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Assessing Recent Trends in Pesticide Use in U.S. Agriculture

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Assessing Recent Trends in Pesticide Use in U.S. Agriculture

Without the use of pesticides or other practices to manage insects, diseases, and weeds, producers may suffer significant losses. Nominal expenditures on pesticides increased steadily for most of the last half-century, and after reaching a plateau in 1998, increased to a record $10.0 billion in 2007, driven primarily by expanded corn acres (ERS, 2008). USDA estimates an additional 9 percent increase in 2008 pesticide expenditures to nearly $11.0 billion. However, in real terms, pesticide expenditures remain well below the 1998 peak, as shown in Figure 1, as do total pounds of pesticides—about 480 million pounds in 2007, as shown in Figure 2.

Farmers use an array of pest management practices resulting in a diverse pattern of agricultural chemical use. Both herbicides and insecticides are important in corn and cotton production, while soybean producers rely mostly on herbicides. In recent years, we have witnessed a significant trend toward replacing relatively hazardous active ingredients with less hazardous ones. We see, for example, a major shift from metholachlor to acetochlor in Illinois corn pesticide use (Figure 3).

All pesticides used in the United States must be approved by the Environmental Protection Agency (EPA). In addition to the approval process, Congress mandated that the EPA reregister existing pesticide products to ensure their safety.

Additionally, agricultural chemical use in recent years is known to be influenced by a number of technical and policy factors, in particular rising adoption of genetically engineered (including herbicide tolerant and Bt crops) crops, corn-based ethanol production, as well as climate change, increased conservation, and changes in government programs. Hence, major shifts in use among crops, particularly a recent major jump in corn share of pesticide use, have occurred as summarized in Figure 4.

Inherent differences in chemical characteristics or quality prevent the direct comparison of observed prices of chemicals over time and across regions. Hence, we use an hedonic price function to express the price of a good or service as a function of the quantities of the characteristics it embodies.

In this study, quality-adjusted price and quantity indices are calculated for pesticides used on major crops in U.S. agriculture for 1960-2007 using hedonic methods and compared to actual prices and quantities used. Pesticide potency, hazardous characteristics, and persistence are used as quality characteristics. Separate hedonic functions are estimated for pesticides by crop and pesticide class. Adjusted quantity indices are computed using pesticide expenditures. In the past few years, NASS has limited the amount of pesticide data that it collects. In order to examine recent changes in pesticide use, we supplement NASS data with data from Doane's Marketing Research to create a more complete picture.

Objectives: The paper will: 1) discuss recent trends in pesticide use in major crop production, identifying major national shifts in pesticide use between 1960 and 2007 by commodity and specific trends in herbicide and insecticide use in corn, cotton, and soybeans, 2) use hedonic methods, in particular a Box-Cox transformation with dummy variable intercepts to calculate quality-adjusted price changes and implicit prices of the quality characteristics for 1960 through 2007, 3) examine quality-adjusted price and quality trends in key corn and cotton states, and 4) examine the factors influencing the pesticide trends.

Background

Together with improved new seed varieties, the introduction of chemical pesticides and fertilizers has contributed to substantial increases in agricultural yields in the last 60 years (Fernandez-Cornejo, 2004). New pesticide products have reduced crop losses due to pests, while also reducing the amount of labor and tilling required for pest control. These technological changes have allowed productivity to increase, but have been accompanied by concerns about their impacts on the environment and human health.

After World War II, several new chemicals such as DDT (an insecticide) and 2,4-D (an herbicide) were introduced to agriculture. These substances created greater efficiency in production through lessening pest damage, and reducing the need for tilling (Padgitt, Newton, Penn, and Sandretto, 2000). Atrazine, still the most heavily used herbicide on corn, was introduced in the late 1950s. As adoption of corn hybrids, chemical fertilizers, and pesticides increased, average corn yields rose from 20 bushels per acre in 1930 to 140 bushels per acre by the mid-1990s. At the same time, cotton yields rose nearly fourfold, and soybean yields increased more than threefold (Fernandez-Cornejo, 2004). Increases in crop yields allow less land to be dedicated to agriculture than would otherwise be necessary.

Changes in pest control options available to farmers are the result of a number of technological innovations. After World War II, cultural practices and application of a few inorganic products were joined by new, highly effective organic pesticides. These organic pesticides provided superior crop protection, but by the 1960s concerns about their safety to humans and wildlife ignited calls for tighter pesticide regulation. In 1972, Congress empowered the Environmental Protection Agency to review the safety of existing pesticides. The EPA deemed a few pesticides, such as DDT, dangerous enough to be banned quickly. Other compounds faced more scrutiny in the 1990s, as the EPA required additional studies of individual chemicals' toxicity and gave more attention to the human health risks associated with pesticide residues.

Shifts in pesticide chemical usage and technologies have broad implications. The planting of resistant crop varieties may reduce the amount and toxicity of chemical pesticides required. However, the concentrated use of just a few pesticide products with these crop varieties may accelerate the rate of pest resistance to those chemicals.

Methodology

In the past, agricultural chemical use has been measured and reported in pounds. This approach is straightforward, but limits the analysis of trends over time and across chemicals. After all, one pound of pesticide is not equivalent to a pound of a different pesticide that is twice as effective. To account for these differences in characteristics and provide a standard measure of pesticide usage, we use a hedonic estimation procedure to quality-adjust the prices and quantities as in Fernandez-Cornejo and Jans (1995). This approach allows comparisons of chemical usage over time.

More precisely, hedonic methods take into account the concept that inherent differences in pesticide characteristics or quality prevent the direct comparison of observed prices of pesticides over time and across regions. A hedonic price function expresses the price of a good or service as a function of the quantities of the characteristics it embodies. Thus, a pesticide hedonic function may be expressed as $w = W(X, D)$, where *w* represents the price of pesticide, *X* is a vector of characteristics or quality variables and *D* is a vector of other variables. If the main objective of the study is to obtain price indexes adjusted for quality, as in our case, the only variables that should be included in *D* are county dummy variables, which will capture all price effects other than quality. After allowing for differences in the levels of the characteristics, the part of the price difference not accounted for by the included characteristics will be reflected in the year (or state) dummy coefficients.

In this study, we adopt a generalized linear form, where the dependent variable and each of the continuous independent variables is represented by the Box-Cox transformation. This is a mathematical expression that assumes a different functional form depending on the transformation parameter, and which can assume both linear and logarithmic forms, as well as intermediate non-linear functional forms.

Thus the general functional form of our model is given by:

$$w(\lambda_0) = \sum_{n=1}^{N} \alpha_n X_n(\lambda_n) + \sum_{m=1}^{M} \gamma_m D_m + \varepsilon, \qquad (20)$$

where $w(\lambda_0)$ is the Box-Cox transformation of the dependent price variable

$$w(\lambda_0) = \begin{cases} \dfrac{w^{\lambda_0} - 1}{\lambda_0}, \lambda_0 \neq 0, \\ \ln w, \lambda_0 = 0. \end{cases}$$

Similarly, $X_n(\lambda_n)$ is the Box-Cox transformation of the continuous quality variable X_n where $X_n(\lambda_n) = (X_n^{\lambda_n} - 1)/\lambda_n$ if $\lambda_n \neq 0$ and $X_n(\lambda_n) = \ln X_n$ if $\lambda_n = 0$. Variables represented by *D* are time dummy variables, not subject to transformation; λ, α, and γ are unknown parameter vectors, and ε is a stochastic disturbance.

Data

The analysis employs a new pesticide database that was compiled from USDA pesticide use surveys and the Doane's Countrywide Farm Panel Survey. A complete and consistent price and quantity dataset was gathered for the 1960-2007 period to develop national and state level trends. A separate, more detailed, state panel dataset was developed for 1986 to 2007. Additionally, a set of physical characteristics was collected for each active ingredient for close to 300 pesticides used in apple, corn, cotton, orange, rice, sorghum, soybean, tomato, and wheat.

While pesticide expenditures in U.S. agriculture increased only about 20 percent in nominal terms between 1996 and 2007, there was wide temporal and spatial variation in pesticide use. Pesticide expenditures in the major corn/soybean states grew at a somewhat slower pace, with the Corn Belt only matching the 1996 level in 2007 and Illinois growing only 3 percent. However, total pesticide expenditures in the Lake States, Corn Belt, and Northern Plains ($4.8 billion in 2007) represent a close to 20 percent jump over the 2006 level. The use of GE soybean production boosted glyphosate use sharply between 1996 and 2007—from about 12 million pounds to more than 70 million pounds. For corn production, glyphosate use increased from about 3 million pounds in 1996 to more than 50 million pounds in 2007, and for cotton production from about 10 million pounds to 15 million pounds. Clearly, pesticide use in corn, soybean and cotton production has changed significantly in recent years. Also, ethanol production has boosted corn acres while reducing soybean acres in recent years, implying a significant increase and change in composition of pesticides used.

