Determinants of agricultural chemical price in China's export-oriented vegetable production area

Determinanty ceny chemických látek používaných v zemědělství v exportně orientované produkční oblasti Číny

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Abstract: Agricultural chemicals may have an adverse impact on environment and food safety. The demand prices of such chemicals reveal farmers' willingness to pay and their preferences. This article examines the determinants of the agricultural chemicals price in the export-oriented vegetable production area, Anqiu, Shandong Province, applying the Hedonic Price Model based on the spatial econometric technique to analyze the price. We find that the agricultural chemicals with a different shape and function have different equilibrium prices, and the chemical attributes of permeability, rainfastness, being a substitute of the highly poisonous chemical, having a zero residue, and the internal absorption can all influence the equilibrium prices remarkably. We also find that the prices of biological and non-pollution agricultural chemicals might not be higher than the ordinary agricultural chemicals with the same characteristics. These findings do not show a good sign to the new agricultural chemicals promotion and environmental protection, and should be brought to the government's attention.

Key words: agricultural chemical, China, export-oriented, vegetable production, hedonic price, spatial

Abstrakt: Chemické prostředky v zemědělství mohou mít negativní dopad na životní prostředí a potravinovou bezpečnost. Ceny za tyto chemikálie na straně poptávky ukazují ochotu farmářů platit za ně a jejich preference. Článek zkoumá determinanty cen chemických prostředků v zemědělství v exportně orientované oblasti produkce zeleniny v Anquiu v čínské provincii Shandong, s využitím hedonického modelu ceny založeného na prostorových ekonometrických technikách cenové analýzy. Výzkumem bylo zjištěno, že chemické prostředky s odlišnou formou a funkcí mají rozdílné rovnovážné ceny, a že charakteristiky jako rozpustnost, odolnost proti vyplavení deštěm, forma substitute za vysoce jedovaté chemikálie, nulová rezidua a vnitřní absorpce mohou rovnovážnou cenu velmi výrazně ovlivnit. Rovněž bylo zjištěno, že cena biologických látek a nepolutantních chemikálií nemusí být nutně vyšší než cena běžných zemědělských chemikálií se stejnými charakteristikami. Tato zjištění nejsou dobrým signálem pro zavádění nových typů chemických látek v zemědělství směřujících k ochraně životního prostředí a měla by jim být věnována pozornost vlády.

Klíčová slova: chemické prostředky v zemědělství, Čína, exportní orientace, produkce zeleniny, hedonická cena, prostorová analýza

In the past decade, environmental and food safety issues have drawn a growing attention from the consumers and the government, especially in China. Many food safety incidents in China such as the Sudan I Red Dye found in the tomato paste and the food color (Yan 2005) and melamine tinted the milk powder (Kwok 2008) have pushed China to improve its food safety supervision. Agricultural chemicals can help to reduce the crop damage caused by the insects, weeds and diseases, so to increase yield. However, they may also cause the human health and environmental damages. Developed countries have introduced strict standards

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to regulate the chemicals use to protect environment and the consumer benefits, and these measures put a lot of pressure on China's agricultural exporters, for China's agricultural chemical standards are relatively lower than their counterparts. For example, Japan implemented the Positive List System in May, 2006, and this has significantly reduced China's vegetable exports to Japan afterwards (Wang et al. 2007).

Farmers' adoption of certain types of chemicals is affected by the prices of these chemicals as well as their effectiveness, a direct result of a set of chemical characteristics embedded in them. Market prices of the chemicals are also by and large determined by the levels of these characteristics. It is important to investigate the price determination of agricultural chemicals, especially its relationship with such chemical characteristics. Although many studies relevant to agricultural chemicals have been published, few have addressed this specific issue of price determination especially in China, a large vegetable producer for its domestic market and the international market.

The Hedonic Price Model is frequently used to analyze the relationship between the price of a commodity and its characteristics. The Hedonic Price Model was first discussed by Waugh (1929), further developed by Lancaster (1966), and carefully proved by Rosen (1974). It has been widely applied since then to many areas of economic studies such as the agricultural commodity quality and brand effect. For example, Ethridge and Davis (1982) analyzed the relationship between the cotton price and various attributes of the cotton fiber using the model. Beach and Carlson (1993) applied the model to determine the impact of various attributes of the herbicide on its prices. Fernandez-Cornejo and Jans. (1995) applied hedonic methods to calculate the quality-adjusted price indices for agricultural chemicals used for major crops in the U.S. Chen et al. (1997) evaluated the attributes of the cotton fiber from end users' point of view to study the price-quality relationship. Wang et al. (2006) investigated the impacts of the HACCP authentic labels to the prices of dairy products. Wang and Ge (2008) investigated the effect of the fruit size, grade and packaging styles on the prices of organic apples and pears.

