# CANADA-US AIRSHED MANAGEMENT STRATEGY: POLICY OPTIONS

**BY CARMEN HRANAC**
carmenh@u.wasington.edu

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**ECONOMICS 482**

*In order to compete effectively in the twenty-first century, the United States must not only open itself economically to the global community, but we must also recognize the global nature of our ecology. This ecological awareness manifests itself in the form of transboundary agreements such as the Kyoto Protocol, the statement from the Earth Summit in Rio, and international fishing treaties. Washington State, in conjunction with British Columbia, is pushing this transboundary understanding through many joint strategies, one of these being the Airshed Management Strategy for the Georgia Basin-Puget Sound. The two national government agencies have already signed a Joint Statement of Cooperation, outlining the effort to create a sustainable airshed. The committee has been working on the strategy for the past few years, and has been successful in completing an airshed characterization, identifying the group's main objectives, and outlining a few specific policies of interest. There is now a need for an analysis of the effects of certain air strategies on the ambient air quality in the two nations, specifically the effects of US policies on Canadian air pollution, vice versa, and the effect of international agreements on both countries. The analysis is needed in order to determine if one country is affecting the other's air quality disproportionately, what strategies work in both countries, and thus aid the decision on the most effective international strategy. The report below contains the analysis of Washington State ambient air quality.*

*Five airshed policies were chosen for analysis; the policies range from 1990 to 1999. Two more international agreements were selected for analysis, one in 1991, the other in 2000. We collected data for PM10, CO,* $SO_2$*, and* $O_3$ *from monitoring stations throughout the Puget Sound and Georgia Basin. We also compiled the GDP of BC, the GSP of Washington State, and the population for both regions. The information was input into EVIEWS, a statistical analysis software program, and a regression analysis was computed. We found that joint policies between Canada and the United States had the strongest positive impacts on Washington air quality, and Canadian policies that were stronger in their implementation than their corollary US policies had the most deleterious effect on Washington ambient air. We also found that* $SO_2$ *was mainly unaffected by any policies. From these findings we suggest that the best strategy for airshed management is a region-specific, collaborative-effort strategy on PM10, CO, and* $O_3$ *for the Georgia Basin/Puget Sound transboundary region.*

The Georgia Basin and Puget Sound regions of British Columbia and the United States are currently working on a joint strategy for airshed management in the region. This analysis sets out to identify the best form for that agreement. We intend to show that United States, Canadian, and international air pollution polices are correlated to Washington State criteria air pollution; we intend to show this through a regression analysis on our specific model.

Both Canada and the United States have numerous air control policies already in place. In order to understand the subsequent analysis, we must present a general background on air pollutants and the present policies.

**BACKGROUND ON POLLUTANTS**

Criteria pollutants are air pollutants that the EPA has regulated by "developing health-based criteria (science-based guidelines) as the basis for setting permissible levels."[1] These pollutants include sulfur dioxide $SO_2$), inhalable particulate matter (PM10), nitrogen oxides (NOX), volatile organic compounds (VOX), carbon monoxide (CO), ozone ($O_3$), and lead. Due to insufficient data, NOX, VOX, and lead were excluded from the regressions. However, their sources and effects are still important to the analysis.

*Ozone*

Ground-level ozone – quite different from the stratospheric ozone that protects us – is produced from smokestacks, cars, paints, and solvents. It is the main ingredient to smog, the air pollution experienced in and around urban settings. The pollutants are blown through the air, coming into contact with photons from the sun. The photons, in effect, bake the ozone (and a few other pollutants) into smog. Thus we find smog downwind from urban settings, especially in hot places with little wind. We would expect ozone concentrations to vary with cloud cover, thus – in normal settings – with precipitation. However, in Seattle precipitation is not necessarily a sign of cloud cover; often there are clouds without precipitation. Thus we do not include rain nor temperature in our ozone regression.

