Pesticide Treatment Cost and Climate Change: A Statistical Investigation

Chi-Chung Chen
Assistant Professor
Dept. of Agricultural Economics
National Chung-Hsing University
Taichung, Taiwan

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

Seniority of authorship is shared. This research was partially supported by and is a contribution to the National Assessment of Climate Change , Agricultural Focus Group supported by the U.S. Global Climate Change Office.

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Abstract

One concern of agriculturalists concerning climate change involves the effects on pest populations. Climate change may allow pest migration or population expansions which may adversely affect agricultural productivity, and profitability. This paper examines the effect of current climate variations on the average and variability of U.S. pesticide treatment cost across the U.S. as a proxy for investigating the consequence of changing climate on pest populations. Empirically, the results show that climate change alters the average and variability of pesticide treatment costs. Over the whole U.S. 2090 projected climate change causes a reduction in producer and consumer welfare of about $200 million per year. On a crop by crop basis costs rise from 3-10%.

Pesticide Treatment Cost and Climate Change: A Statistical Investigation

Considerable attention has been devoted to the agricultural effects of climate change (see the reviews by Lewandrowski et al. and Adams et al 1998). However, a number of issues remain unresolved. One issue mentioned as an area in need of further study involves how changes in climate alter pest populations and in turn agricultural profitability. This paper reports on a study regarding that issue. The study was done as part of the US Global Climate Change Research Program sponsored Agricultural Sector study (for details see Reilly et al).

Basic Approach

An examination of the implications of climatic change for pest populations and farm profitability may be carried out in several different ways. Patterson et al pursued a deductive approach based on current experience with pest infestation, migration and viability thresholds. They concluded that climate change would shift pest populations since it would shift important determinants of pest incidence, namely temperature, precipitation distribution, and wind patterns. However, they only addressed the issue on a pest by pest basis and did not provide quantitative estimates of effects on productivity and/or profitability.

An alternative approach is possible based on economic concepts. An approach to measuring the economic consequences of environmental alterations involves the costs of averting behavior (Freeman). In the pest case, if infestations increase then farmers would avert subsequent damages by altering pest treatments. Furthermore, economic theory postulates that, on the margin, the costs of the altered pest population should be matched by the change in pest treatment cost (PTC). Thus, an approach to examining the profitability/productivity shift due to climate induced pest population shifts is to examine the way shifts in climate between regions and years alter the pattern of PTC.

Per acre PTC varies by crop, region, and year. Changes in climate from region to region and year to year influence pest population and incidence in turn altering: a) total per acre PTC, b) the mixture of compounds employed and c) the application rates for any given crop. Thus, an investigation of the way per acre PTC for a crop vary over alternative climates across time and space can be carried out to gain insight into how changes in climate affect pest populations and resulting PTC.

This paper reports a statistical analysis of the interrelationship between PTC and climate using an approach much like that used in Mendelsohn et al. Namely, regression analysis will be used to examine how per acre PTC is influenced by variations in temperature and precipitation. This regression is based on a multi year, multi location data series drawn from USDA pesticide usage surveys coupled with NOAA weather data.

Data

State level PTC data for corn, cotton, potatoes, soybeans and wheat from 1991 to 1997 were drawn from the USDA, ERS report *Agricultural Chemical Usage*. These data are survey based per acre averages of insecticide, herbicide, and fungicide use by compound, crop, location and year. The compounds reported by crop are identified in Table I. The state-crop combinations for which data were available are listed in Table II. Within this study a total per acre PTC was computed by summing over all compounds the amount used times the 1995 price (drawn from the 1997 USDA report *Agricultural Resources and Environmental Indicators*). Such a calculation implicitly considers the substitution of alternative pesticides as climate, and pest incidence varies. Note , usage of this data set only permits examination of the pesticide component of the climate/pest related costs and not any costs arising from alterations in tillage or other input usage. Also note the effect of altered CO_2 levels could not be observed since meaningful variation in CO_2 level is not observable in the data.

Associated climate data were drawn from a NOAA web-page. The rainfall data were added to annual totals to reflect not only cropping season supply, but also water stored in soils or reservoirs. Temperature data used were the March to September average for all crops except for wheat in winter wheat areas. In that case, October to April temperature data were used. State level temperature and rainfall data were derived as averages across all weather stations in a state.