Data on agricultural chemical trends has previously been published by Osteen and Szmedra (through 1982) and by Lin et al. (through 1992). This study extends the data on selected chemical use through 2007.

Herbicide Use Trends

More than half the pounds of pesticides used in the U.S. are herbicides, chemicals designed to control weeds. Corn, cotton, and soybean production have the largest shares of herbicide use for individual crops; with corn alone accounting for approximately half of the herbicides used each year. Herbicide use peaked in 1998 for the most important corn, cotton, and soybean states, but one-third of these states matched or showed increases in 2007 (Table 1: Herbicide use by state).

Several changes in agricultural practices seem to be driving the shifts in herbicide use, including the adoption of herbicide tolerant crops, tillage systems, and government programs.

In addition to recent changes in the total quantity of herbicides applied, there have been shifts in the particular active ingredients applied to major crops. In the mid-1990s, the introduction of herbicide tolerant crops augmented pest management options. Cotton, soybean, and corn varieties designed to resist glyphosate, a broad-spectrum herbicide, appeared on the market. The use of glyphosate per acre on corn, cotton, and soybeans has risen in almost every year since 1996, while the total use of other herbicides has dropped in almost every year since 1996.

Herbicide tolerant crops: The percentage of herbicide tolerant (HT) corn planted has increased from three percent in 1996 to just over 50 percent in 2007 (Figure 5). Glyphosate, the herbicide most used with the HT crops, use rose gradually over that period and more slowly than in soybean or cotton production. Atrazine remains the most heavily used corn herbicide.

By 2007, 70 percent of cotton acreage was HT. Glyphosate use increased correspondingly, the one tenth of a pound per acre in 1996 increased almost 15-fold by 2007 (Figure 6). Use of other herbicides has fallen by half since 1996, meaning that glyphosate accounted for more than half of the total herbicide used on cotton in 2007.

Soybeans have experienced the highest level of HT adoption among the three crops, over 90 percent of the soybean acres in 2007 (Figure 7). Use of Glyphosate on soybeans has risen, with a decline in the use of other herbicides.

Overall, the adoption of GE crops is associated with reduced pesticide use (Fernandez-Cornejo and Caswell, 2006). Figures 5, 6, and 7 summarize trends in HT adoption and pounds of glyphosate applications per acre compared to other herbicides applications per acre for corn, cotton, and soybeans. For both cotton and soybeans, glyphosate applications per acre are now much higher than for other herbicides. In the case of corn the trend toward more HT corn compared to traditional corn hybrids is accelerating in recent years as are applications of glyphosate relative to other herbicides.

Insecticide Use Trends

Insecticide use has fluctuated from year to year and crop to crop, as have the choices of active ingredients. Besides changes in crop acreage, these fluctuations may result from a number of factors: changes in pest pressure, changes in agricultural practices, changes in pesticide regulation, and changes in technology.

The banning of some organochlorines, such as DDT, forced growers to change chemicals in the 1970s. Higher pest pressure in some years resulted in higher rates of insecticide application. In rare cases, the EPA even issued exemptions for insecticides not normally permitted by the EPA. Moreover, older insecticides may become less effective as pests develop resistance, resulting in higher rates of application or switching to new products.

In the 1990s, a class of insect resistant crops called Bt crops, was also developed, using the DNA of *Bacillus thuringiensis* (Bt), a bacterium harmful to some insects, including the European corn borer. Insecticide use for the major corn, cotton, and soybean states peaked in 2000 (influenced by the Boll weevil eradication program in Texas) for the most important corn, cotton, and soybean states, and has trended strongly downward since as more efficacious insecticides replace older higher dose insecticides. (Table 2: Insecticide use by state).

Bt crops: The overall trend in insecticide use shows that along with the adoption of Bt corn, there has been a gradual decline in insecticide use per acre on corn (Figure 8). In addition, research by ERS and others suggests that, controlling for other factors, insecticide use declined with the adoption of Bt corn and Bt cotton (Fernandez-Cornejo and Caswell, 2004).

It should be noted, however, that by protecting the plant from certain pests, Bt crops can also prevent yield losses compared with non-GE hybrids, particularly when pest infestation is high. This effect is particularly important for Bt corn, which was introduced in the mid 1990s to control the European corn borer (ECB). Since chemical control of the European corn borer was not always profitable, and timely application was difficult, many farmers accepted yield losses rather than incur the expense and uncertainty of chemical control. For those farmers, the introduction of Bt corn resulted in yield gains rather than pesticide savings. On the other hand, another type of Bt corn introduced in 2003 to provide resistance against the corn rootworm, which was previously controlled using chemical insecticides, does provide substantial insecticide savings (Fernandez-Cornejo and Caswell, 2006).

The boll weevil eradication program: Cotton has the highest total use of insecticides and the highest adoption of Bt crops, at almost 60 percent in 2007 (Figure 9). Insecticide use has fallen over the same period, but fluctuations in cotton insecticide applications are also impacted by the boll weevil eradication program.

Since the 1970's, cotton growers and governments have worked toward eradicating the boll weevil, an insect affecting cotton. Different cotton growing regions joined the program in different years. Typically the first year of participation entails heavy application of pesticides (generally malathion). In subsequent years, the boll weevil population is monitored and treated as needed. A new wave of cotton producing regions began participation starting in 1993. The spike in cotton insecticide applications in 1999 and 2000 coincides with two million cotton acres joining the program in Texas.

Quality-Adjusted Results

Quality-adjusted price indices are calculated for pesticides for the U.S. and for key corn/soybean and cotton states for 1960-2007 using hedonic methods. Inherent differences in pesticide characteristics or quality prevent the direct comparison of observed prices of pesticides over time and across regions. Hence, we use a hedonic price function to express the price of a good or service as a function of the quantities of the characteristics it embodies--pesticide potency, hazardous characteristics, and persistence. The use of quality-adjusted pesticide indices is critical in calculating agricultural productivity and in estimating aggregate supply models. Given the number of pesticide ingredients and the rapid changes in pesticide use, development of readily modifiable state level data files and hedonic models is desirable.

The hedonic regression results validate the use of the hedonic framework. Figures 10 through 21 show the quality-adjusted price and quantity series for the United States and five key corn/soybean and cotton states— California, Illinois, Iowa, North Dakota, and Texas.

Examining figures 10 and 11 we observe that, as expected, the quality-adjusted price indices (i.e., the prices that would have obtained if quality had remained constant) are always lower than the corresponding unadjusted prices (unadjusted or actual prices reflect the improved quality and therefore are worth more). Similarly, the quantity indices adjusted for quality are larger that the unadjusted quantity indices because the amount of pesticides used in U.S agriculture would have been larger if pesticide quality had remained constant instead of improving (Fernandez-Cornejo and Jans, 1995).

The U.S. results suggest two major findings. First, we observe in Figure 10 that quality-adjusted prices have tailed off sharply in recent years as generally lower cost glyphosate replaced other herbicides used on GE crops. Second, while the aggregated actual quantities show no upward movement since 1998, the quantity indices adjusted for quality shows a very small increase, which is less than the modest 10 percent increase in nominal expenditures and in line with the slight decline in actual quantities of pesticides used (Figure 2).

Two groups of states can be identified in terms of their quality-adjusted evolution over the last decade. For example, the quality-adjusted quantity index increases somewhat for Illinois and Iowa due to declining adjusted prices; quality-adjusted quantities appear to have declined somewhat in California and Texas. In sharp contrast, crop mix changes (dramatic shifts into corn as minimum temperature increased and as improved GE corns came on line) in North Dakota led to a sharp increase in quality-adjusted pesticide quantities. Clearly, just examining pesticide expenditure or aggregate unadjusted quantities gives a distorted picture of trends in pesticide use.

