distance and Bearing weighted radiative power (Fire Intensity)

e = Error term

(2) is the second-stage and (1) is the first-stage equations. The following controls W are used to take into account seasonal weather and time changes of respiratory diseases that are not due to PM2.5 levels. Statistically significant interactions were found between month and temperature/school holidays respectively. Logically, temperature is related to seasons and holidays fall on the same months.

3 Reasons for chosen Instrumental Variables

Atmospheric Inversion and adjusted Radiative Power are used as the instrumental variables (IV) for the endogenous PM2.5. Validity of IV is based on the assumption that it only affects respiratory infection through their impact on PM2.5 levels. An increase in atmospheric inversion causes more pollutants (PM2.5) to be trapped in the atmosphere, thus negatively affecting health. Similarly, higher weighted radiative power would lead to higher levels of pollutants, thus PM25 and health. However, this could be violated when the IV listed affects weather conditions, thus citizen's going out behaviour. The chosen IVs are unlikely to affect health directly as it is not easily noticeable by people, and the information is not easily obtained by the public in Singapore, unlike PM2.5 levels. Selected individuals may be able predict the occurrence and effects of these IVs, making the above IVs invalid. However, this is suspected to be a negligible group of people.

Wald and Weak Instrument test reports high F-statistics and low p-value, suggesting that instruments are sufficiently strong. (Fig 4) However, the Wu-Hausman and Sargan test shows that the OLS estimator might be equally consistent and run risk of over-identification respectively. Dropping the radiative power instrument would lead to better Wu-Hausman test results, but makes PM2.5 variable insignificant. (Fig 5) However, In my opinion, radiative power (fire intensity) should be included for above reasons.

4 Results

Results show that an average of one $\mu g/m^3$ increase in PM2.5 levels over the week leads to a statistically significant 2.83 increase in daily visits for respiratory tract infection. Constituting the baseline would be the mean over the same months in other years. The baseline mean PM25 and during the haze is 24.27 and 66.11 respectively. Baseline respiratory infection visits are 2347.5. There is an increase in 4.99% from baseline in respiratory clinic visits. The predicted values are significantly lower compared to Koplitz et al (2016). Koplitz's result may have failed to take into account the avoidance measures taken by Singapore government and its citizens. For example, the government gave out free N95 mask, halted outdoor activities, constant warnings and advice for the public. The citizens similarly took precautions by spending less time outdoors. Hence, Koplitz's estimate might be an overestimation for Singapore compared to other places where there's a lack of protection from the penetration of particles. Infrastructure and affluence in Singapore limits penetration of pollutants, the usage of purifier/Air-conditioner, enables the government and citizens to undertake avoidance measures. Compared to housing in less developed places where houses are more ventilated and facilitate pollutants penetration. Hence, different country's characteristic may influence morbidity/mortality results.

5 Robustness Check

Temporary increases in pollution levels may result in delayed infection symptoms. Though the IV test on lagged respiratory visits was found insignificant. (Fig 7)

It is possible that PM2.5 impacts are not linearly distributed. At lower PM2.5 levels, there would be a smaller increase in visits compared to higher levels, where increases may be more impactful. However, a quadratic equation was found insignificant.

A test with placebo instruments which are randomly generated atmospheric inversion and adjusted radiative power. This is to ensure that the estimates are not a result of weak instrument bias. The results derived were largely insignificant, showing that the instruments used in the IV regression were picking up meaningful rather than spurious variation in PM2.5 levels. (Fig 6)

6 Conclusion

Overall, results suggest that an increase in PM2.5 levels would lead to more visits for respiratory infection. However, a caveat is that aside from PM2.5, other pollutants, such as CO, NO, O_3, UFP, can have independent health effects. This can interfere with the interpretation of the estimates of PM2.5. There is a trend towards finer particles such as UFP causing an increase in health problems, thus a portion may not be due to PM2.5 levels.

Ideally, an IV regression of the main pollutants as the endogenous variables would be optimal. In addition, personal variables such as age, asthma in parents, exposure to smoke at home, gas stove etc. should be included as controls. These personal covariates may affect the person's susceptibility to respiratory tract infection and are important controls. Finally, independent country's characteristics' is important to determine ultimate impact from pollutants. Which may explain the less than expected impact of PM25 on Singapore's morbidity and mortality.