In this article, we compare two spatial econometric models in a hedonic price framework to estimate the relative impacts of the various utility-bearing characteristics of agricultural chemicals to the price. The remaining part of this paper has the structure as follows: the next section explains the hedonic price model; empirical data are described in the following section; the 4th section explains the spatial economics model with a test for spatial autocorrelation, and the empirical results are discussed in section 5. The concluding remarks are given at the very end.

HEDONIC PRICE FUNCTION FOR AGRICULTURAL CHEMICALS

An agricultural chemical is an output for the chemical's manufacturer, but an input for crop growers. The characters of the chemical will have an impact on the final farm production and this impact will be revealed in the course of the transaction between farmers and consumers. The information flow in the farm market is assumed effective, and market values of the chemical attributes are determined when market participants in a market transaction try to maximize their profits.

Because agricultural chemicals are composed of a vector of attributes (z_1, z_2, ..., z_n), the relationship of the price of an agricultural chemical and its attribute z_1, in the market can be expressed as a hypothetical function $P(z_1, z_2^*, \cdots, z_n^*)$. This function is determined in the bargaining process between buyers and sellers.

According to Rosen (1974)'s framework, with the given manufacturing technology, there is a bid curve, $C_1(z_1, z_2^*, \cdots, z_n^*; W_t^*)$, for a farmer derived from the

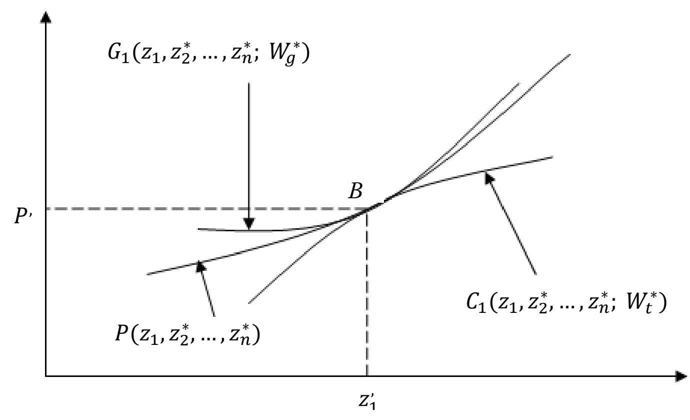

Figure 1. Illustration of hedonic price model

farmer's profit function, W_t. The bid function defines the amount that the farmer is willing to pay for the attribute z_1 at a constant profit level, W_t^*, given $z_2 = z_2^*, z_3 = z_3^*, ..., z_n = z_n^*$. There is a family of bid curves representing different farmers with different levels of technologies.

A manufacturer's offer curve, $G_1(z_1, z_2^*, \cdots, z_n^*; W_g^*)$ in Figure 1, is derived from the manufacturer's profit function, W_g^*. Given $z_2 = z_2^*, z_3 = z_3^*, ..., z_n = z_n^*$, points on the offer curve define the minimum prices that the manufacturer is willing to accept for selling the agricultural chemical attribute z_1. There is a family of offer curves representing different manufacturers having different resource endowments.

When the bid curve is tangent to the offer curve at point B in Figure 1, the farmer's and the manufacturer's profits reach the highest. At point B, the marginal value product for the agricultural chemical equals the marginal cost of using z_1, $P(z_1)$, as an input for the farmer. In the same way, the marginal cost of producing z_1 equals the marginal value of an additional unit of z_1 sold in the market at point B for the manufacturer. That means the farmer and the manufacturer choose the point B jointly to produce for W_t^* and W_g^*.

When the attributes supplied by manufacturers and demanded by farmers are matched, the market prices of characteristics, z_1, are represented by the locus of tangencies between the offer and bid curves in a plane. The shape of the locus is determined by the market participants' desire of profit maximization. The envelop function depicts the agricultural chemical attribute, z_1, and can be derived from a hedonic price equation:

$$P = f(z_1, z_2^*, \cdots, z_i^*, \cdots, z_n^*; X)$$

where X represents a vector of other factors that affect the price. A partial derivative of the equation with respect to z_i yields the marginal implicit price of agricultural chemical attribute i, which measures the impact of agricultural chemical attribute i on its price.