Conclusions

Nominal pesticide expenditures, driven primarily by expanded corn acres reached a record $10.0 billion in 2007. USDA forecasts a 9 percent increase in 2008 pesticide expenditures to nearly $11.0 billion. However, in real terms, pesticide expenditures remain well below the 1998 peak, as do total pounds of pesticides—about 480 million pounds in 2007. And, the quality-adjusted quantity of pesticides used is virtually flat in the last decade, but trends in major pesticide using states have begun to diverge sharply. In this study quality-adjusted price and quantity indices are calculated for pesticides used on major crops in U.S. agriculture for 1960-2007 using hedonic methods and compared to actual prices and quantities used. Pesticide potency, hazardous characteristics, and persistence are used as quality characteristics. Separate hedonic functions are estimated for pesticides by crop and pesticide class. Adjusted quantity indices are computed using pesticide expenditures

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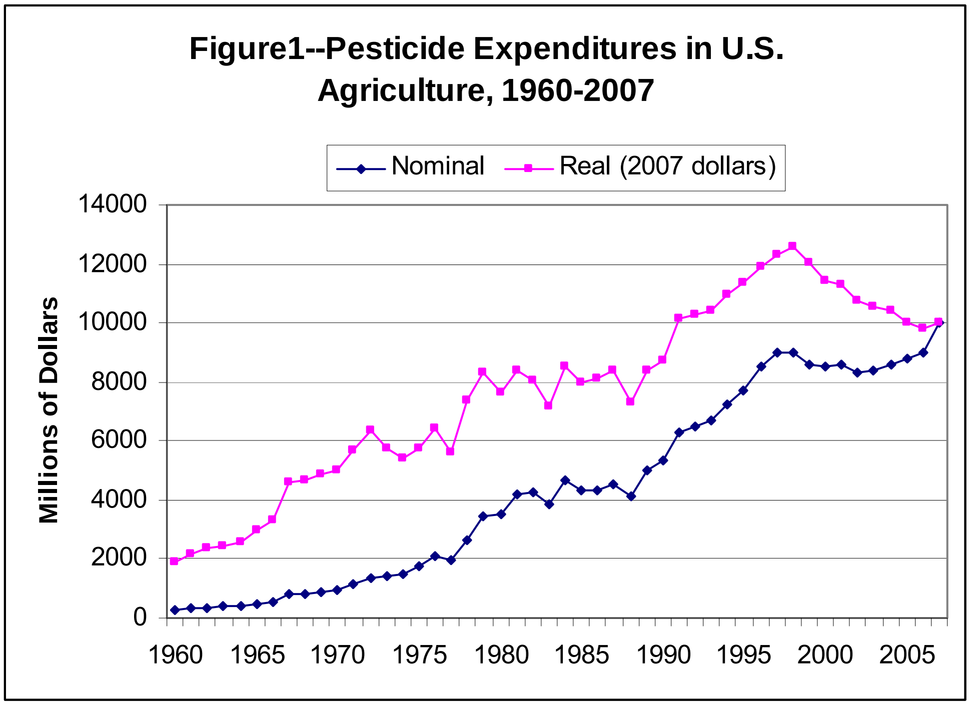
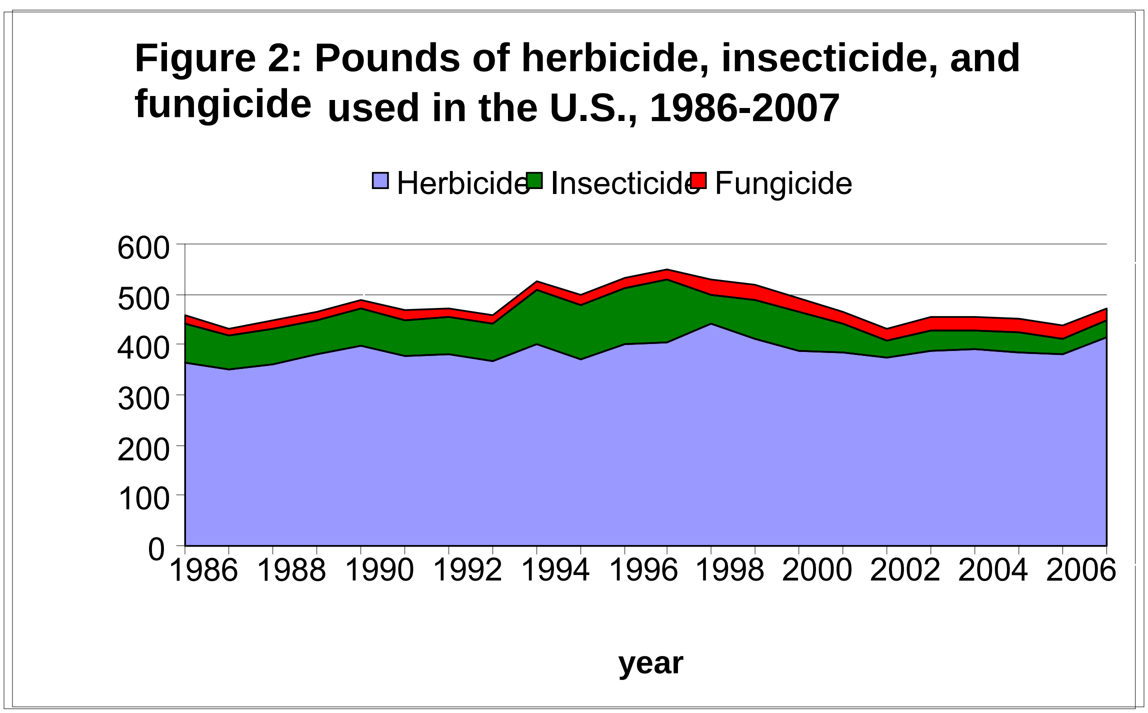
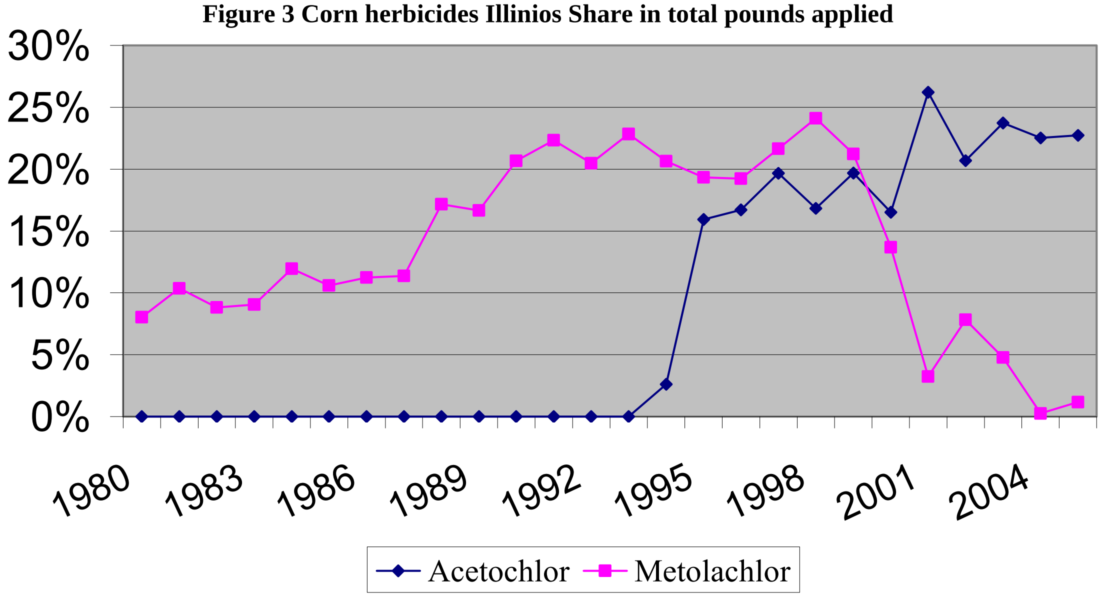


Source: ERS estimates.



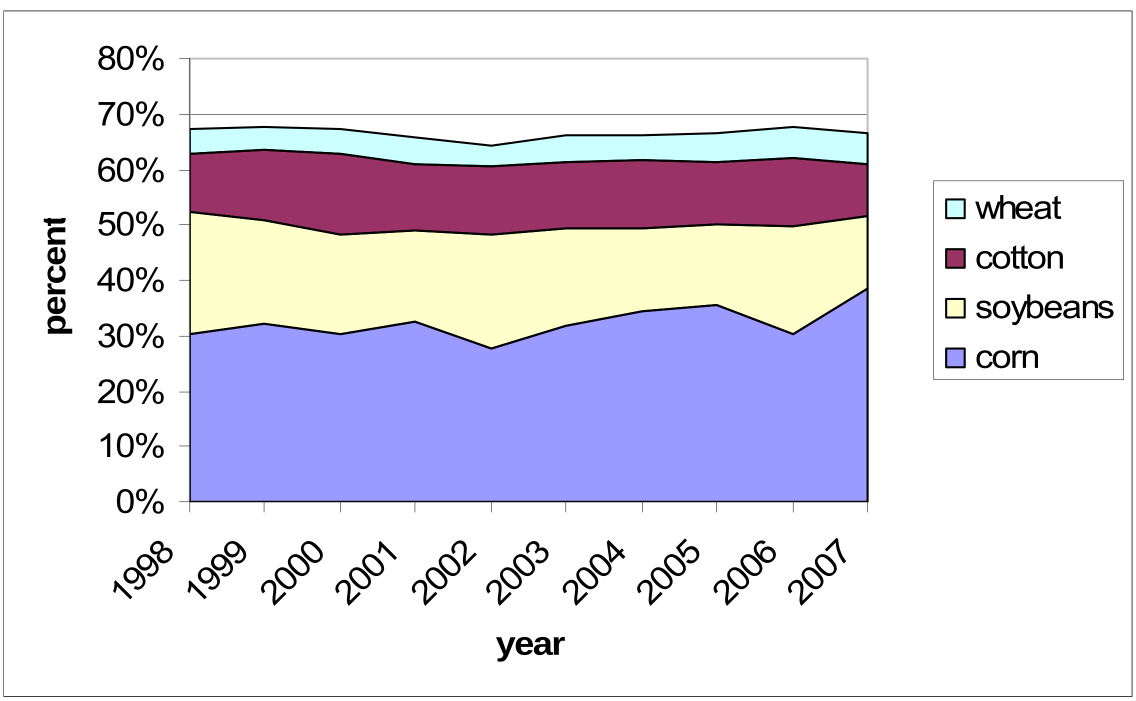
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research. Includes major crops.

