A summary overview

Tracking global transport of pollutants

Challenges to U.S. health and international trade

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Introduction

Pollution from U.S. and international sources affects agricultural production and public health in Oregon and the rest of the world. At the same time, agriculture in the past used chemicals that still create risks from pollution today and agriculture currently relies on a number of chemicals and management practices that are defined as pollutants when misused. While U.S. producers follow strict regulations, international producers may not be similarly constrained or at least observant of requirements. Because many international competitors in agriculture do not fully incorporate their environmental costs into their prices or exercise the same level of care as do Oregon producers, the international competitors' gain an advantage. Their products can be sold at lower prices thereby reducing revenues and markets for Oregon agricultural products.

How can Oregonians' health be protected from globally transported and locally generated pollutants? How can the field of competition be leveled in terms of management costs for environmental quality and the resulting prices for agricultural and many other goods produced in Oregon?

To address these questions, decision makers need careful analyses that can show the current levels of pollution and their sources, models of how pollutants are transported, how they change over time and predictions of future pollutant levels including their potential effects.

Scientists from the OSU College of Agricultural Sciences are addressing these issues from a number of perspectives. A particularly far reaching effort is under the direction of Staci Massey Simonich, professor of environmental and molecular toxicology at OSU. Simonich, her U.S. and international colleagues, and graduate students are using OSU Agricultural Experiment Station, federal (National Institutes of Health, National Science Foundation, and National Park Service), and private funds to measure, analyze, and explain the effects of pollutants that are globally transported. Their studies range from the health impacts of burning coal and biomass fuels on people in the United States and China to the effects of globally transported pollutants on the pristine environments of national parks.

[1] Numerous scientists gave freely of their time for interviews and offered helpful suggestions. In particular, Staci Massey Simonich, professor, Department of Environmental and Molecular Toxicology. Gwil Evans edited this report and Elizabeth Webb, both of the College of Agricultural Sciences, also provided many useful ideas that increased the report's clarity.

In this brief analysis we estimate the portions of the Oregon economy that this research affects. We provide:

- An **overview of the Oregon economy and the agriculture and food industry** to which the research discoveries contribute;
- A profile of **how environmental factors affect the Oregon economy**;
- An **economic estimate and specific examples** of how workers and the Oregon economy are affected by the pollution that the OSU research addresses;
- An **estimate of the economic effects of the research dollars** that OSU research brings into the state;
- An **example of benefits beyond the market** that are provided by the research; and
- An **option to consider that could enhance the economic effects** of the tracking global pollutants research.

Overview of the agriculture and food industry and other industries that are impacted by this research

Every economy is highly dependent on the productivity of its labor force and its quality of life is an important factor necessary to recruit and retain a productive workforce and for businesses to hire that workforce. Oregon's efforts to maintain and improve its natural environment have earned it a reputation as an environmentally responsible state with an excellent quality of life. That reputation has helped Oregon develop a creative and productive workforce and a diverse set of industries.

Pollutants from both U.S. and international sources can have a significantly negative impact on worker productivity in terms of increased incidence of both disease and death. Based on the most currently available 2009 data from the Bureau of Economic Analysis, Oregon has approximately 2.2 million jobs,[2] $142.1 billion in personal income,[3] and net state product of $153 billion.[4]

Because all agricultural production is susceptible to the effects of pollution, understanding and minimizing pollution is critical to the agriculture and food industry. The Oregon agriculture and food industry directly supports 261,000 jobs, which is twelve percent of the workforce, $11 billion in net product or seven percent of the statewide total, and is economically linked to 423,000 jobs, which is 19 percent of the statewide total, and $23 billion in net product or 15 percent of Oregon's net production.[5]

[2] SA25N - Total full-time and part-time employment by NAICS industry (2009 data) 2011. *Regional Economic Accounts.* U.S. Department of Commerce - Bureau of Economic Analysis. http://www.bea.gov/regional/spi/
[3] SA05N - Personal income by major source and earnings by NAICS industry (2010 preliminary data) 2011. *Regional Economic Accounts.* U.S. Department of Commerce - Bureau of Economic Analysis. http://www.bea.gov/regional/spi/
[4] MIG, Inc., IMPLAN System (2009 data and software) 2011. 502 2nd Street, Suite 301, Hudson, WI 54016. http://www.implan.com
[5] Ibid

How environmental factors affect labor productivity and the public

Air pollutants cause a number of chronic disease (morbidity) effects like chronic bronchitis or cough, restricted activity and congestive heart failure and can have mortal health effects by shortening life particularly for those with respiratory diseases like asthma.[6]