A key assumption for the hedonic model is the market clear, which can be satisfied in our empirical case. We empirically investigate the agricultural chemical retail stores in Anqiu, the Shandong Province. Anqiu is famous for the garlic and ginger production. These crops have a long growing history in this area and the demand and supply of certain characters of agricultural chemicals are usually in equilibrium. Based on the familiarity with the agricultural chemical market, manufacturers can set a reasonable price to have nearly all the outputs sold.

Furthermore, the manufacturers successfully manage the supply chain so that there is a little mark up between the wholesale price and the retail price. In the year before we collected the data, there is no sign of any significant price change. As a result from our observation in the range of time and space, the market clear is approximately a real situation. The retail price can be an effective replace for the equilibrium price.

DATA SOURCE AND VARIABLE SELECTION

The data for this study are collected from the sampling of agricultural chemical retail stores of Anqiu, the Shandong Province, by the researchers of the School of Agricultural Economics and Rural Development at the Renmin University during October in 2007. Anqiu is an important vegetable exporting city for garlic and ginger. The volume of the export accounts for 14% of the entire Chinese export of such vegetables (Wang et al. 2007). Anqiu is known as the vegetable basket for Korea and Japan and many products are famous worldwide. Being the typical vegetable export area, the relationship between the attributes of agricultural chemical and the prices there can be a good representation of the coof agricultural chemical markets of the vegetable export-oriented areas in China.

Although there is a resemblance of industrial organizations in different small towns in Anqiu, the level of income, cognition, cropping tradition, transportation and information varies. There is a difference in the price of similar agricultural chemicals. We have chosen 14 agricultural chemical markets in Anqiu to represent the variability, one of which is in the city of Anqiu and the other 13 are in towns within the same region. The spatial distribution of the 14 markets is indicated in Figure 2. Over 500 questionnaires were collected in these areas, among which 352 were valid, accounting for 65.2%. The distribution of the valid samples is reported in Table 1.

Variables used in the empirical study are introduced in Table 2. The price is measured as the expenditure per crop rotation for each mou[1] of land instead of the price per 1 packaged unit (a bag or a bottle). This is because it is not directly comparable among the original labeled prices as alternative varieties have different packages and in different densities. Standardizing all the prices into per 1 mou expenditure makes them consistent, which is also what farmers care for most as a production input. In this study, the chemical's

[1]mou = 0.067 hectare

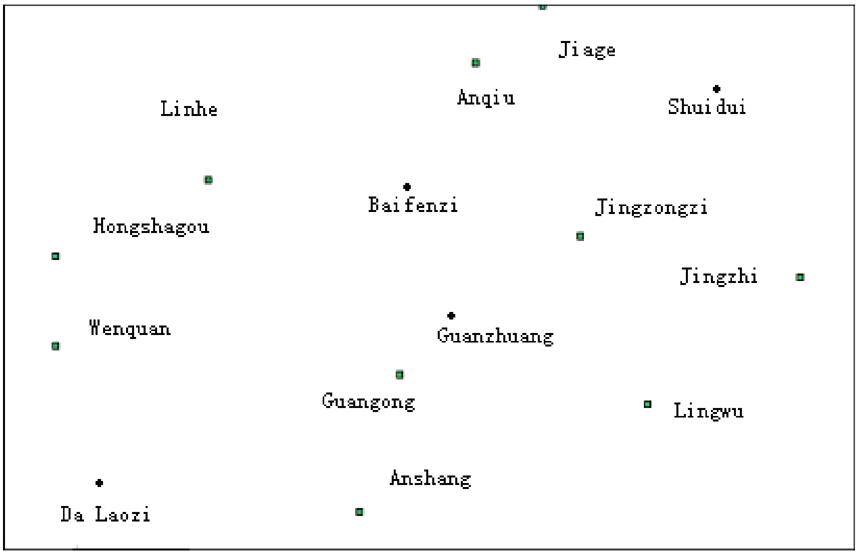

Figure 2. Spatial distributions of the sample markets

retail price is measured by the ratio of its labeled price to the effective land use, referred to as the average price per 1 mou (with the unit: Yuan/mou):

Average price per 1 mou=Labeled price/Effective acreage of each package

where the effective acreage of each package is calculated as the quotient of the volume in each package and the recommended volume use per mou.