*Sulfur Dioxide*

Sulfur dioxide is primarily produced from the combustion of "unclean" fuel, specifically coal. Coal is quite heterogeneous, with many impurities; one of the main impurities is sulfur, which combines with oxygen during combustion to become sulfur dioxide. The largest source of sulfur dioxide is coal-fired power plants. Sulfur dioxide, like ozone, is also blown on the wind; it is a component of smog, as well as one of the main contributors to acid rain.

*Inhalable Particulate Matter*

Combustion of fuels (mainly solid, but also diesel) contributes PM10 to our atmosphere. The main sources are coal-fired power plants, wood stoves, agricultural burning, dust from fields and roads, and diesel engines. Particulate matter is small enough to float on the air and be inhaled by humans and animals, but is large enough to cause bad health effects to those humans and animals. It, too, contributes to smog in our cities. We would expect PM to vary with temperature/precipitation in an area.

*Carbon Monoxide*

Carbon monoxide comes from any combustion process, and is a serious poison to all animals (including humans).

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[1] www.epa.gov

*Nitrogen Dioxide*

Nitrogen dioxide also comes from combustion, mainly in diesel and gasoline engines as well as utility boilers. Like sulfur dioxide, this criteria pollutant travels on the wind and creates acid rain when combined with moisture.

*Volatile Organic Compounds*

VOX comes from combustion processes, mainly from the SI (spark ignition) internal combustion engine; this is the engine used in almost all commercial cars, as opposed to the diesel engine in large trucks. These compounds can cause cancer and blood diseases in humans.

*Lead*

Our atmosphere contains lead in large part due to our SI engines. The automotive industry used lead as an additive to prevent "knocking" in the engine; once combusted, the lead was released into our atmosphere.

## BACKGROUND ON POLICIES

*Clean Air Act (US), 1990*

The Clean Air Act (CAA) of 1990 was an upgrade to the previous Clean Air Act of 1970. Among other things, this act controls emissions of all of our selected pollutants. For sulfur dioxide, the Act sets up a tradable permits scheme with an overall reduction of forty percent less than 1980 levels by the year 2000. This is generally considered to be the most efficient scheme for handling pollution, and one would expect a large reduction in sulfur dioxide from the Act.

PM10, carbon monoxide, and ozone had a somewhat similar, although more regulated, tradable permits scheme. Companies are allowed to increase their emissions if 1)emissions are reduced somewhere else in the region to more than offset the effect of the increase, or 2) the company decreases their pollution in another aspect of their production. This allows for more efficient reallocation of the pollution.

*Canada-USA Air Quality Agreement (International), 1991*

This agreement sets up guidelines for both nations on acid rain emissions. It reiterates the CAA of the US on sulfur dioxide, and sets emission targets for Canada. Importantly, it also sets guidelines for NOX emissions, specifically on gasoline- and diesel-powered cars.

*Greater Vancouver Regional District's (GVRD's) Airshed Quality Management Strategy (Canada), 1994*

This policy is all-encompassing, setting strict emission guidelines for the specific region of the Georgia Basin. All criteria air pollutants are addressed in the policy.

*BC's Action Plan for Clean Air (Canada), 1995*

Here British Columbia sets out their specific steps in meeting national standards for clean air.

*GVRD Bylaws (Canada), 1996*

These bylaws deal mainly with reductions in gasoline- and diesel-powered engine emissions.

*GVRD's Air 2000 (Canada), and US Regional Haze Rule (US), 1999*

The GVRD's Air 2000 program is an initiative designed to increase implementation efficiency. It is open to anyone who wishes to participate and comment on the implementation plans for specific policies. The program seeks to increase innovation and effectiveness of implementation goals.

The US Regional Haze Rule deals mostly with PM10 and sulfur dioxide emissions in recreational areas such as national parks. The plan requires state implementation plans from each state; these so-called SIPs must show the state regulatory agency's plan to decrease PM10 and sulfur dioxide in these public areas.

*Ozone Annex (International), 2000*

This is an addition to the earlier Canada-US air agreement. It simply includes limitations on ozone levels to "downwind" communities.