Estimation Background

Pest populations conceivably could vary in either overall incidence or frequency of outbreaks. We wished to investigate how changes in climatic conditions altered both average PTC as well as variation in PTC. Thus, we needed a method which permitted estimation of functional relationships between climate measures and the mean and variance of PTC. McCarl and Rettig did such an estimation to investigate how changes in ocean upwelling and salmon smolt releases influenced total salmon catch using a statistical approach developed by Just and Pope. That approach will be used here. The function proposed for usage by Just and Pope is as follows:

$$y = f(x) + h(x)\, g$$

where

y is the dependent variable, in this case PTC per acre.

x is the independent variables, in this case precipitation, temperature and possible other factors.

$f(x)$ is a function to be estimated which, after estimation, tells how the average dependent variable value relates to the independent variables. In this case how average PTC is influenced by changes in temperature, precipitation and other factors.

$h^2(x)$ tells how the variance of the dependent variable relates to the independent variables(note this is the square of h(x)). In this case this function indicates how variance of PTC is influenced by changes in x

g is an error term.

Estimation of the model above requires specification of the independent variables x, estimation approach, exact functional forms for $f(x)$ and $h^2(x)$ and estimation method. Each is discussed below.

Specification of Independent Variables – x

Estimation of the model requires a choice of the independent variables, namely the choice of x. In this study we were primarily concerned with the effects of climate factors and did not have a lot of degrees of freedom in any state. Thus we opted for a simple specification with the x variables being temperature, precipitation and time (to pick up any systematic technical change in PTC). Other factors such as crop prices and substitute input prices could have been used but these effects do not vary across the places in the sample and their effects over time will be picked up by the panel estimation method employed as discussed next.

Estimation Approach -- Panel Data

The data to be used in the estimation are of a form that has commonly been called a panel (Baltagi). Statistical investigations of panel data characteristics have led to estimation processes which control for common factors influencing a member (state) over any repeated observations (such as soil or irrigation characteristics) or all members in a repeated observation(i.e. events broadly occurring during a year such as a drought or a high planting season price). Panel related considerations relative to fixed or random effects as well as time effects need to be resolved in setting up the estimation.

Panels can contain either fixed or random effects. Testing for such effects in essence asks whether there are state specific factors omitted from the model beyond temperature, rainfall and crop, which cause systematic shifts in PTC and need to be controlled for (through so called fixed effects) or whether those effects are random in nature. This is tested by using Honda's one way test statistic as presented in Baltagi (p.62). We found with 99% confidence that a random state effect existed for corn, potatoes, soybeans, and wheat PTC. However, the test result for cotton indicated the presence of state specific fixed effects so we included dummy variables for each state.

Second, the classical assumption when random effects are found is that the errors are panel member specific. However, these also could be caused by characteristics of the years (such as droughts or price expectations) that are above and beyond our climate variables and our use of a time trend to pick up technological change. Baltagi and Li present a series of tests to examine time effects.

The tests failed to reject the null hypothesis, indicating there is no systematic omitted time effect for PTC for any of the crops. This suggests that we do not need to control above and beyond the controls in the panel estimation process for the many economic variables (such as crop or input prices) that shift from year to year which might have influenced PTC.

Functional Form

The specific forms of f(x) and h(x) need to be chosen. For this study, we considered linear and log-linear(or Cobb-Douglas) functional forms for f(x) and $h^2(x)$. The best fitting functional form was determined by using a likelihood ratio test over the power transformation parameters associated with the dependent and independent variables via the Box Cox Transformation (Box and Cox 1964). In turn, the specific f(x) and $h^2(x)$ forms estimated for corn, potato, and soybean per acre PTC are linear

$$f(X,\beta) = \beta_0 + \beta_1 \cdot Rain + \beta_2 \cdot Temp + \beta_3 \cdot Time$$

$$h^2(X,\alpha) = \alpha_0 + \alpha_1 \cdot Rain + \alpha_2 \cdot Temp + \alpha_3 \cdot Time$$

where Rain is regional specific precipitation, Temp is regional specific temperature, and Time is time trend. The best $f(X,\beta)$ and $h^2(x,\alpha)$ for wheat are

$$\ln f(X,\beta) = \beta_0 + \beta_1 \cdot \ln Rain + \beta_2 \cdot \ln Temp + \beta_3 \cdot \ln Time$$