The characteristics used in the hedonic price model are those which can be determined by manufacturers and recognized by farmers. We classify the agricultural chemical characteristics into two groups: basic characteristics and selected characteristics. Basic characteristics include the package, the form, the function and the toxicity. The selected characteristics are those not necessarily possessed by each product, e.g. plant accessibility, or those with a large variability, e.g. the effective time. These selected characteristics can be further classified into three groups: production, environmental character and quality.

Table 1. Distribution of the sample data

Townships	Sample size
Guanzhuang	22
Shidui	22
Linhe	22
Baifenzi	27
Hongshagou	18
Jingzhi	36
Gandong	33
Anshang	22
Jinzongzi	24
Linwu	13
Wenquan	19
Anqiu	27
Jiage	36
Dalaozi	33

Not only own characteristics of the chemical, also the marketing time can influence the price. New products usually enjoy a high price and the price goes down over time. In this article, we include the marketing time as a control variable in the model. Another important factor affecting the average price per 1 mou is the size of the package (sales standard), bottle or bag, because it affects the cost of packaging and the risk of wasting. These variables are also listed in Table 2.

SPATIAL ECONOMETRIC TECHNIQUES

Hedonic price model

A linear model is specified for the hedonic price, where the dependent variable is the logarithm of the price:

$$\ln P = \alpha_0 + \sum_i \alpha_i Z_i + \alpha_{kj} Z_k Z_j + \alpha_t \ln t + \varepsilon$$

where P is the average per mou price, α_0 is the intercept, t is the time in market for the chemical, ε is the random error for the model. i represents *met, gla, pel, pow, susp, sect, fung, herb, time, perm, watpro, dura, sale, mild, abs, rem, bio, pol, cert, pat, sub*, and *mid*.

Table 2. Explanatory variables for the agricultural chemicals' characteristics

Variable type	Variable symbol	Variable name	Value	Expected sign
Package	z_{met}	metal	yes,1; no,0	+
	z_{gla}	glass	yes,1; no,0	+
		(default: plastics)		
Form	z_{met}	graininess	yes,1; no,0	–
	z_{pow}	powder	yes,1; no,0	–
	z_{susp}	suspended material	yes,1; no,0	–
		(default: liquid)		
Function	z_{sect}	insecticide	yes,1; no,0	+
	z_{fung}	fungicide	yes,1; no,0	+
	z_{herb}	herbicide	yes,1; no,0	+
		(default: plant-growth regulation)		
Toxicity	z_{mid}	medium toxicity	yes,1; no,0	–
		(default: low toxicity)		
Production	z_{time}	effective time	day	+
	z_{perm}	hypertonicity	with,1; without,0	+
	z_{vatpro}	rainfastness	with,1; without,0	+
	z_{dura}	time to expiration	year	–
	z_{sale}	sales volume standard	acre	–
	z_{mild}	plant accessibility	with,1; without,0	+
	z_{abs}	internal absorption	yes,1; no,0	+
Environmental character	z_{rem}	zero residue	with,1; without,0	+
	z_{bio}	biogen	with,1; without,0	+
	z_{pol}	no pollution	with,1; without,0	+
Quality	z_{cert}	certificate	with,1; without,0	+
	Z_{pat}	patent	with,1; without,0	+
	Z_{sub}	substitute for high poisonous chemical	yes,1; no,0	+

z_{time} z_{dura} and z_{sale} are in logarithm and an interaction term of $z_{sect} \times z_{pow}$ is also included[2].

Because our data are from 14 different geographic locations, spatial effects, especially spatial dependence and spatial heterogeneity should be considered as important factors here. Neglect of spatial considerations in econometric models may lead to serious errors in the interpretation of regression diagnostics as well as the significance of the estimates (Anselin 1988; Anselin, Bera 1998). Combining the spatial econometric techniques with the hedonic price model, the Spatial Hedonic Model has been developed and applied by Kim et al. (2003) and Cohen and Coughlin (2007). The model can be adopted in this study if the spatial effects exist.