**REGRESSION MODEL**

An ordinary least squares regression was done on the three pollutants included. The dependent variable was always the pollutant concentration for the given year (1986-2001) at the specific monitoring station. PM10 concentrations are given as the mean annual value, CO and sulfur dioxide concentrations are the highest-reported 1hr max for the year, and ozone concentrations are the highest-reported 8hr max for the year. The independent variables were the gross state product (GSP) of Washington State for the specific year of the data point, the population of Washington State, again for the specific year, a time variable that was comprised solely of the year correlating to the point, a precipitation (annual inches) variable, a temperature (mean degrees Fahrenheit) variable, and the air policies. The air policies were treated as dummy variables, with a zero value for years before the policy was instated and a one value for all the subsequent years. We determined variables to be significant at the90% level – only these variables are reported. See Appendix A for a translation of the variables. The results are as follows:

*PM10 RESULTS*

WAPM = (0.000341)WAPMGSP + (-5.72E-05)WAPMPOP + (4.757)WAPMX2 + (3.789)WAPMX5 + (0.1578)WAPMYR

t-statistic for WAPMGSP: 2.489 (probability of 1.32%)
t-statistic for WAPMPOP: -3.974 (probability of 0.01%)
t-statistic for WAPMX2: 1.696 (probability of 9.06%)
t-statistic for WAPMX5: 1.798 (probability of 7.29%)
t-statistic for WAPMYR: 4.559 (probability of 0%)

*OZONE RESULTS*

WAO3 = (-0.016)WAO3X4
t-statistic for WAO3X4: -1.696 (probability of 9.2%)

*CARBON MONOXIDE RESULTS*

WACO = (-8.98E-06)WACOPOP + 1.837WACOX2 + 1.443WACOX6 + 0.0233WACOYR
t-statistic for WACOPOP: -2.15 (probability of 3.25%)
t-statistic for WACOX2: 1.812 (probability of 7.16%)
t-statistic for WACOX6: 2.121 (probability of 3.52%)
t-statistic for WACOYR: 2.0767 (probability of 3.92%)

**ANALYSIS**

*PM10 RESULTS*

PM10 results showed that there was a large increase as a result of the Canada-US Agreement of 1991. These results are a bit less intuitive, considering the fact that this agreement focused on acid rain. The reasons for the increase are two-fold. First, the stipulation to decrease NOX was realized *by a decrease in diesel emission.* Diesel emissions are a main source of PM10 emissions. Second, the agreement was primarily for the easternmost parts of Canada and the US; the strategy was realized as a result of the public outcry over Midwest coal plants creating acid rain in eastern Canada. We can conclude that diesel transport was shifted to the western part of the two countries as a result of tighter restrictions in the eastern areas. This shift resulted in higher PM10 concentrations in the area under study.

An increase is shown from the GVRD's Bylaws of 1996. These bylaws pertained to diesel and gas emissions. At first glance, this would seem to favor PM10 reductions. But, we must consider the fact that these emission guidelines were much more stringent than those set out in the 1991 international agreement. I conclude that the stricter guidelines in BC pushed transport, especially marine, down to Washington State, causing for the increase in PM10 concentrations.

There was a small increase in particulate matter as a result of GSP increases. Surprisingly, there was a (very small) decrease in PM concentrations with an increase in population. Finally, there was a positive correlation between the year and the concentrations.

*OZONE RESULTS*

Ozone results show the *only* decrease -- and an extremely small one at that – in ambient air concentrations being due to the BC's Action Plan for Clean Air. These results are fairly surprising, especially considering that the 2000 agreement focused only on ozone problems. We can only conclude that, due to ozone's very complicated formation process, present strategies have generally not worked.

*CARBON MONOXIDE RESULTS*

We find that CO concentrations increased with the 1991 Canada-US joint agreement. Again, this result is to be expected as a shift from the east to the west.