$$\ln h^2(X,\alpha) = \alpha_0 + \alpha_1 \cdot \ln Rain + \alpha_2 \cdot \ln Temp + \alpha_3 \cdot \ln Time$$

where ln is the natural log. Finally, the $f(X,\beta)$ and $h^2(X,\alpha)$ for cotton employ a log-linear function with fixed regional effect dummy variables. The functions are:

$$\ln f(X,\beta) = \sum_i \beta_{0i} D_{0i} + \beta_0 + \beta_1 \cdot \ln Rain + \beta_2 \cdot \ln Temp + \beta_3 \cdot \ln Time$$

$$\ln h^2(X,") \; ' \; "_0 \; \% \; "_1 (\ln Rain \; \% \; "_2 (\ln Temp \; \% \; "_3 (\ln Time$$

where i is the index of region(or state), and D_{0i} is a dummy variable for region i.

Form of Final Estimation

Since the Just and Pope functional form was introduced there have been a number of studies regarding best estimation method. This work culminated in Saha, Havenner, and Talpaz who recommend that a maximum likelihood approach should be used. Therefore, we will use a panel based MLE approach. In doing that approach, the functional form for each crop is incorporated into the log-likelihood function

(1) $$\ln L = -\frac{1}{2}[n * \ln(2 \quad) + \sum_{i=1}^{n} \ln(h^2(X_i, a)) + \sum_{i=1}^{n} \frac{(y_i - f(X_i, b))^2}{h^2(X_i, a)}].$$

The parameters " and $ are estimated via a single-stage nonlinear maximization of (1), under the assumptions that $y_i \sim N(f(X_i, b), h^2(X, a))$ and $e_{it} \sim N(0,1)$.

Results

The estimated impacts of rainfall and temperature on average PTC and it's variability are displayed in tables III to V. The estimation results in table III for f(x) show that the impacts on average PTC by climate while Table IV contains the computed percentage change in PTC due to a one percent change in the climate items (commonly called the elasticity). These results show increases in precipitation significantly increase PTC for all five crops. For example, when rainfall increases by one percent, we find that corn PTC increases by 0.45 percent. The results show mixed effects of temperature. A one percent increase in temperature (measured in degrees Fahrenheit) increases potato PTC by 1.41 percent. Corn, cotton, and soybeans PTC also increase with temperature but wheat costs decrease. Such results are not unreasonable since one could argue that wetter and hotter conditions are more hospitable for pests and diseases as is commonly argued when comparing southern and northern pest incidence(see for example the discussion in Patterson et al where such factors are argued as key determinants of weed and insect incidence). A different temperature effect for wheat is also not unexpected since much of the wheat is either winter wheat or grown in relatively higher latitudes where cold temperatures are more important than for the other crops.

The impacts of climate on h(x), the variability of PTC, are displayed in tables V and VI. The results show that hotter temperatures increase the variance of PTC cost for corn, potatoes, and wheat while decreasing it for soybeans and not changing it for cotton. For example, the results show that a one percent increase in temperature will increase the variance of PTC by 3.65 percent. A rainfall increase is also found to increase the PTC variability for cotton while decreasing that for corn, potatoes, soybeans, and wheat. Such results are again not unreasonable as hotter temperatures for the crops and less rainfall are generally found to be variance increasing causing greater fluctuations in pesticide use. The exception is precipitation for the relatively more drought tolerant cotton which experiences greater variances the wetter the climate and soybean precipitation influences which is less the hotter it is.

Size of Effects under Climate Change Projections

The total size of the PTC effects depend on the simultaneous effects of temperature and precipitation. The magnitude of the joint effect can be explored by employing climate change projections. We evaluated our estimated functions using the regional climate change projections that arose under the U.S. Global Climate Change Research Program's National Synthesis project. Table VII contains the estimated alterations in PTC for selected cases under the Hadley and Canadian climate change simulator 2090 projections (for details on the scenarios see the U.S. Global Change Research Program home page). The results show uniform increases in average PTC for corn, soybeans, cotton, and potatoes and mixed results for wheat. Table VIII presents parallel results for PTC variance and shows uniform variance increases for corn and potatoes with a decrease for soybeans and mixed effects for wheat and cotton.