Test for spatial autocorrelation

Moran's *I* residual test is the most common method to test the spatial autocorrelation. For the general model: $Y = X\beta + \varepsilon$, the function of Moran's *I* residual test is defined as:

$$I = \varepsilon^T W \varepsilon \big/ \varepsilon^T \varepsilon$$

where ε is the error estimate in the regression function and W is a matrix of spatial weights which defines the correlation between the spatial objects. W_{ij} is equal to 1 if sample i and sample j are within five kilometers and thus considered within one market, and 0 otherwise[3].

[2]The null hypothesis H_0: the coefficient for each possible cross effect term is zero, it is tested insignificant, except $z_{sect} \times z_{pow}$, which is significant.

[3]Sample i and sample j are supposed to be in the same market if they are within five kilometers.

The statistics of the Moran's *I* follows normal distribution with the expectation $E(I)$ and variance $V(I)$, defined as

$$E(I) = \frac{trace(MW)}{(n-k)}$$

where $M = E - X(X^TX)^{-1} X^T$, E is a unit matrix of $n \times n$; and

$$V(I) = \frac{\{trace(MWMW^T) + trace[(MW)^2] + [trace(MW)]^2\}}{\left((n-k)(n-k+2)\right)^{-E(I)^2}}$$

So the standard normal distribution form of the Moran's *I* statistic is:

$$Z = \frac{(I - E(I))}{\sqrt{V(I)}} \sim N(0,1)$$

The null hypothesis is: under this model, there is no spatial autocorrelation between the regression residual errors.

Spatial hedonic model

If spatial correlations are identified from the sample, two types of spatial econometric models, the spatial lag model (SLM) and the spatial error model (SEM), can be considered.

SLM mainly captures neighborhood spillover effects in the form:

$$Y = \rho WY + X\beta + \varepsilon$$

where Y is the dependent variable, X is the exogenous variable of $n \times k$; ρ is the coefficient of the spatial regression; WY is spatially lagged dependent variable; W is an n by n weight matrix. ε is the random error.

SEM is defined as:

$$Y = X\beta + \varepsilon$$

where $\varepsilon = \rho W\varepsilon + u$

or $Y = X\beta + [I - \rho W]^{-1} u$

where u is an error term that is distributed normally with zero mean and the constant variance. The parameter ρ reflects the spatial dependence of the observed sample data which implies the direction and the extent of the impact from the nearby observations[4]. The parameter β reflects how much impact the independent variable X can exert on dependent variable Y. The effect of spatial dependence exists in the error which measures the impact from the error impulse from the nearby sample regarding to the dependent variable on this sample.

There exists a major difference between the two models. The SLM captures the impact on a particular price observation from the nearby observations, allowing prices at different stores within the same market to affect each other directly. The expected price at one location is conditional on each other nearby. The SEM means that only the error terms across different spatial units are correlated. The expected prices are unconditional on each other, but the variance and higher moments may.

Although the Moran's *I* test can identify the spatial correlations, it cannot suggest which of the two models is preferable. The LM-Error, LM-Lag and Robust LM-Error, Robust LM-Lag tests are used for this purpose. The GEODA 0.9.5-I software is used in this process.

A significant Robust LM-Error with an insignificant Robust LM-Lag is a clear indication that the SEM is superior to the SLM and vice versa.

The maximum likelihood estimation, the instrumental variable estimation, or the generalized moments methods are more efficient than the least squares methods in a case like this. In this study, we use the GEODA 0.9.5-I to estimate with the maximum likelihood the method suggested by Anselin (1988). It is also convenient to obtain the LM test statistics.

RESULTS AND ANALYSIS

The Moran's *I* test statistics is 3.93, with a p-value less than 1% before the consideration of spatial effects in the hedonic price model. This indicates that the sample residuals have a significant spatial relationship to be considered. As noted previously, this spatial correlation will affect the unbiasedness and the validation of the estimation. So it is necessary to include the spatial econometric techniques in the hedonic price model.

Further, the LM tests identifies that the spatial error model is more appropriate to these data which implies that the impact of the sample distribution to estimates is not due to the direct interaction between the prices of agricultural chemicals in different places, but due to the similar shocks in the residuals from the same market (Table 3). We know from the test results that the spatial error model effectively accounted for the impact of the spatial effect with the maximum likelihood estimation. The final errors are now independent and identically distributed, and the estimates are valid in depicting the relationship

[4]Nearby observations mean those observations are in the same market.