Figure 3 Corn herbicides Illinios Share in total pounds applied



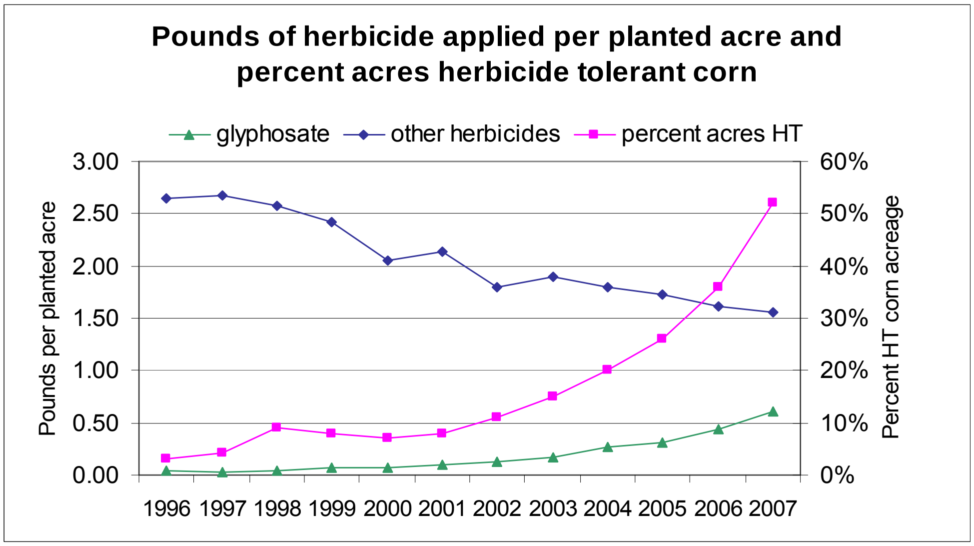
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research

Figure 4. Share of Major Crops in Total Pesticide Expenditures (1998-2007)



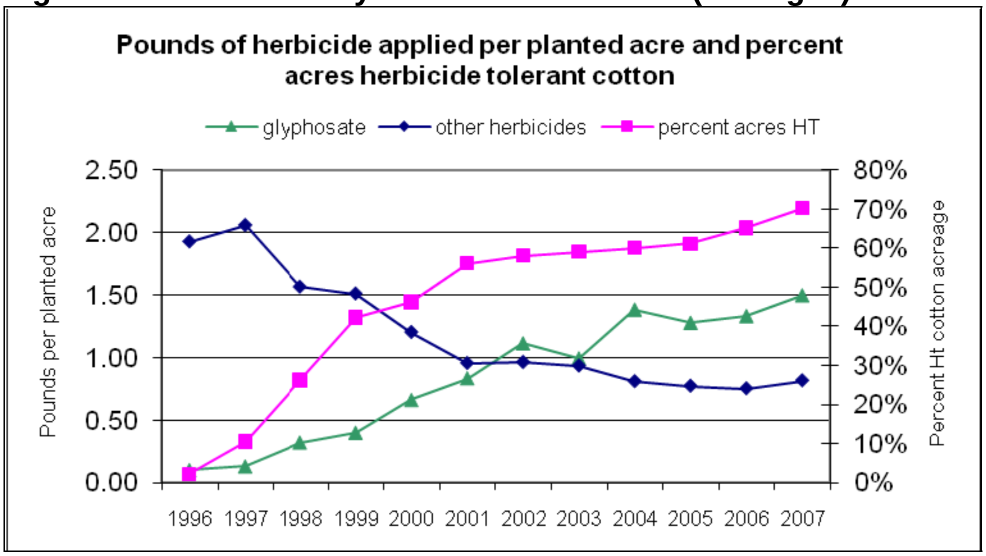
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research

Figure 5: Data Summary statistics for Corn (averages)



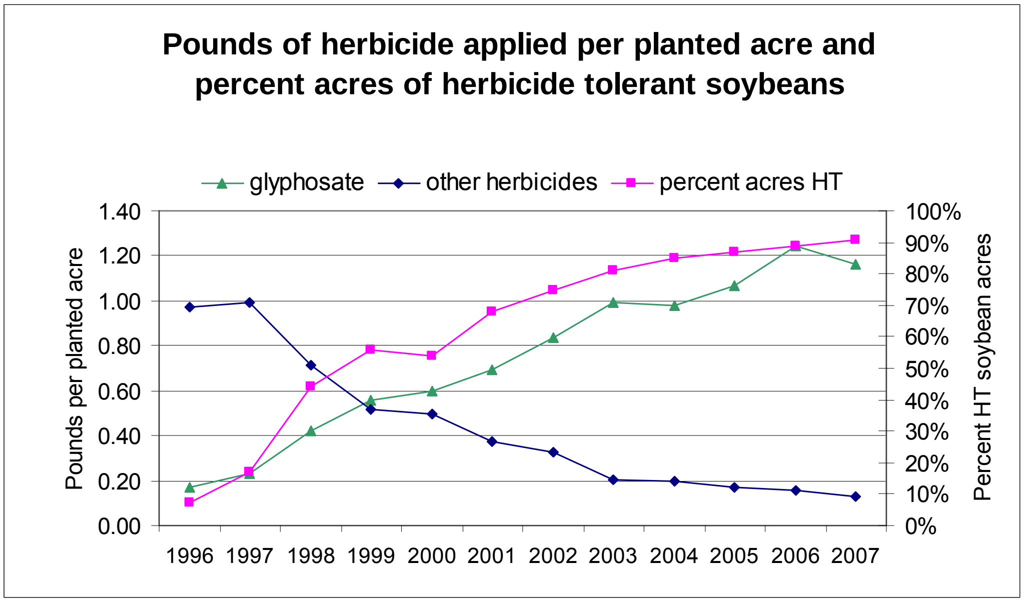
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research; NASS Quick Stats; Agricultural Resource Management Survey (ARMS) 1996-1998; Objective Yield Survey 1999; June Agricultural Survey 2000-2008

Figure 6: Data Summary statistics for Cotton (averages)



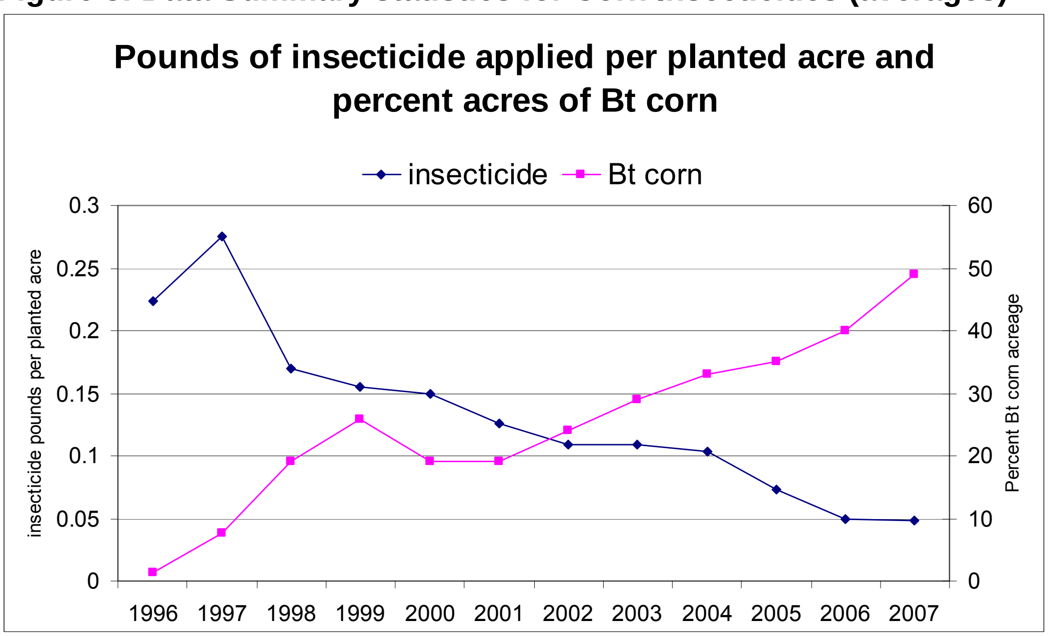
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research; NASS Quick Stats; Agricultural Resource Management Survey (ARMS) 1996-1998; Objective Yield Survey 1999; June Agricultural Survey 2000-2008