800 Words.

A Additional Data

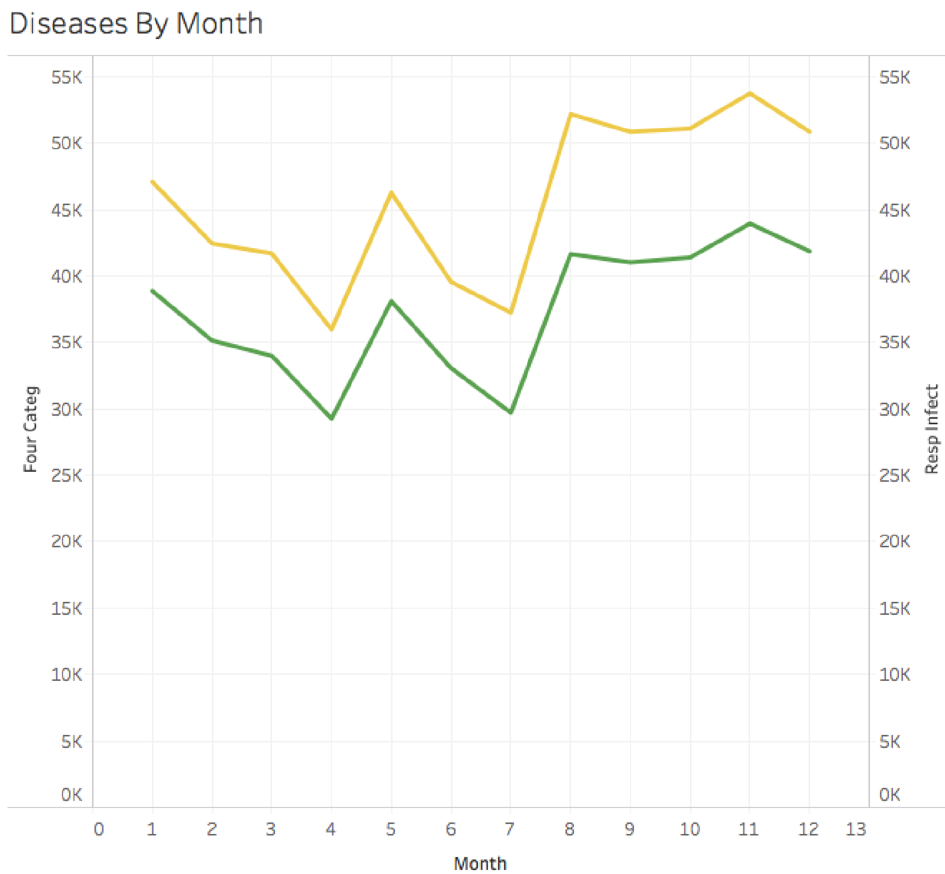

Fig 1: Sum of all 4 diseases (Yellow line) to Sum of Respiratory tract infection (Green line) visits to clinic per month

	Dependent variable:
	Number of visits to the clinic for respiratory related illness
PM2.5	2.83*
	(1.54)
School Holidays	-564.06***
	(173.22)
Month	-510.59**
	(236.90)
Year	-26.30
	(21.28)
Temperature	-166.81***
	(49.03)
Wind speed	-1.05
	(16.73)
Precipitation	-24.30***
	(9.24)
Dew Point	-7.15
	(11.57)
Humidity	14.94*
	(8.42)
Month:Temperature	16.69*
	(8.47)
Month:Precipitation	1.53
	(1.11)
Month:SchoolHolidays	55.42***
	(20.00)
Constant	59,408.60
	(42,780.49)
Observations	175
R2	0.41
Adjusted R2	0.37
Residual Std. Error	214.99 (df = 162)
Note:	*p<0.1; **p<0.05; ***p<0.01

Fig 2: OLS regression

	Dependent variable:
	Number of visits to the clinic for respiratory related illness
PM2.5	2.83*
	(1.54)
School Holidays	-564.06***
	(173.22)
Month	-510.59**
	(236.90)
Year	-26.30
	(21.28)
Temperature	-166.81***
	(49.03)
Wind speed	-1.05
	(16.73)
Precipitation	-24.30***
	(9.24)
Dew Point	-7.15
	(11.57)
Humidity	14.94*
	(8.42)
Direction-Bearing weighted FRP	16.69*
	(8.47)
Atmospheric Inversion	1.53
	(1.11)
month	55.42***
	(20.00)
Constant	59,408.60
	(42,780.49)
Observations	175
R2	0.41
Adjusted R2	0.37
Residual Std. Error	214.99 (df = 162)
Note:	*p<0.1; **p<0.05; ***p<0.01