Table 3. Two LMs test results

Test	Test value	p-value
LM-Lag	4.30	0.04
Robust LM-Lag	0.01	0.90
LM-Error	8.48	0.003
Robust LM-Error	4.19	0.04

between the attributes and the price of agricultural chemicals in Anqiu.

The regression results from the spatial error model are reported in Table 4. There is no significant difference among the three packaging styles: metal, glass or plastic. This indicates that farmers are rational and realize that the value of the chemicals does not lie in the packaging form. The price of chemicals in the granulated form is much lower than the other two forms, liquid and suspended forms. This may be because the liquid and suspended form can be relatively easier for the crops/insects to absorb.

When other factors remain the same, insecticides, herbicides and fungicides have a higher average price per 1 mou than plant growing regulators. The differences among insecticides, herbicides and fungicides are rather small, and they are actually insignificant as indicated by the separate tests that are not reported here.

There is also no significant difference between the medium toxic chemicals and low toxic ones, which is in sharp contrast with the U.S. based research conducted by Beach and Carlson (1993). Because the more toxic the chemical is, the more health risk the users are exposed to, and the less the U.S. farmers are willing to pay for it. However, the farmers in Anqiu are more concerned about the effectiveness of the chemicals than their own health. Chemicals with a higher toxicity usually are more effective in the terms of killing insects. Another research on agricultural chemicals based on data from Henan Province of China conducted by Shi (2006) had the same conclusion that the effectiveness of agricultural chemicals is the most important factor when farmers make their purchase decisions.

The market time has a significant negative effect on price, which confirms the condition that new products always enjoy market attention and gradually lose it to newer products.

The impact of production characteristics on agricultural chemical price

The characters of plant accessibility and the effective time are insignificant, indicating that they have a little influence on the chemical price. A possible explanation is that the farmers do not have sufficient information regarding the agricultural chemical choice. The research among farmers in the Zhejiang Province, China (Lu et al. 2000), indicates that the farmers' decisions on agricultural chemicals mainly depend on their direct observations and experiences. They do not pay attention to the effective time or the plant accessibility which is not clearly observable, so they will not pay for these characteristics.

The increase of time to expiration has a significant negative impact on the average price per 1mou. The expiration time is always beyond two years, long enough for the chemicals to be used up, so it does not bring positive value to farmers. On the other hand, the longer the time to expiration, the inertia the chemical is and this will have a negative impact on the effectiveness. As a result, farmers are more likely to choose agricultural chemical with shorter time to expiration, as long as longer than a crop season.

The estimate coefficient of the internal absorption is negative and significant at the level of 10%. This indicates that agricultural chemicals with the characteristic of internal absorption have a lower price. Chemicals with the internal absorption characteristic may enter into the plant's cells through the cell walls, are more effective in killing pests, weeds, and fungi and in regulating the crops, however, they may bring risky effects on the health of the consumers. This may influence the export of vegetables and affect the growers' income in turn, because vegetables from Anqiu are primarily exported to Japan and Korea where vegetables using those kinds of chemicals are normally sold at lower prices.

The results that the characteristics like rainfastness and hypertonicity have significant positive impacts on the prices follow the conventional wisdom.

The impact of environmental characteristics on agricultural chemical price

The coefficient of the variable, zero residue, is significantly positive, which indicates that agricultural chemicals with a zero residue have relatively higher prices when the other characters are kept the same. Because the agricultural chemical residues not only affect the environment, but also influence the safety of the vegetables directly, the characteristic of zero residue has a dual nature of the food safety and environmental friendliness. The chemical residual standard is set quite strict in the international markets. High residues not only influence the current price of the exported vegetables, but they also can harm the