Figure 7: Data Summary statistics for Soybeans (averages)



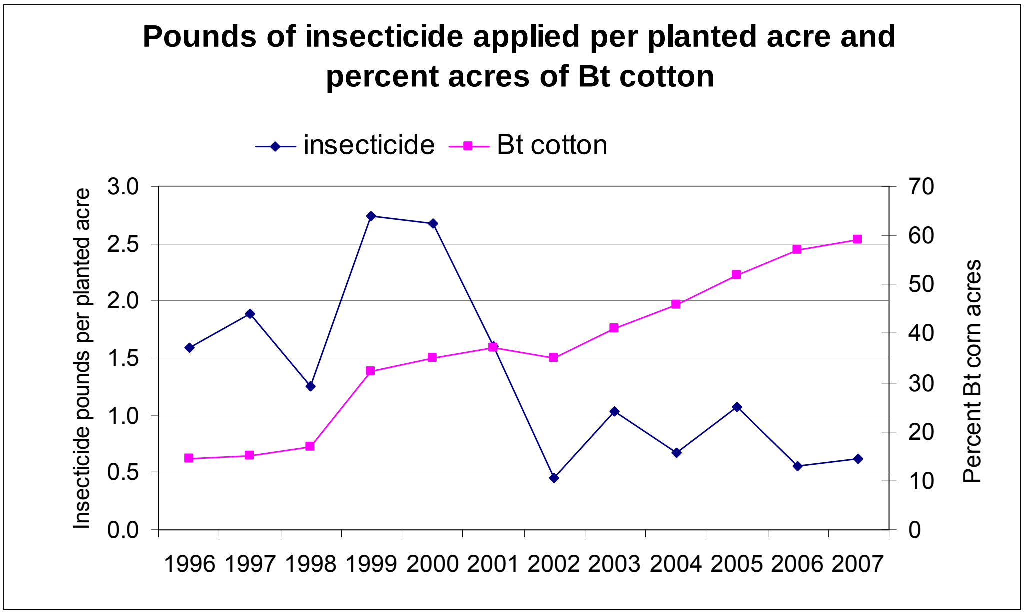
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research; NASS Quick Stats; Agricultural Resource Management Survey (ARMS) 1996-1998; Objective Yield Survey 1999; June Agricultural Survey 2000-2008

Figure 8: Data Summary statistics for Corn Insecticides (averages)



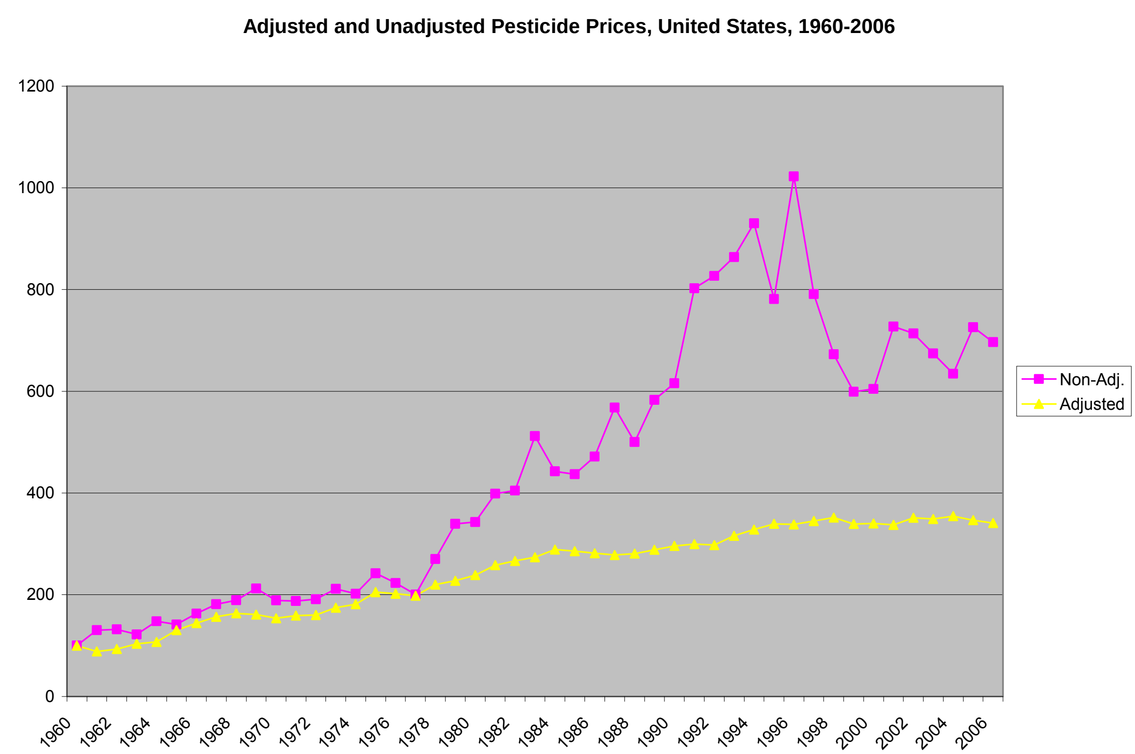
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research; NASS Quick Stats; Agricultural Resource Management Survey (ARMS) 1996-1998; Objective Yield Survey 1999; June Agricultural Survey 2000-2008

Figure 9: Data Summary statistics for Cotton Insecticides (averages)



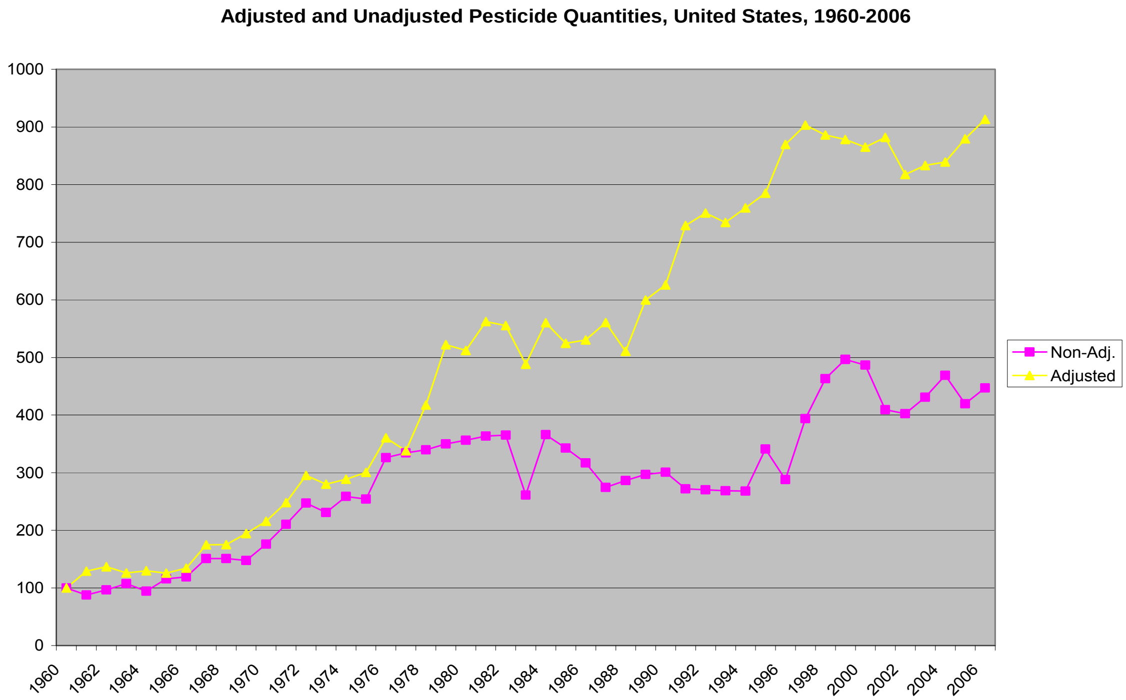
Sources: NASS Agricultural Chemical Usage Summaries; Doane Marketing Research; NASS Quick Stats; Agricultural Resource Management Survey (ARMS) 1996-1998; Objective Yield Survey 1999; June Agricultural Survey 2000-2008