CO concentrations increased with the policies in 1999. This increase can be attributed to a more flexible, more easily implemented policy in Canada pushing pollution to Washington. There is a decrease in pollution from an increase in population – very surprising, but this coefficient is extremely small, leading to a negligible impact. There was also a positive coefficient for the time variable and CO concentrations.

As can be seen from the analysis, the worst scenario for Washington State pollution is to have a policy elsewhere that is stricter in it's emissions reductions, causing a shift of pollution to the Puget Sound. Thus, the United States is best suited to a joint strategy with Canada on all of their air pollution policies. The best strategy must be region-specific, flexible, and very open to easy collaboration. This is our recommendation for the upcoming strategy planning.

# APPENDIX A:
# VARIABLE TRANSLATIONS

Break-Down of symbols:
All of the variables take the form of

(WA)(some pollutant)(some variable associate with that pollutant)

- "WA" stands for Washington State; the variable is for Washington State values alone

- "Some Pollutant" is just the shorthand version of the chosen pollutants –

| | |
|---|---|
| pm10 | PM10 annual means (in ug/m^3) |
| co | Carbon Monoxide 1hr max |
| o3 | Ozone 8hr max |

- "Some Variable associated with that pollutant" is the different variables selected for analysis. These variables correspond to the specific pollutant years

| | |
|---|---|
| gsp | Gross State Product of Washington State for the pertinent year |
| pop | Population of Washington State for the pertinent year |
| x1 | Clean Air Act, 1990 (dummy variable) |
| x2 | Canada-USA Air Quality Agreement, 1991 (dummy variable) |
| x3 | GVRD's AQMP, 1994 (dummy variable) |
| x4 | BC's Actions Plan for Clean Air, 1995 (dummy variable) |
| x5 | GVRD's Bylaws, 1996 (dummy variable) |
| x6 | GVRD's Air 2000, US's Regional Haze Rule, 1999 (dummy variable) |
| x7 | Ozone Annex, 2000 (dummy variable) |
| rain | Annual rainfall, inches |
| temp | Annual mean temperature, degrees Fahrenheit |
| yr | Time variable |

So, for example,

- wacox3 is the dummy variable of the GVRD's AQMP associated with Washington State carbon monoxide levels.
- waco is the carbon monoxide levels for Washington State
- wacogsp is the Gross State Product of Washington State associated with the carbon monoxide levels.

# APPENDIX B: BIBLIOGRAPHY

1) http://www.ijc.org/agree/air.html#d\

2) http://www.parl.gc.ca/information/InterParl/Associations/U_S/Newport/page09-e.htm

3) http://www.aqd.nps.gov/ard/vis/rhr.html

4) www.epa.gov

5) www.economagic.com

6) http://lwf.ncdc.noaa.gov/oa/climate/research/cag3/WA.html

# APPENDIX C:
# REGRESSIONS

## PM10 Regressions

Dependent Variable: WAPM
Method: Least Squares
Date: 12/10/02 Time: 17:34
Sample(adjusted): 1 415
Included observations: 415 after adjusting endpoints

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| WAPMGSP | 0.000341 | 0.000137 | 2.489283 | 0.0132 |
| WAPMPOP | -5.72E-05 | 1.44E-05 | -3.974673 | 0.0001 |
| WAPMRAIN | -0.206121 | 0.142101 | -1.450529 | 0.1477 |
| WAPMTEMP | -0.684703 | 0.438507 | -1.561439 | 0.1192 |
| WAPMX1 | 1.804468 | 3.136540 | 0.575305 | 0.5654 |
| WAPMX2 | 4.757078 | 2.804538 | 1.696207 | 0.0906 |
| WAPMX3 | 1.657534 | 1.893691 | 0.875293 | 0.3819 |
| WAPMX4 | 2.122900 | 2.214817 | 0.958499 | 0.3384 |
| WAPMX5 | 3.789011 | 2.107161 | 1.798159 | 0.0729 |
| WAPMX6 | -4.529527 | 2.939660 | -1.540834 | 0.1241 |
| WAPMX7 | -0.187751 | 2.796820 | -0.067130 | 0.9465 |
| WAPMYR | 0.157802 | 0.034612 | 4.559175 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.496658 | Mean dependent var | 27.51084 |
| Adjusted R-squared | 0.482919 | S.D. dependent var | 10.07160 |
| S.E. of regression | 7.242319 | Akaike info criterion | 6.826249 |
| Sum squared resid | 21137.83 | Schwarz criterion | 6.942730 |
| Log likelihood | -1404.447 | Durbin-Watson stat | 1.572438 |