Since pollutants are typically a contributing though not the only factor related to morbidity and mortality, the estimates of the health effects attributable to pollutants vary from study to study.[7, 8]

Still, "…the air contains varying levels of pollutants originating from motor vehicles, industry, housing, and commercial sources. The effects of air pollution have multifaceted consequences for human welfare in areas such as health, agriculture, and the ecosystem…" [9]

"The overall transport of pollutants in the free atmosphere of the middle latitudes is from west to east due to prevailing westerly winds."[10] Depending on the time of year, between 3 and 30 percent[11] of the pollutants in Oregon originate from outside Oregon and the U.S. and are transported to Oregon by prevailing winds. The portions of pollutants that are transported into Oregon from other countries have the potential to overload our environmental capacity to the point that we cannot provide for the health and productivity of Oregonians. Oregon may need to reduce production or add costly technology to production facilities to "make room" for the inflow of internationally generated pollutants thereby increasing the costs of Oregon industries and reducing their competitiveness.

A 1999 analysis by the U.S. Environmental Protection Agency notes:
"For example, regulation of emissions from the electric utility industry that results in higher electricity rates would have both supply-side and demand-side responses. In secondary markets, the increased electricity rates affect production costs for various industries and initiate behavioral changes (e.g., using alternative fuels as a substitute for electric power). With each affected market, there are also associated externalities that should be included (to determine the total costs of pollution to society)."[12]

Particulate matter (PM) comprises a range of components from soot to soil and offers an example of the difficulty of precisely determining the effects of pollutants. PM is categorized by size and composition. Particles that are of particular concern measure less than 10 (PM_{10}) or 2.5 ($PM_{2.5}$) micrometers. Estimating the composition and deposition, as well as the impacts, of particulate matter is complex.

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[6] Yang, Trent, Kira Matus, Sergey Paltsev and John Reilly 2004/2005. *Economic Benefits of Air Pollution Regulation in the USA: An Integrated Approach*. MIT Joint Program on the Science of Policy of Global Change. MIT E40-428, Cambridge, MA 02139-4307(USA). pp. 7-8.
[7] Ibid
[8] Pervin, Tanjima, Ulf-G Gerdtham and Carl H Lyttkens 2007. *Societal costs of air pollution-related health hazards: A review of methods and results*. Cost Effectiveness and Resource Allocation 2008, 6:19.
[9] Ibid
[10] Kolb, Charles E. Chair – Committee on the Significance of International Transport of Air Pollutants 2010. *Global Sources of Local Pollution – An Assessment of Long-Range Transport of Key Air Pollutants to and from the United States*. National Research Council of the National Academies. Washington, D.C.: The National Academies Press. p. 19 and Appendix B.
[11] Interview with Staci Simonich, June 1, 2011.
[12] United States Environmental Protection Agency 1999.*The Benefits and Costs of the Clean Air Act 1990 to 2010.* EPA-410-R-99-001.

To characterize the extent of the negative impacts of any pollutant, including particulate matter, on the net state product of Oregon, one may estimate what *proportion of production is lost* to pollutants. Or, one may estimate the *per capita cost* of pollution. In addition, it can be helpful to focus on *specific examples* that demonstrate how pollutants can affect products and the people who produce them, such as the effect of ozone on crops, or the extent to which air pollution exacerbates a disease like asthma.

What proportion of state product is lost to pollution?

Estimates from studies of the negative effects of pollution on gross domestic product from a number of countries range from 0.35 to 4.4 percent.[13] These estimates are confounded because most of the studies consider pollutant exposure when people are outdoors and most people in developed countries spend the majority of their time indoors. Considering this limitation, a rough estimate of the effects of pollution in Oregon is approximately 2 percent of net state product.

Detail on our calculation of the loss of state product is provided in Appendix A, section 1. In summary, however, we estimate that more than 79,000 full- and part-time jobs are lost as a consequence of the effects of pollution at a cost of almost $5.8 billion to the state's economy.

What are per capita costs of pollution?

Per capita cost is another way of looking at the negative effects of pollution. Per capita cost estimates of pollution range from less than a dollar to $2,000.[14] The broad range of these estimates to some degree reflects uncertainty related to monetizing negative effects of pollution, but to a greater degree it emphasizes the importance of determining *what variables* the researcher is considering. For this analysis, we focus on how reduced productivity and a less efficient economy affect all Oregonians. In our per capita estimate, we have not included estimates from projections that have a much higher variance (such as quality of life and longevity of life). Our rough estimate of the per capita effects of pollution's negative impacts on worker productivity and the economy is *$20 per year for each Oregonian*.[15] The calculation of total cost, then, is this: Oregon population of 3,834,074[16] X $20 = $76,681,480 annually.