Fig 3: IV regression

```
Diagnostic tests:
                 df1 df2 statistic p-value
Weak instruments   2 161    26.306 1.3e-10 ***
Wu-Hausman         1 161     1.144  0.2864
Sargan             1  NA     5.444  0.0196 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 215 on Inf degrees of freedom
Multiple R-Squared: 0.4114,     Adjusted R-squared: 0.3678
Wald test: 158.6 on 12 DF,  p-value: < 2.2e-16
```

Fig 4: IV regression diagnostic tests

```
Coefficients:
                                 Estimate Std. Error z value Pr(>|z|)
(Intercept)                    148663.196  98469.260   1.510   0.1311
endata$pm25                        31.221     18.905   1.652   0.0986 .
endata$schoolHol                 -985.814    482.318  -2.044   0.0410 *
endata$month                      137.922    572.779   0.241   0.8097
endata$year                       -75.140     50.291  -1.494   0.1351
endata$tp                         -18.564    128.087  -0.145   0.8848
endata$ws                          57.445     52.534   1.093   0.2742
endata$pp                         -40.907     18.016  -2.271   0.0232 *
endata$dewPointDep                -53.572     39.491  -1.357   0.1749
endata$hm                          75.575     49.651   1.522   0.1280
endata$month:endata$tp             -8.660     21.615  -0.401   0.6887
endata$month:endata$pp              2.709      1.758   1.541   0.1233
endata$schoolHol:endata$month     100.347     47.800   2.099   0.0358 *

Diagnostic tests:
                  df1 df2 statistic p-value
Weak instruments    1 162     4.010  0.0469 *
Wu-Hausman          1 161     6.791  0.0100 *
Sargan              0  NA        NA      NA
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 455.9 on Inf degrees of freedom
Multiple R-Squared: -1.647,     Adjusted R-squared: -1.843
Wald test: 44.47 on 12 DF,  p-value: 1.271e-05
```

Fig 5: IV regression with only weighted radiative power as instrument

```
  Res.Df Df      F Pr(>F)
1    161
2    163 -2 1.1207 0.3286
```

Fig 6: Placebo instrument test

```
Coefficients:
                                  Estimate Std. Error z value Pr(>|z|)
(Intercept)                      8910.0028 34837.6955   0.256   0.7981
endata$pm25                         1.6654     1.2505   1.332   0.1829
endata$schoolHol                 -446.3216   176.2252  -2.533   0.0113 *
endata$month                     -420.2011   249.8202  -1.682   0.0926 .
endata$year                        -0.4169    17.2995  -0.024   0.9808
endata$tp                        -201.6820    51.5331  -3.914 9.09e-05 ***
endata$ws                         -29.1216    17.2908  -1.684   0.0921 .
endata$pp                          -9.8132    10.2779  -0.955   0.3397
endata$dewPointDep                 -6.4884    10.5198  -0.617   0.5374
endata$hm                           8.0578     8.7682   0.919   0.3581
endata$month:endata$tp             13.7537     8.9496   1.537   0.1243
endata$month:endata$pp             -0.1242     1.2378  -0.100   0.9201
endata$schoolHol:endata$month      52.4057    20.5709   2.548   0.0108 *
```

Fig 7: PM2.5 levels on lagged respiratory tract infection visits test

References

[1] Jans. J., Johansson P., Nilsson J.P. (2014) Economic Status, Air Quality, and Child Health: Evidence from Inversion Episodes.

[2] Ward. C.J. (2015). It's an ill wind: The effect of fine particulate air pollution on respiratory hospitalizations.

[3] Deryugina T., Heutel G., Miller N. H., Molitor D., Reif J. (2016). THE MORTALITY AND MEDICAL COSTS OF AIR POLLUTION: EVIDENCE FROM CHANGES IN WIND DIRECTION*.

[4] Koplitz et al. (2016). Public health impacts of the severe haze in Equatorial Asia in September–October 2015: demonstration of a new framework for informing fire management strategies to reduce downwind smoke exposure.

[5] Wright S. (2016). Study estimates 100,000 deaths from Indonesia haze.

[6] Channel News Asia (2016). Study on haze related deaths 'not reflective of actual situation.

[7] Channel News Asia (2016). Study on haze related deaths 'not reflective of actual situation.

[8] Alberto S. (2016). Environmental Data Appendix.