Pesticide Usage as Influenced by Climate: A Statistical Investigation

Chi-Chung Chen
National Chung Hsing University

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Chi-Chung Chen
Assistant Research Scientist
Department of Agricultural Economics
Texas A&M University
College Station, TX.
chen@dust.tamu.edu
(409)845-3153

Bruce A. McCarl
Professor
Department of Agricultural Economics
Texas A&M University
College Station, TX.
mccarl@tamu.edu
(409)845-1706

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Abstract

The effects of climate change on agricultural pesticide populations has been an open question. We examine this question statistically using data on pesticide usage costs as they vary across the U.S. Empirically, we find that more rainfall increases pesticide usage costs for corn, wheat, soybeans, and potatoes while hotter weather increases pesticide costs for corn, cotton, soybeans, and potatoes but decreasing the cost for wheat. We also found that hotter temperature increases the variance of pesticide costs for corn, cotton and potatoes while decreasing it for soybeans and wheat. A rainfall increase is found to increase the pesticide cost variability for cotton while decreasing that for soybeans, wheat and potatoes.

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Considerable attention has been devoted to agricultural effects of climate change as reviewed by Lewandrowski et al. and Adams et al. One issue that has been discussed has involved how changes in climate might change pest populations and in turn the costs of pest treatment. However, evidence on the nature of such cost increases is lacking in literature. This paper reports on a statistical analysis of how changes in climate appear to have altered observed average costs and variability of pesticide use. This will be done using a statistically based approach much as done in Mendelsohn et al to infer how costs of pesticide usage are influenced by temperature and precipitation change. This be done using a pooled time series cross-sectional data series on agricultural pesticide usage drawn the USDA pesticide usage surveys coupled with NOAA regional weather series. We investigate the effects of climate alterations for U.S. corn, wheat, cotton, soybeans and potatoes.

Data

State level pesticide usage for corn, wheat, cotton, soybeans and potatoes from 1991 to 1997 were drawn from *Agricultural Chemical Usage*, USDA, ERS. These data give statistical survey based average use data for various insecticide, herbicides, and fungicides compounds by crop and year. The compounds reported by crop are identified in table I. The states for which data were available vary by crop and are listed in table II. In this study a total cost of pesticides was computed by multiplying the pesticide use by category by annual prices from the 1997 USDA *Agricultural Resources and Environmental Indicators* report. We use aggregate total cost data to reflect pesticide substitution as climate and pesticide prices vary.

Associated climate data were also needed. Climate data were drawn from the NOAA home-page. The rainfall data used were cropping year totals to reflect not only cropping season supply but also water stored in soil or irrigation delivery systems. Temperature data used were the March to September average for all crops except for winter wheat areas. In winter wheat areas for the wheat pesticide costs we used the October to April temperature data. State level temperature and rainfall data were derived by averaging all data for weather stations in a region.

Methods

This study used the approach laid out by Just and Pope to estimate both average pesticide cost and the variance of pesticide cost. Under that approach we estimate a function of the form

$$(2) \quad y = f(X) + h^{\frac{1}{2}}(X)e$$

where y is total pesticide cost per acre, and X is a set of independent explanatory variables including temperature and rainfall. Just and Pope show that after estimation f(X) gives the average effect of the independent variables on pesticide cost, while h(X) (the square of the function estimated) gives the effect of the independent variables on variance. Just and Pope propose either using feasible generalized least squares(FGLS, or called three steps) or maximum likelihood(ML) to estimate the f(X) and h(X) functions. Saha et al. found that the estimators under ML approach are more consistent and efficient. Therefore, a ML estimation approach will be adopted in this paper. In turn by examining $h^{1/2}(x)$ if the marginal effects of any independent variable are positive then increases in that variable increase the standard deviation of pesticide cost while a negative sign implies increases in that variable reduces the pesticide cost variance.