A specific example: grain crops

While the agriculture and food industry can cause pollution, voluntary and required changes in management practices built on research from the OSU College of Agricultural Sciences and other research institutions over many years have reduced the levels of pollution from U.S. agriculture.

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[13] I Pervin, Tanjima, Ulf-G Gerdtham and Carl H Lyttkens 2007. *Societal costs of air pollution-related health hazards: A review of methods and results*. Cost Effectiveness and Resource Allocation 2008, 6:19.
[14] Ibid.
[15] Ibid.
[16] Ann Saker December 21, 2010. *Census shows Oregon's population robust but clearly slowing by 2010.* The Oregonian.

Concerns are shifting from U.S. agriculture as a *source* of pollution to agriculture and food production being *negatively impacted by pollution*—particularly by ozone. While ozone in the upper atmosphere protects the earth from harmful levels of ultraviolet radiation, at ground level ozone can be harmful to humans, other animals, and crops.

The USDA Agricultural Research Service asserts: "Ground-level ozone causes more damage to plants than all other air pollutants combined…Ozone is formed in the troposphere when sunlight causes complex photochemical reactions involving oxides of nitrogen (NOx), volatile organic hydrocarbons (VOC) and carbon monoxide that originate chiefly from gasoline engines and burning of other fossil fuels. Woody vegetation is another major source of VOCs. NOx and VOCs can be transported long distances by regional weather patterns before they react to create ozone in the atmosphere, where it can persist for several weeks."[17]

Research on the crop effects of ozone has been underway for 40 years. The most representative Oregon crop that has been studied is wheat. Up to a 25 percent loss was recorded in field trials of winter wheat in the 1980's.[18] Environmental Protection Agency estimates suggest an upper bound on lost production of 9.11 percent due to ozone.[19]

Detail on our calculation of the economic effect of pollution on grain crops is provided in Appendix A, section 2. In summary, however, we estimate that a reduction in Oregon grain production by approximately 10 percent results in the loss of more than 1,000 full- and part-time jobs; reduces labor income by more than $9.5 million, and reduce the value of grain production by more than $55 million.

Another specific example: asthma

People with asthma are particularly susceptible to the negative effects of airborne pollutants. "In 2009, Oregon ranked among the top five states with the highest proportion of adults with asthma in the nation."[20] Oregonians who have been diagnosed with asthma are 11.1 percent of the adult population.[21]

Workers in 65 percent of Oregon's jobs encounter ambient fine particulate matter of 10 micrometers or greater, and 72 percent of Oregon's industrial enterprises emit similar ambient fine particulate matter. These "…levels of fine particles decrease lung function, can trigger asthma attacks, and increase emergency department visits for asthma."[22]

[17] United States Department of Agriculture/Agricultural Research Service 2010. *Effects of Ozone Pollution on Plants*. http://www.ars.usda.gov/Main/docs.htm?docid=12462
[18] Ibid.
[19] United States Environmental Protection Agency 2010.Report on the Environment. http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewInd&lv=list.listbyalpha&r=219646&subtop=381
[20] Garland, Rodney, MS, Oregon Asthma Program Epidemiologist 2010. *The Burden of Asthma in Oregon: 2010.* Health Promotion and Chronic Disease Prevention Section, Office of Disease Prevention and Epidemiology, Public Health Division, Oregon Health Authority. http://public.health.oregon.gov/DiseasesConditions/ChronicDisease/Asthma/Pages/burdenrpt.aspx
[21] Centers for Disease Control and Prevention (CDC) 2010. *Behavioral Risk Factor Surveillance System Survey Data*. Atlanta, Georgia: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention.
[22] Garland 2010. p. 29.

If Oregon's workforce has asthma at about the same rate, 11.1 percent, as the adult population in Oregon and is vulnerable to asthma attacks or at least some reduced level of productivity when particulate matter in the atmosphere equals or exceeds 10 micrometers and 65 percent of the jobs are in that type of environment, then at least 158,400 jobs are experiencing reduced production due to higher levels of particulate matter in the air (11.1 percent X 65 percent = 7.2 percent; workers in 2.2 million jobs X 7.2 percent = 158,400).

Economic effects of research dollars received from outside Oregon

A more modest yet significant economic effect of the OSU scientists' work is from the research funding that is awarded from outside the state and spent primarily within the state. The funding is approximately $600,000 annually. Sixty percent is spent for salaries, thirty percent for supplies, and ten percent for equipment. Table 1 summarizes the economic effects of the research expenditures in Oregon. Each dollar of outside funds that is received is spent and respent to more than double the original dollars ($1,227,719 total spending minus the $600,000 original spending = $627,719).