Figure 10: United States Price Indices for Pesticides



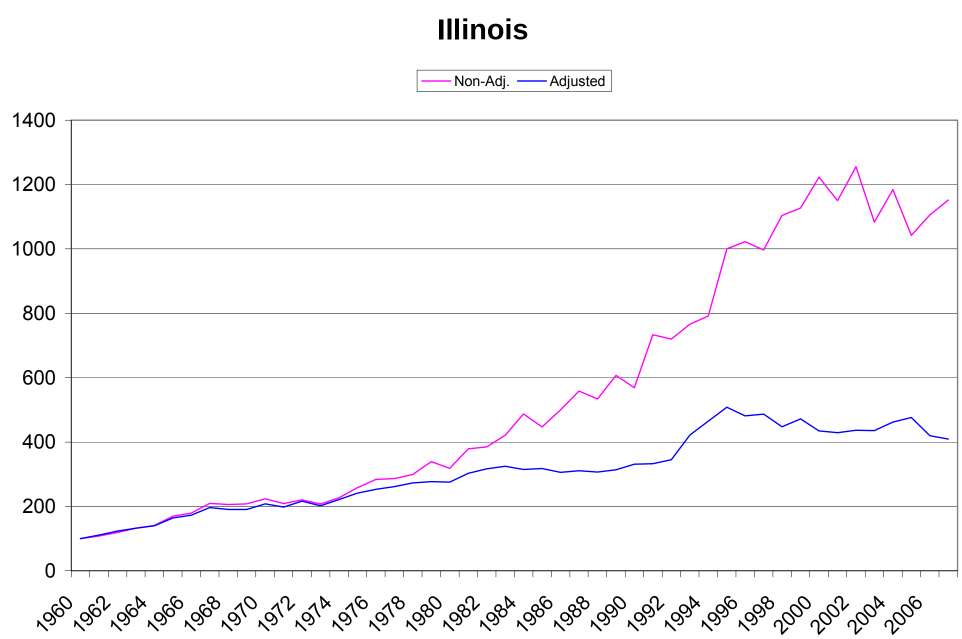
Source: ERS estimates

Figure 11: United States Quantity Indices for Pesticides



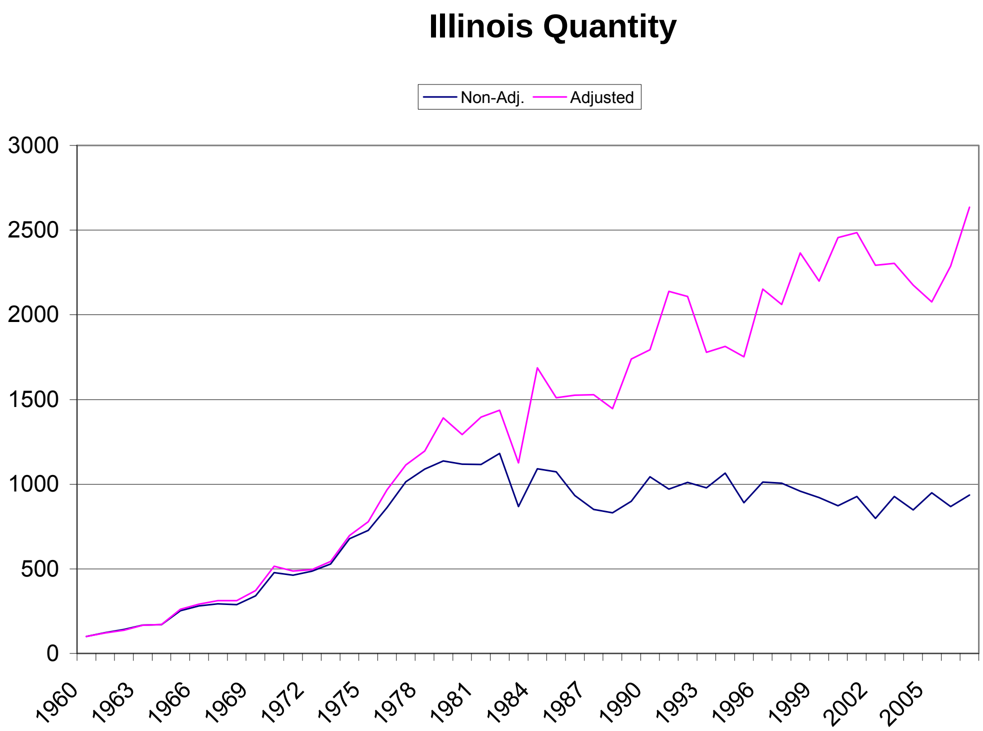
Source: ERS estimates

Figure 12: Illinois Price Indices for Pesticides



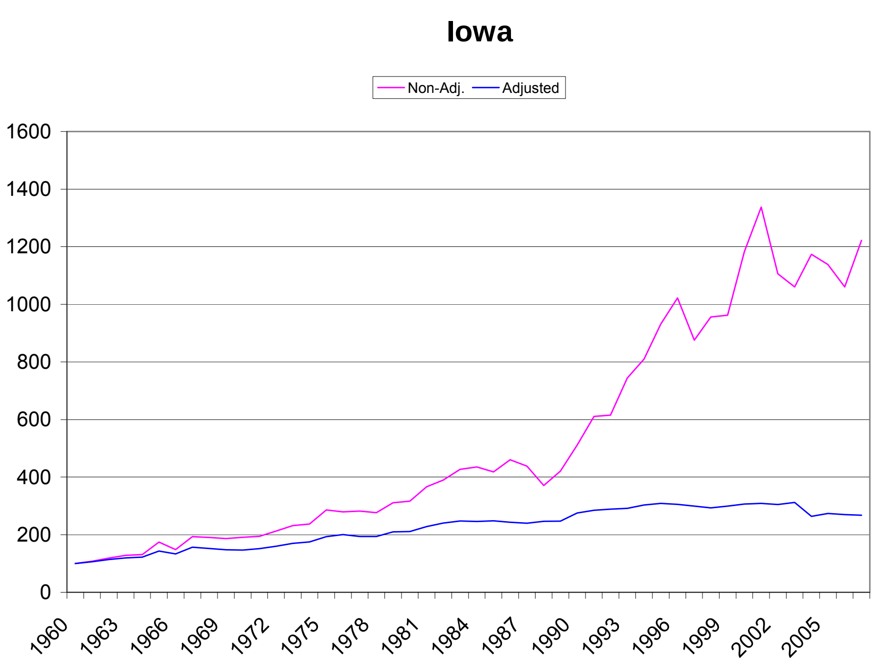
Source: ERS estimates

Figure 13: Illinois Quantity Indices for Pesticides



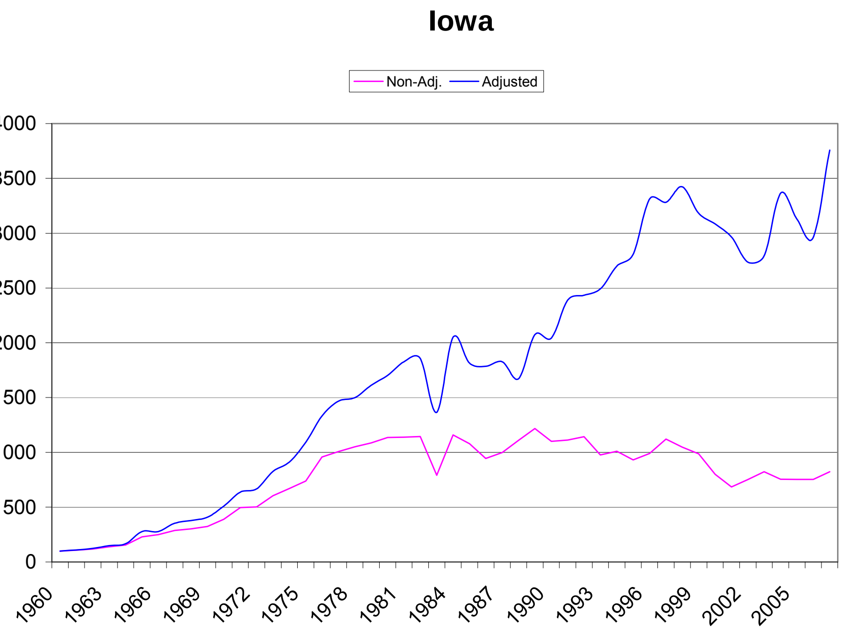
Source: ERS estimates

Figure 14: Iowa Price Indices for Pesticides



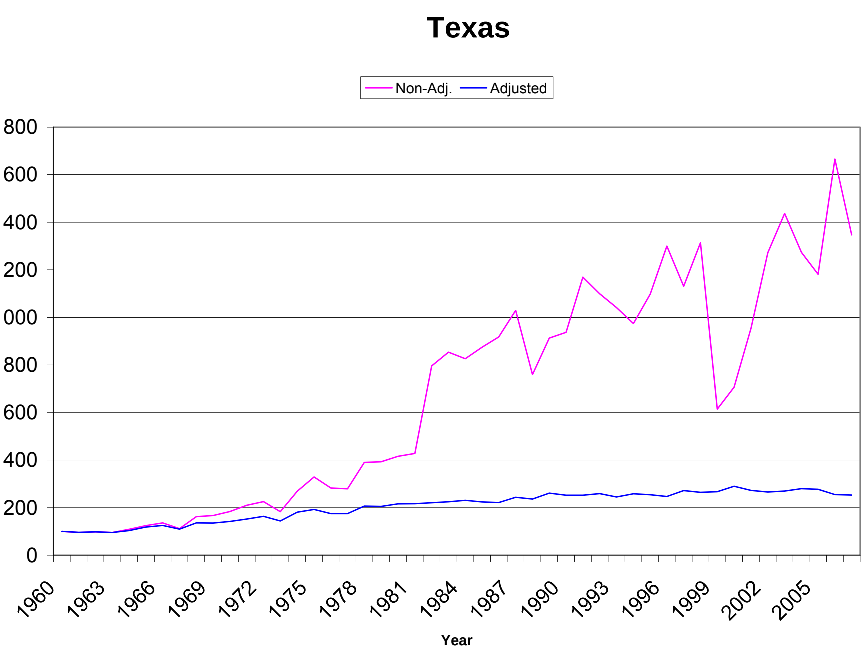
Source: ERS estimates

Figure 15: Iowa Quantity Indices for Pesticides



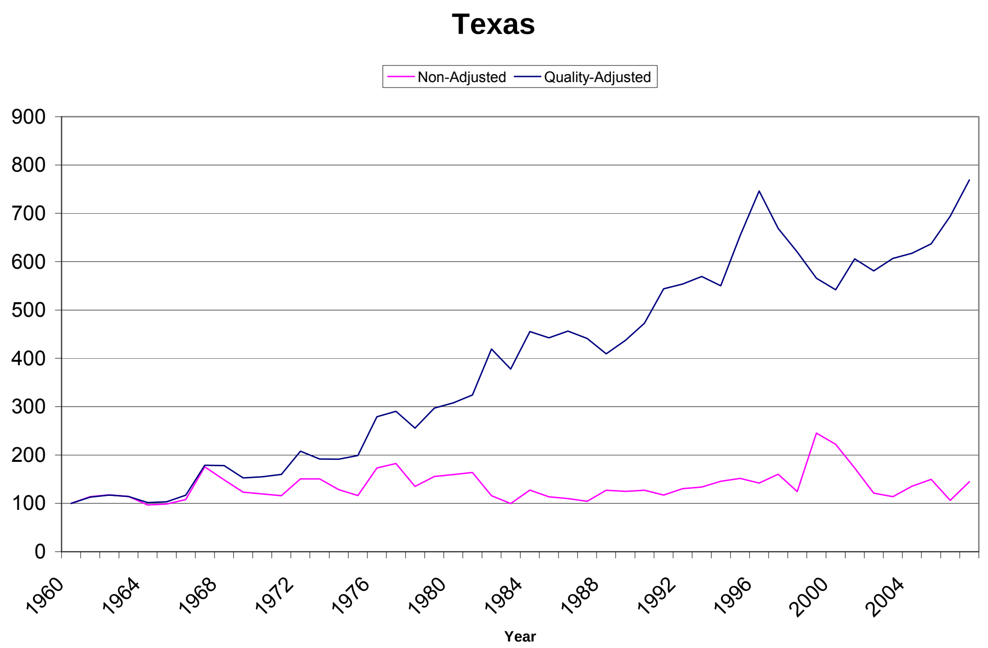
Source: ERS estimates

Figure 16: Texas Price Indices for Pesticides



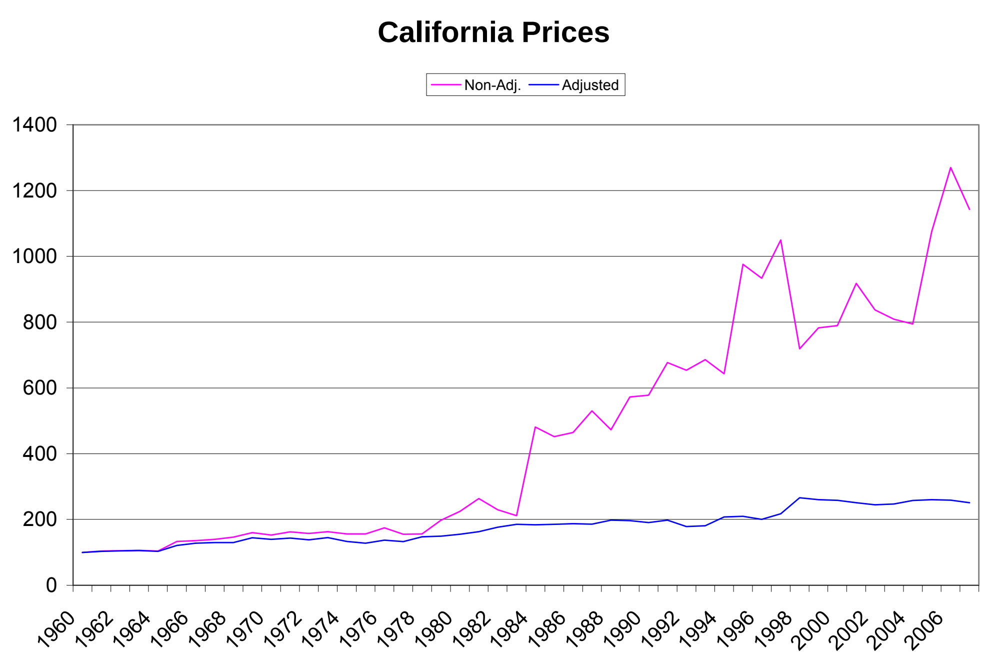
Source: ERS estimates

Figure 17: Texas Quantity Indices for Pesticides



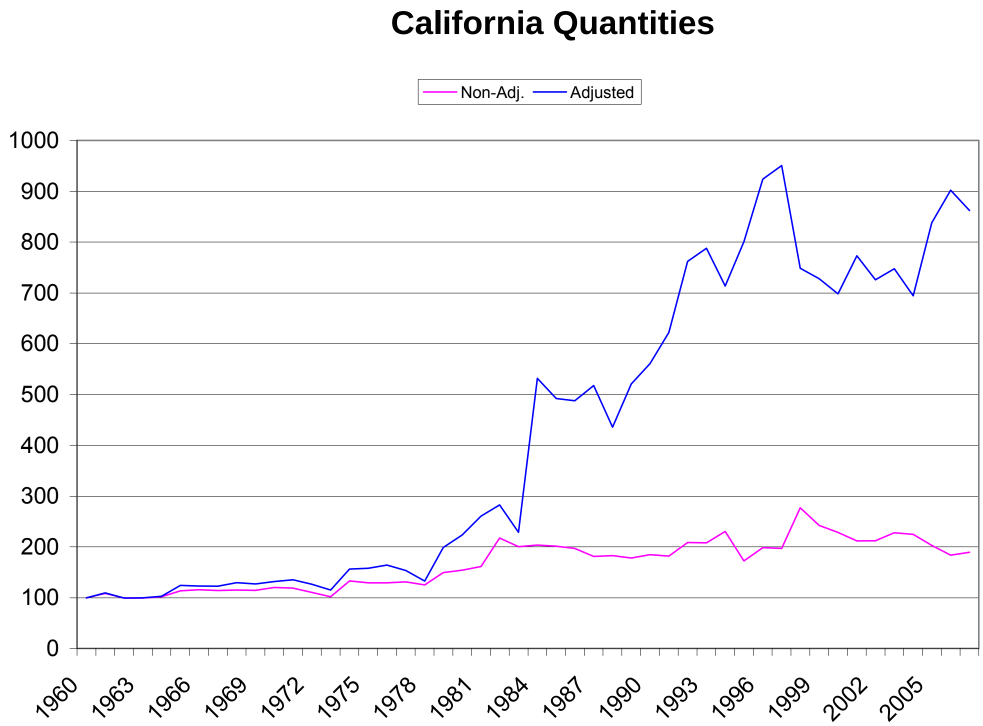
Source: ERS estimates

Figure 18: California Price Indices for Pesticides



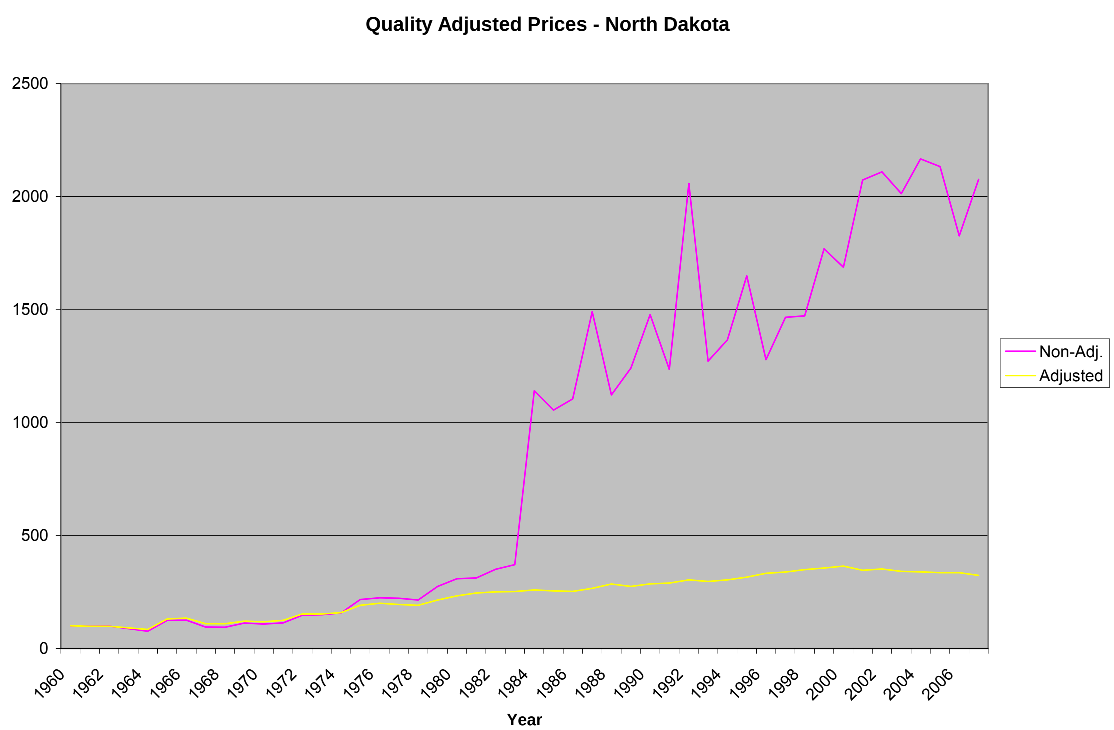
Source: ERS estimates

Figure 19: California Quantity Indices for Pesticides



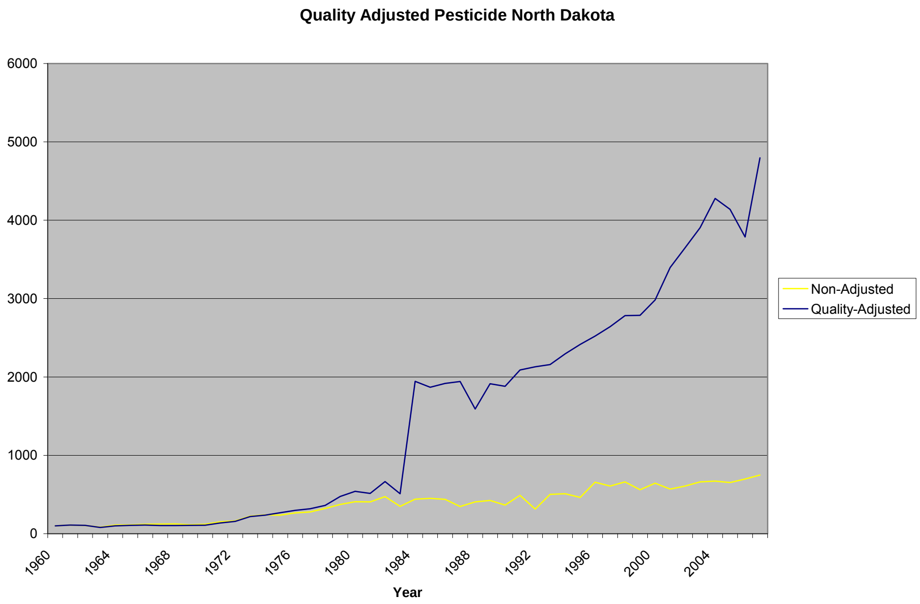
Source: ERS estimates

Figure 20: North Dakota Price Indices for Pesticides



Source: ERS estimates

Figure 21: North Dakota Quantity Indices for Pesticides



Source: ERS estimates