Results

The estimated impacts of rainfall and temperature on pesticide cost and its variability by climate are displayed in tables III to VI. The estimation results in table III show that the impacts of the pesticide usage cost by climate. Table IV contains the computed percentage change in cost due to the per percentage change in the climate characteristics using the data in table III. We find that the impacts of precipitation on pesticide usage cost for these five crops are all positive and significant except for cotton. This indicates that increased rainfall increases pesticide cost. For example, when rainfall increases by one percent, we compute that corn pesticide costs increase by 1.49 percent. We find mixed effect of temperature. A one percent temperature increase (measured in degrees Fahrenheit) increases potatoes costs by 2.67 percent. Corn, cotton, and soybeans costs also increase with temperature but wheat costs decrease.

The impacts of climate on the variability of pesticide usage cost are more complicated and are displayed in tables V and VI. We found that a hotter temperature increase the variance of pesticide cost for corn, cotton and potatoes while decreasing it for soybeans and wheat. For example, the results shows that a one percent increase in temperature will increase the corn year to year cost variance by 6.96 percent. A rainfall increase is also found to increase the pesticide cost variability for cotton while decreasing that for soybeans, wheat and potatoes.

Finally and for perspective we used the regional estimates of climate change arising under the Canadian and Hadley simulators used under the US Global Climate Change Research Program's National Synthesis using the 2090 climate projections to obtain estimates of the effects of projected climate change on pesticide usage cost for selected crops in selected regions. These involved plugging the projected precipitation and temperature changes for the selected regions into the formulas and computing the projected pesticide usage cost in the tables IV. The results are given in table VII show uniform increases in corn, soybeans, cotton, and potatoes pesticide usage cost and mixed results for wheat.

Concluding Comments

An investigation of regional pesticide cost data shows systematic variations as climate characteristics change. Average per acre pesticide usage cost for corn, soybeans, wheat, and potatoes increases as precipitation increases. Similarly, average pesticide usage cost for corn, cotton, soybeans, and potatoes increase as temperature increases while the pesticide usage cost for wheat decreases. Climate also affects the year to year variability of pesticide cost with more rainfall decreasing cost for soybeans, wheat, and potatoes but increasing it for cotton. Increased temperature reduces the variability of pesticide cost for soybeans and wheat but increases it for corn, cotton, and potatoes. Finally, note this work is limited by a lack of coverage of altered CO_2 effects since meaningful variation in the CO_2 level is not observable in the sample.

Table I. Type of Pesticides Used by Crop

	CORN	COTTON	SOYBEANS	WHEAT	POTATOES
HERBICIDES					
2-4, D	x		x	x	
Alachlor	x		x		
Atrazine	x				
Bentazon			x		
Butylate	x				
Chlorimuron			x		
Cyanazine	x	x			
Dicamba				x	
Glyphosate		x		x	x
Imazquin			x		
MCPA				x	
Metolachlor	x	x	x		x
Metribuzin			x	x	x
Pendimethalin		x	x		x
Sethoxydim			x		
Trifluralin		x	x	x	x
INSECTICIDES					
Aldicarb		x			
Carbaryl					x
Carbofuran	x				x
Chlorpyrifos	x	x		x	
Dimethoate		x		x	x
Esfenvalerate		x			x
Fonofos	x				x
Methomyl		x			
Methyl Parathion		x	x	x	x
Permethrin				x	x

Phorate		x			x
Terbufos	x				
FUNGICIDES					
Chlorothalonil					x
Mancozeb					x
Maneb					x
Metalaxyl					x

(Note): The pesticides reported in table 1 cover the major pesticide groups used for each crop. Other pesticides may be used but are minor.

Table II. States for Which Pesticide Data Are Available by Crop

Crop	State
CORN	IL, IN, IA, MI, MN, MO, NE, OH, SD, WI.
COTTON	AZ, AR, CA, LA, MS, TX.
SOYBEANS	AR, IL, IN, IA, LA, MN, MS, MO, NE, OH, TN.
WHEAT	CO, ID, KS, MN, MT, ND, NE, OK, OR, SD, TX, WA.
POTATOES	CO, ID, ME, MI, MN, NY, ND, OR, PA, WA, WI.