Table 1. Effects of OSU research funding received from outside Oregon

Type of Effect	*Employment Full & Part-time Jobs*	*Labor Income ($)*	*Net Product/Value Added ($)*	*Output ($)*
Direct Effect	6	360,000	360,000	600,000
Indirect Effect	2	84,150	130,135	214,766
Induced Effect	4	137,383	246,239	412,953
Total Effect	12	581,533	736,374	1,227,719

Contributions beyond the market

To this point, the examples have been based on well-established markets. Many of the places and environmental attributes that are damaged by airborne pollutants and affected or protected by this research are not directly traded in established markets. A person may never even visit or use a pristine place or spend a dollar getting to or visiting that place, yet that person may benefit from and be willing to pay to protect those places from globally transported pollutants. A study in which the Simonich team participated was the Western Airborne Contaminants Assessment Project (WACAP). Simonich was one of the principal authors of the final report.[23]

[23] Landers, Dixon et al. 2008. *The Fate, Transport, and Ecological Impacts of Airborne Contaminants in Western National Parks (USA) – Final Report: Volume I.* U.S. Environmental Protection Agency EPA/600/R-07/138. http://www.nature.nps.gov/air/studies/air_toxics/docs/2008FinalReport/WACAP__Report_Volume_I_Main.pdf

The study measured a range of pollutants in 20 national parks; Crater Lake National Park was among them. Globally transported pollutants had reached even remote locations in those parks. "Semi-volatile organic compounds (SOCs) and heavy metals were the primary focus of the study. The SOCs fall into four general classes: current-use pesticides (CUPs), North American historic use pesticides (HUPs), industrial/urban use compounds (IUCs), and combustion byproducts. The primary heavy metal of concern is mercury (Hg)…Contaminants were found in all WACAP lakes." [24] Simonich also conducts research using data gathered from around Oregon including Mt. Bachelor, Mary's Peak, and the Confederated Tribes of the Umatilla Indian Reservation.

Measuring the value of maintaining natural environments, due to the lack of market information, is certainly imprecise. Still, economists have completed a great deal of research and developed an extensive number of reports and articles analyzing the ecological services that places like national parks provide. Also, during the 1980's and 1990's economists estimated the nonuse or passive use values that Americans assign to natural environments. A study in 2009 by Bruce Peacock, National Park Service economist, estimated the value to U.S. households of ecological services of the natural environment on the Lower Colorado River at $26.25 per household per year.[25] Interestingly, an exhaustive review in 1993 by Thomas Brown, U.S. Forest Service economist, estimated nonuse and use values (e.g. recreation) of an extensive number of natural environments per household per year between $19 and $36 (when converted to 2011 dollars).[26]

Using Peacock's specific estimate and Brown's earlier work, $26.25 per household per year seems to be a reasonable—and probably conservative—estimate of the value of maintaining pristine natural environments. There are 1,464,196 households in Oregon.[27] An estimate of the annual value Oregonians place on the types of natural places that Simonich's research addresses is $38.5 million.

The OSU global transport of pollution research program: Options to enhance economic contributions

Simonich and her colleagues have successfully competed for grants to fund this research. She currently leads a laboratory with five graduate students and five faculty scientists and technicians, yet the funding is provided for specific purchases.

It is important for scientists who study pollutants that are transported into Oregon to go to the source or suspected source of those pollutants to understand their origins and determine the likelihood that the pollutants can be mitigated at the source or will require management in Oregon. An example of the need for this type of research was Simonich's analysis and reporting

[24] Ibid. pp. E-1 and E-15

[25] Peacock, Bruce 2009. *Economic Values of National Park System Resources Within The Lower Colorado River Basin: A Compilation of Existing Data and Proposal for Future Work.* National Park Service, U.S. Department of the Interior. Fort Collins, Colorado. http://www.usbr.gov/uc/rm/ amp/twg/mtgs/09jun22/ NH_WhitePaper.pdf

[26] Brown, Thomas C. 1993. *Measuring Nonuse Value: A Comparison of Recent Contingent Valuation Studies W-133*. U.S. Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins Colorado. http://www.fs.fed.us/rm/value/docs/Brown-nonuse%20value-W133.pdf

[27] U.S. Census Bureau 2011. State and County QuickFacts – Oregon. http://quickfacts.census.gov/ qfd/states/41000.html

from the 2008 Beijing Olympics. The Chinese were committed to minimizing pollution during the Olympics. Simonich was able to help with those efforts and develop valuable baseline data. She personally financed most of those travel costs.