Table1. Herbicide use on selected Corn, Cotton, and Soybean states, 1986-2007

Millions of pounds of active ingredient

	1986	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	% An Growth Rate 98 to 07
CALIFORNIA	8.0	15.6	16.7	17.2	16.5	17.4	17.7	19.1	19.0	18.1	18.5	1.70
ILLINOIS	40.4	44.7	42.7	39.4	43.3	37.5	43.2	39.2	44.3	38.8	44.5	-0.45
INDIANA	24.2	24.6	22.5	20.9	22.3	19.8	19.8	21.3	20.8	22.0	26.5	0.74
IOWA	41.4	49.7	46.0	38.1	32.6	36.2	39.4	36.2	35.8	36.2	38.8	-2.40
KANSAS	12.8	20.1	21.5	19.8	25.4	20.8	21.6	20.8	23.0	20.8	23.1	1.44
LOUISIANA	7.3	8.5	9.3	7.6	8.2	8.1	6.8	7.6	6.8	6.9	8.1	-0.48
MICHIGAN	12.3	10.5	11.3	9.7	8.7	8.9	8.3	8.3	9.0	8.6	9.1	-1.43
MINNESOTA	22.8	25.3	21.3	20.7	22.1	18.6	22.0	21.3	20.1	20.1	20.9	-1.91
MISSISSIPPI	8.7	8.9	9.8	8.2	8.7	7.6	8.2	7.9	7.4	8.5	8.5	-0.46
MISSOURI	15.1	17.9	17.2	14.2	15.2	16.1	15.5	16.3	16.1	16.2	17.9	0.00
NEBRASKA	23.8	28.3	29.7	26.1	23.0	21.0	24.8	25.9	26.8	24.6	24.9	-1.28
NORTH DAKOTA	6.6	15.7	13.0	13.8	12.7	13.7	14.5	14.2	14.9	13.0	15.7	0.00
OHIO	17.8	15.4	16.0	14.9	14.5	15.2	14.7	14.2	15.6	15.0	16.1	0.44
SOUTH DAKOTA	11.4	17.6	12.7	13.2	13.9	12.2	13.7	14.0	14.2	12.6	15.4	-1.34
TEXAS	15.2	23.2	21.4	22.1	19.2	22.7	21.6	24.5	19.8	19.0	22.7	-0.22
WISCONSIN	12.7	10.1	7.9	8.7	9.0	7.1	9.1	9.2	8.8	8.8	9.5	-0.61
Total	287.7	342.3	324.2	299.6	300.5	288.1	306.1	304.9	308.0	295.0	326.1	-0.48

Sources: NASS Agricultural Chemical Usage Summaries and Doane Marketing Research data