The results may also be examined in terms of economic implications. Under the National Agricultural Assessment, the ASM model of McCarl et al. was used (much as in prior climate change assessments Adams et al 1990,1999) to investigate the consequences of climate scenarios on total sectoral performance (McCarl and Reilly). As part of that effort the results on average climate induced changes in PTC based on the above functions were factored into the climate impacts estimation. In turn we found PTC alterations due to climate change produced a negative impact reducing societal welfare by about $200 million per year (McCarl and Reilly present details on the total welfare exercise). Such a result offsets between 5 and 10% of the estimated gains to climate change found under the national assessment and amount to about 5% of current farm net income. It also amounts to about 3% of pesticide costs.

Concluding Comments

Many have argued that climate change may cause an increase in pest damages. This study conducted a statistical investigation to quantify the economic costs arising due to such factors. Specifically we examined how pest treatment costs varied over the climatic diversity observed across time and space in the United States as a way of examining how pest populations shift given climate alterations. The results show pest treatment costs under the 2090 projections of climate from the Hadley and Canadian simulators exhibit increases of 3-10% for corn, soybeans, cotton, and potatoes and mixed results for wheat. Factoring those changes into the U.S National Assessment framework shows a $200 million per year projected loss to society due to climate change related pesticide treatment cost effects. Such results show that with the onset of climate change there will be a need to evolve improved pest management strategies and that as argued in Patterson et al the "challenge from pests may increase".

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.

Table II. Crops and States for Which Pesticide Data were Available

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

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

Crop	Precipitation	Temperature	Time	Constant
CORN	0.6540	0.8200	-2.3465	-11.966
	(25.22*)	(18.38*)	(-30.01*)	(-4.88*)
COTTON	0.0242	0.9783	0.1253	1.6406
	(1.82*)	(6.12*)	(9.53*)	(1.76*)
POTATOES	1.3034	2.4479	9.8340	-109.34
	(24.17*)	(13.26*)	(34.26*)	(-10.82*)
SOYBEANS	0.0471	0.5719	-0.2080	32.647
	(2.81*)	(14.33*)	(-3.54*)	(15.94*)
WHEAT	0.6813	-1.5058	0.3793	4.6158
	(24.14*)	(-15.63*)	(31.35*)	(12.51*)

(Notes): Temperature is measured in degrees Fahrenheit and rainfall is measured in inches.
t-ratios are presented in parentheses and a * sign indicates 95% significance.
Cotton and Wheat functions are log-linear.

Table IV. Percentage Change in Per Acre Pesticide Treatment Cost for a One Percent Change in Average Climate Measures

Unit:%

	Precipitation	Temperature
CORN	0.45	0.98
COTTON	0.02	0.97
POTATOES	0.42	1.41
SOYBEANS	0.03	0.52
WHEAT	0.68	-1.51

(Notes): These data are computed by dividing the parameters in table III by U.S. average PTC and multiplying by the average climate condition for a crop.
Temperature percentage change is based on degrees Fahrenheit.

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

	Precipitation	Temperature	Time	Constant
CORN	-0.0117	0.1269	0.0968	-6.9528
	(-3.55*)	(21.35*)	(8.98*)	(-22.41*)
COTTON	0.3167	0.6848	-0.1089	-10.061
	(4.40*)	(0.74)	(-1.86*)	(-2.62*)
POTATOES	-0.0311	0.1666	-0.0016	-6.2325
	(-10.54*)	(11.13*)	(-0.08)	(-7.31*)
SOYBEANS	-0.0174	-0.0579	-0.0873	5.2119
	(-6.51*)	(-10.15*)	(-9.03*)	(18.41*)
WHEAT	-1.1365	3.6539	0.5042	-16.977
	(-16.79*)	(15.48*)	(17.19*)	(-18.98*)

(Notes): Temperature is measured in degrees Fahrenheit and rainfall is measured in inches. t-ratios are presented in parentheses and a * sign indicates 95% significance.

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

	Precipitation	Temperature
CORN	-0.01	0.15
COTTON	0.31	
POTATOES	-0.01	0.09
SOYBEANS	-0.01	-0.05
WHEAT	-1.13	3.65

(Notes):

Similar calculation as explained for Table IV.
Results are only computed for estimated parameters with t ratios which exceed 1.8.
Temperature percentage change is based on degrees Fahrenheit.