The tragic earthquake that struck Japan on March 11, 2011, provides another example of situations in which there is a need for OSU researchers to investigate a source of pollution, or to focus local monitoring efforts on pollutants that may affect Oregon, or both. The potential to affect Oregon was significant for pollutants from radiation leaks and other sources in aftermath of the Japanese quake and tsunami. Without funds available on short notice, the ability of OSU scientists to measure potential danger to Oregonians was limited. A modest investment of approximately $50,000 per year would help provide for mobilization and shipping of equipment, and for travel costs for scientists, thus helping inform valuable, protective steps for Oregon's economy and environment.

For additional information, please direct questions to:

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Economic	Bruce.Sorte@oregonstate.edu	or 541-231-6566

Reference websites

http://oregonstate.edu/superfund/project6

http://toxics.usgs.gov/definitions/pah.html

Appendix A

Introduction to economic estimate

To estimate the economic impacts of research programs like Simonich's, one must determine the magnitude of the problem in Oregon that her research addresses: the negative impacts of pollution on workers and industry. Because we have not found direct ways to precisely attribute to Simonich's work a reduced level of pollutants or a resulting increase in the Oregon net state product, we have provided conservative estimates and examples of the problems on which her lab is focused.

It is important to note that Simonich's laboratory in the College of Agricultural Sciences at OSU is the only one in Oregon studying global transport of pollutants to Oregon. In this section, we sketch the magnitude of the industrial output that Simonich and other OSU scientists help to protect.

In the prior sections, we described four ways to portray the economic effects of pollutants:
1) percentage reduction of net state product,
2) per capita cost,
3) a specific example (wheat or grain crops) from the agricultural and food industry, and
4) a specific example of the productivity effects caused by one of the health problems (asthma) related to air borne pollutants.

In the following two sections, we provide additional detail on estimates of the economic effects of items (1) and (3) above. *The effects from each approach must stand on their own and not be added together. They represent different ways to make such estimates and they overlap with one another.*

Appendix A, Section 1:
Pollution reduces the state product

Measuring a two percent change in Oregon's economy as the result of pollution may be carried out using an input-output model (IMPLAN) and "shocking" it with the change. Table 2 shows a two percent change in the Oregon economy in a two digit North American Industrial Classification System summary. It expresses the effects in terms of jobs and net state product or the value-added income that could be lost. These effects could include everything from reduced availability of clean water for production processes or residential use to reduced tourism due to inversion layers that are accentuated and made more dangerous by airborne pollutants.

Table 2. Effects of pollutants reducing state product by two percent

Description	*Employment - Full & Part-time Jobs*	*State Product/Value Added ($)*
Total	**79,319**	**5,788,235,678**
Ag, Forestry, Fish & Hunting	2,631	99,652,635
Mining	161	9,713,616
Utilities	228	101,542,372
Construction	2,690	151,150,234
Manufacturing	4,622	534,346,994
Wholesale Trade	3,055	406,431,664
Retail trade	8,765	428,116,753
Transportation & Warehousing	2,670	187,468,711
Information	1,496	217,622,106
Finance & insurance	4,450	513,863,717
Real estate & rental	4,969	888,037,591
Professional- scientific & tech svcs	6,384	438,594,943
Management of companies	1,292	146,624,482
Administrative & waste services	5,467	222,570,586
Educational svcs	1,863	50,186,165
Health & social services	9,327	511,166,829
Arts- entertainment & recreation	2,160	43,659,909
Accommodation & food services	5,781	188,705,104
Other services	4,030	151,121,408
Government	7,278	497,659,858

Appendix A, Section 2:
Calculating consequences of pollution for the state's grain crops

Table 3 shows the ***direct effects*** or the first-round spending in grain crops; ***indirect effects*** or spending with suppliers; and ***induced effects***, which are created by workers and business owners in grain farming and their suppliers at all levels spending their incomes within their communities.

Table 3. Effects of ozone reducing Oregon grain production by ten percent

Type of Effect	*Employment Full & Part-time Jobs*	*Labor Income ($)*	*Net Product/Value Added ($)*	*Output ($)*
Direct Effect	887	2,309,259	11,286,322	30,098,278
Indirect Effect	167	5,188,617	9,578,650	18,296,206
Induced Effect	58	2,251,948	4,042,197	6,772,356
Total Effect	1,112	9,749,824	24,907,169	55,166,840