Table 2. Insecticide use by state, 1986-2007

Millions of pounds of active ingredient

	1986	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
CALIFORNIA	11.89	10.97	10.64	9.76	9.34	8.02	8.30	8.03	7.31	6.76	7.15
ILLINOIS	5.28	1.88	2.08	3.01	1.78	1.16	1.79	2.01	1.94	1.03	1.17
INDIANA	2.97	1.57	1.08	0.98	1.11	0.80	1.39	0.85	0.96	0.44	0.53
IOWA	4.82	1.66	2.42	1.08	0.95	0.70	0.87	0.77	1.01	0.69	1.41
KANSAS	0.82	1.02	0.59	0.83	0.46	0.48	0.45	0.32	0.30	0.30	0.40
LOUISIANA	1.60	3.05	4.76	5.06	2.39	1.10	2.18	1.47	1.44	1.43	0.75
MICHIGAN	1.67	0.88	0.82	0.81	0.76	0.63	0.53	0.56	0.48	0.40	0.39
MINNESOTA	3.32	0.96	1.12	0.98	0.62	0.70	0.78	0.84	0.96	1.66	1.30
MISSISSIPPI	3.03	4.88	6.81	6.27	3.49	1.30	1.73	1.41	1.80	2.02	1.20
MISSOURI	2.00	0.72	0.57	0.74	0.43	0.60	0.55	0.60	0.43	0.73	0.53
NEBRASKA	3.07	1.85	1.36	1.65	1.33	1.08	0.82	1.17	0.38	0.48	0.40
NORTH DAKOTA	0.78	0.64	0.47	0.61	0.46	0.52	0.45	0.39	0.45	0.93	0.50
OHIO	1.29	0.48	0.33	0.66	0.33	0.41	0.20	0.28	0.40	0.26	0.22
SOUTH DAKOTA	1.65	0.35	0.18	0.19	0.05	0.19	0.21	0.53	0.34	0.19	0.21
TEXAS	4.00	5.04	25.25	22.48	16.35	2.73	4.36	2.50	6.87	1.03	2.07
WISCONSIN	1.98	0.95	0.84	0.68	0.54	0.34	0.41	0.41	0.42	0.24	0.24
Total	50.15	36.88	59.31	55.79	40.39	20.77	25.01	22.15	25.49	18.59	18.48

Sources: NASS Agricultural Chemical Usage Summaries and Doane Marketing Research data