Table VII. Percentage Change in Pesticide Treatment Cost under alternative projected 2090 Climates

	Canadian Climate Model					Hadley Climate Model				
	Corn	Cotton	Potatoes	Soybeans	Wheat	Corn	Cotton	Potatoes	Soybeans	Wheat
CA		5.84					4.43			
CO			6.94		-9.28			12.62		7.65
GA		2.67					2.37			
ID			20.02					14.69		
IL	16.16			3.08		12.65			1.81	
IN	8.89			2.70		13.39			1.83	
IA	23.17			3.60		13.92			1.95	
KS					11.38					11.00
LA		3.71					2.41			
MN			7.69	2.28				9.21	1.82	
MT					-8.89					5.19
MS		3.78					2.42			
ND			5.24					10.16		
NE	2.97			2.86	-12.99	9.52			2.08	4.80
OK					-3.38					10.48
SD	15.18				7.29	13.09				11.87
TX		3.90			-7.88		2.43			0.53
WA			12.56					10.17		

Table VIII. Percentage Change in Variance of Pesticide Treatment Cost under alternative projected 2090 Climates

	Canadian Climate Change Scenario					Hadley Climate Change Scenario				
	Corn	Cotton	Potatoes	Soybeans	Wheat	Corn	Cotton	Potatoes	Soybeans	Wheat
CA		34.60					17.79			
CO			24.06		21.67			6.58		-8.82
GA		-4.44					8.01			
ID			17.51					6.70		
IL	43.06			-89.70		12.77			-63.37	
IN	59.06			-60.89		10.58			-66.44	
IA	33.60			-119.42		12.71			-69.30	
KS					-13.27					-15.65
LA		-0.54					3.61			
MN			15.72	-46.67				6.34	-49.65	
MT					20.81					-5.01
MS		-4.51					4.84			
ND			25.21					6.60		
NE	88.08			-42.66	28.34	34.71			-55.91	-4.35
OK					11.40					-14.63
SD	57.22				-6.20	19.61				-16.78
TX		1.95			17.78		3.49			1.78
WA			7.92					10.42		

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September 14, 2000

Dr. Stephen H. Schneider,
Editor, Climatic Change.
Professor, Dept of Biological Sciences.
Senior Fellow, Institute for International Studies.
Stanford University.
Stanford, CA 94305-5020.

Dear Dr. Schneider,

Enclosed please find a revision of the manuscript **An investigation of the relationship between pesticide usage and climate change** that has now been retitled **Pesticide treatment cost and climate change: a statistical investigation**. In this revision, we have attempted to address all of the reviewer's comments. We do find some of the review comments to be not entirely consistent with our view of the work and tried to clarify these items by rewriting the paper. We present discussion of our revisions, reservations and reactions in the attached responses to the reviewer's comments.

We do believe you find this revision to be substantial and we assert that from our viewpoint it does appropriately deal with **all** of the review suggestions excepting the one on metric concerns. We stand fully ready to switch to metric, but we did not do it here as we found the tone of the review to be negative and will invest the time if the paper is tentatively accepted.

Thank you for your consideration.

Sincerely yours,

Bruce A. McCarl

Responses to the reviewer comments

Thank you for your comments on the paper, we believe our consideration of and responses to the comments has materially improved the quality of the paper. We do have ever have a few places where we choose not to go as far as your comments might imply as detailed below.

Pages entitled **assessment of response to reviewer a**

Comments 1, 3, 4

We agree with your assessment and did not find any specific items we needed to respond to here.

Comment 2– editing

The manuscript was thoroughly edited with all the specific comments considered and altered plus a lot more.

The only element of the editing we find meritorious of comment is that we standardized the terminology has raised in section 2 to pest treatment cost and used it throughout.

Pages entitled **assessment of response to reviewer b**

Comment 1– importance

We added more material on the importance and rewrote the conclusions and abstract relative to this point. However, we are sure we did not go as far as you wished us to go. There are three reasons

1. Your comments imply that the results are small and thus not important. Actually they are on the order of 5-10% of the total climate change impact on agriculture so that must also be small. By this standard should we should just forget climate change impacts on agriculture entirely? We don't think so. We would like $200 million annually to be given to us so find the number significant.