Table III. Regression Results for Effects of Climate on Per Acre Pesticide Cost

Crop	Precipitation	Temperature	Constant
CORN	0.7351	0.9222	-30.183
	(25.85)	(19.00)	(-11.30)
COTTON	0.0059	0.9730	-17.213
	(0.26)	(8.39)	(-2.27)
SOYBEANS	0.0632	0.5523	32.343
	(3.78)	(13.22)	(15.04)
WHEAT	0.1211	-0.1160	7.7950
	(29.25)	(-21.30)	(24.41)
POTATOES	1.3684	2.5914	-89.564
	(22.76)	(11.99)	(-7.54)

(Note): Temperature is measured in degrees Fahrenheit and rainfall is measured in inches.

Table IV. Percentage Change in Pesticide Cost for a One Percent Change in Average Climate Measures Unit:%

	Precipitation	Temperature
CORN	1.49	1.87
COTTON		1.94
SOYBEANS	0.09	0.78
WHEAT	2.86	-2.74
POTATOES	1.41	2.67

(Note): The percentage change for pesticide cost is computed by dividing the coefficient parameters in table 3 by the U.S. average pesticide cost for a crop across all years and places.
Results are only computed for estimated parameters with t ratios which exceed 1.9.
Temperature percentage change is based on degrees Fahrenheit and rainfall percentage is based on inches.

Table V. Regression Results on Influence of Climate on Variance of Pesticide Usage Cost

	Precipitation	Temperature	Constant
CORN	-0.0008	0.1179	-6.2453
	(-0.22)	(19.56)	(-19.93)
COTTON	0.0093	0.0497	-2.1377
	(4.03)	(3.65)	(-2.42)
SOYBEANS	-0.0190	-0.0500	4.4399
	(-7.52)	(-8.96)	(16.33)
WHEAT	-0.0489	-0.0225	0.4838
	(-25.45)	(-7.15)	(2.83)
POTATOES	-0.0372	0.1273	-3.4946
	(-12.00)	(8.25)	(-4.02)

(Note): Temperature is measured in degrees Fahrenheit and rainfall is measured in inches.

Table VI. Percentage Change in Variance of Pesticide Usage Cost for a One percent Change in Average Climate Measures

	Precipitation	Temperature
CORN		6.96
COTTON	0.39	3.44
SOYBEANS	-0.83	-3.20
WHEAT	-1.33	-1.34
POTATOES	-1.15	7.14

(Note): The percentage change for pesticide variability cost is computed by multiplying the coefficient parameters in table 5 by the average precipitation and temperature across all years and places.
Results are only computed for estimated parameters with t ratios which exceed 1.9.
Temperature percentage change is based on degrees Fahrenheit and rainfall percentage is based on inches.

Table VII. Percentage Increase in Crop Pesticide Usage Cost for 2090 Year by Scenario

	Canadian Climate Change Scenario					Hadley Climate Change Scenario				
	Corn	Soyb.	Cott	Wht	Pota.	Corn	Soyb.	Cott	Wht	Pota.
CA			5.16					4.69		
CO				-10.29	7.33				9.15	13.25
GA			4.23					2.66		
ID					21.03					15.42
IL	18.19	3.26				14.23	2.00			
IN	10.01	2.72				15.07	2.04			
IA	26.07	3.94				15.66	2.17			
KS				13.60					12.93	
LA			5.36					3.12		
MN		2.25			8.10		1.90			9.67
MT				-9.85					6.28	
MS			5.83					3.01		
ND					5.54					10.67
NE	3.35	2.69		-14.54		10.72	2.16		5.83	
OK				-3.48					12.34	
SD	17.08			8.88		14.73			13.96	
TX			5.41	-8.78				3.15	0.81	
WA					13.19					10.68

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