## OZONE Regressions

Dependent Variable: WAO3
Method: Least Squares
Date: 12/10/02 Time: 17:26
Sample(adjusted): 1 154
Included observations: 154 after adjusting endpoints

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| WAO3GSP | 2.08E-07 | 3.72E-07 | 0.560602 | 0.5759 |
| WAO3POP | -3.03E-08 | 4.03E-08 | -0.751050 | 0.4538 |
| WAO3X1 | 0.012381 | 0.012163 | 1.017936 | 0.3104 |
| WAO3X2 | -0.014111 | 0.011905 | -1.185290 | 0.2379 |
| WAO3X3 | 0.011305 | 0.009813 | 1.152003 | 0.2512 |
| WAO3X4 | -0.016047 | 0.009461 | -1.696157 | 0.0920 |
| WAO3X5 | -0.000750 | 0.008246 | -0.090940 | 0.9277 |
| WAO3X6 | -0.007332 | 0.008730 | -0.839853 | 0.4024 |
| WAO3X7 | 0.006020 | 0.007634 | 0.788544 | 0.4317 |
| WAO3YR | 0.000114 | 7.92E-05 | 1.433535 | 0.1539 |

| | | | |
|---|---|---|---|
| R-squared | 0.172372 | Mean dependent var | 0.089818 |
| Adjusted R-squared | 0.120645 | S.D. dependent var | 0.023170 |
| S.E. of regression | 0.021727 | Akaike info criterion | -4.757764 |
| Sum squared resid | 0.067979 | Schwarz criterion | -4.560560 |
| Log likelihood | 376.3479 | Durbin-Watson stat | 1.792250 |

# Carbon Monoxide Regressions

Dependent Variable: WACO
Method: Least Squares
Date: 12/10/02 Time: 17:28
Sample(adjusted): 1 193
Included observations: 193 after adjusting endpoints

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| WACOGSP | -9.25E-06 | 2.89E-05 | -0.319999 | 0.7493 |
| WACOPOP | -8.98E-06 | 4.17E-06 | -2.154485 | 0.0325 |
| WACORAIN | -0.029505 | 0.070846 | -0.416460 | 0.6776 |
| WACOTEMP | 0.153931 | 0.160903 | 0.956670 | 0.3400 |
| WACOX1 | 1.434438 | 1.612916 | 0.889344 | 0.3750 |
| WACOX2 | 1.837085 | 1.013816 | 1.812049 | 0.0716 |
| WACOX3 | 0.738523 | 0.955391 | 0.773005 | 0.4405 |
| WACOX4 | 0.699764 | 1.134589 | 0.616756 | 0.5382 |
| WACOX5 | 1.262148 | 0.810486 | 1.557272 | 0.1212 |
| WACOX6 | 1.443355 | 0.680353 | 2.121480 | 0.0352 |
| WACOX7 | 0.465624 | 1.187484 | 0.392110 | 0.6954 |
| WACOYR | 0.023355 | 0.011246 | 2.076720 | 0.0392 |

| | | | |
|---|---|---|---|
| R-squared | 0.506135 | Mean dependent var | 7.556995 |
| Adjusted R-squared | 0.476121 | S.D. dependent var | 2.724095 |
| S.E. of regression | 1.971686 | Akaike info criterion | 4.255815 |
| Sum squared resid | 703.6461 | Schwarz criterion | 4.458676 |
| Log likelihood | -398.6861 | Durbin-Watson stat | 1.977020 |