2. In our judgement it is important to objectively present estimates of the magnitude of such costs. We feel this is important regardless of the size of the estimates particularly given there are numerous pieces that cite pest changes as important or a missing factor in the total evaluation as we cite in the paper. We believe the estimates have information value regardless of their size.

3. You want us to compare the size of the welfare change in total with the pesticide cost but we are not totally comfortable with this as the cost change it is only a welfare shift measure under a perfectly inelastic demand curve which is not the case.

Thus, we did add a little discussion and some percent change estimates in the section about the national assessment results but did not emphasize smallness or consider dismissing the whole thing as a small matter to the extent the reviewer would seem to be advocating.

Comment 2 limitations and assumptions on pesticide cost

We thought we did respond but you have raised a broader specification issue in your interpretation of the original comments. To address this we have added yet more but again did not go as far as the your comments imply. We did this because

a. We do not agree that it is easy to get data that would allow us to unravel changes in costs of other inputs (such as labor and tillage) isolating out the pest /climatic shift related proportion of those costs. We discuss this limitation in the paper.

b. We used the panel data estimation method so we could control for the items that in your words would be "allowing of a more conceptually complete approach to pesticide costs". We did introduce wording to this effect in the new choice of independent variables section we added into the paper and the section on the panel approach. The panel data approach is designed to obviate the need for treating the factors you mention such as "temporally disparate commodity and input prices, program revisions, technologies..". This is a basic characteristic of panel data modeling and differentiates it from structural modeling. Our references (particularly those by Baltagi) discuss this point as to a small point does the text but we did not introduce a lot more as we do not think this is the place to introduce a large treatment of panel versus structural modeling.

c. The omission of variables from an econometric model does not bias coefficient estimates as long as the included variables are not highly correlated with the omitted ones. Given our focus on temperature and precipitation we do not feel that there are compelling arguments that these factors would be highly correlated with the omitted prices etc that might influence PTC. Also we were keenly interested in the total estimates of the climate item effects and not other items so we feel the regression as specified serves our purpose.

We did add material on the panel and to independent variables to clarify relative to this comment.

comments 3,4

We agree with your assessment and did not find any specific items we needed to respond to in your assessment here.

comment 5. result reasonableness

We added more to this but could not go as far as the review comments imply.

> We added discussion relative to the point that we felt the results were not unreasonable and introduced referencing to prior published paper on this topic in the journal by Paterson et al. However we are unwilling to project ourselves into position where we totally assert the reasonableness of the climate change driven alteration in pesticide expenditures across the country. We actually were doing statistical modeling without a priori assumptions to see if the types of results that a number of agricultural experts are in fact saying should happen are in fact happening across the data series we can observe (see the lit review in Patterson et al who say the "challenge from pests will **probably** increase"). As such the finding that climate change increases pesticide cost confirms what many entomologists, weed scientists and other agricultural experts have been saying and therefore must be reasonable.

comment 6

extensive editing done.

Pages entitled **additional comments**

General comment 1.

We don't agree that the paper is devoid of economic content and purpose. We believe that a hedonic approach to seeing whether pesticide cost increases due to climate shifts is inherently economic as is the panel data control of systematic factors. Thus we feel this paper does have both economic and statistical content.

On the comments about the reviewer B comments we discussed our responses in our reviewer B section above.

General Comment 2

We stand fully ready to switch to metric, we did not do it here as we found the tone of the review to be negative and will invest the time if the paper is tentatively accepted.

Specific comment 1

Change made

Specific comment page 2

We used the 1995 data for prices so all data are real 1995 dollars. We did not go back with prices as the compound prices do not change much and felt we the composition change was all we should reflect not price changes.

Specific comment page 3

Wording change adopted and a little more clarifying language introduced

We did expand our case for out choice of independent variables in the new section on independent variables. The panel argument is also enhanced.

We tried functional forms with interaction terms but did not find the interactions significant

Specific comment page 7

We added a little on this and added references to the prior intuition and science based piece by Patterson et al that in effect argues our findings should have arisen.

On the f(x) and h(x) comment, we do not understand this comment very well. The estimation method assumes a mean preserving spread for h(x). Consequently discussion of the distributions independently is the same as discussing them jointly ie h(x) and f(x) are independent given an x estimate. So we did not try to revise our discussion.