Table 4. Regression coefficients under two econometric models

	Econometric model without considering spatial effect		Spatial error model	
	coefficient	*t*-statistics	coefficient	*t*-statistcs
ρ			0.42	3.83
Package				
Metal	0.20	0.61	0.15	0.49
Glass	0.10	1.05	0.10	1.02
Form				
Graininess	–0.40	–2.16**	–0.48	–2.68***
Powder	–0.02	–0.13	–0.02	–0.13
Suspended Material	–0.14	–0.67	–0.12	–0.60
Function				
Insecticide	0.57	3.80***	0.56	3.92***
Fungicide	0.60	3.92***	0.58	4.01***
Herbicide	0.63	3.74***	0.64	4.00***
Toxicity				
Medium Toxicity	0.02	0.19	0.02	0.28
Production				
In (effective time)	–0.001	–0.02	0.02	0.33
Hypertonicity	0.21	2.70***	0.20	2.60***
Rainfastness	0.14	1.92	0.15	2.16**
In (time to expiration)	–0.44	–1.68*	–0.57	–2.26**
In (sale volume standard)	–0.72	–25.81***	–0.71	–27.26***
Plant Accessibility	–0.11	–1.35	0.01	0.12
Internal Absorption	–0.13	–1.90*	–0.13	–1.88*
Environmental Character				
Zero residue	0.17	1.99**	0.16	2.01**
Biogen	0.06	0.65	–0.006	–0.06
No pollution	–0.02	–0.20	–0.03	–0.36
Quality				
Certificate	–0.08	–0.84	–0.07	–0.76
Patent	–0.01	–0.04	0.002	0.02
Substitute for High Poisonous Chemical	0.30	2.72***	0.29	2.70***
Powder×Insecticide	–0.84	–4.28***	–0.86	–4.65***
In (market time)	–0.12	–2.81***	–0.12	–2.92***
Sample Number	352		352	
R^2	0.72		0.73	
Log Likelihood	–321.79		–317.93	
F-statistic	32.78		–	
Prob (Breusch-Pagan)	0.0004		0.004	
Prob (Jarque-Bera)	0.0000		–	

Note: ***significant at 1%, **significant at 5%, *significant at 10% level environment and thus affect the price of vegetables in the next rotation. It is known that Japan has the strictest chemical residual control system in the world (Chen, Qian 2007). The income of farmers in Anqiu relies heavily on the export to Japan and this system pushes farmers to reduce their level of chemical residues. This indicates that the increasingly strict safety test in the international trade already has an impact on the chemicals choice of Chinese farmers. On the other hand, this result is in sharp contrast with the studies conducted in several non-export vegetable bases in Henan (Shi 2006).

The characteristic of "no pollution" is not significant and we find that farmers are indifferent to the environmental pollution. Although the cost of "no pollution" agricultural chemical is high, this kind of agricultural chemical cannot have a high price because of the buyers' unwillingness to pay for a premium.

The characteristic of the "biogen" is not significant and this indicates that there is no difference between the price of the biological chemical and that of the traditional agricultural chemical. Biological chemicals are more environment friendly and safe to humans and animals. However, from the conversations with the farmers, we found that many farmers are critical of its effect. This is consistent with the results from the "no pollution", and additionally the chaotic biological chemical standards in China also contribute to the low price of the biological chemical.

The impact of the quality characteristics on the agricultural chemicals price

The coefficient of "substitute for high poisonous chemical" is positive and statistically significant. Since 2003, the promotion project of the substitute for high poisonous chemicals has prevailed in China which results in a high acceptance of these substitutes. Farmers agree that they have at least the same effect to crops as highly poisonous ones and are willing to pay a price premium for them to replace the highly poisonous chemicals.

The "certificate" and "patent" are not statistically significant. Farmers do not have a high cognition of them and are unwilling to pay a high price. Usually, the products with a patent should have a higher price but there are various kinds of agricultural chemicals and the techniques that are easily copied. There are many substitutes in the market and the products with a patent cannot have an advantage in price. This is also in sharp contrast with the result of Beach and Carlson (1993). In their study, the patent has a significant positive influence on the price of a weeding chemical. This may be due to the different attitudes towards the patent between the manufacturers and farmers in China and their counterparts in the US.

The measurement of the impact of selected characteristics on price

Table 5 shows the calculation of the semi-elastic coefficient of the average price per 1 mou to the selected characteristics of virtual variables and also gives the extent of impact of the change of the virtual characteristics to agricultural chemicals average price per 1 mou. For the dummy characteristic variables, "the semi-elastic coefficient of the average price per 1 mou to a certain characteristic" in the table shows the extent of the change of the agricultural chemical average price per 1 mou (in percent) when the attribute is added. "The extent of impact" shows the

Table 5. The impact of selected characteristics on price

Characteristics	Average value	Coefficient	Semi-elastic coefficient of average price per mou to certain characteristic (%)	Extent of impact (Yuan/mou)
Hypertonicity	0.69	0.20	21.86	1.73
Rainfastness	0.46	0.15	16.18	1.28
Internal Absorption	0.48	–0.13	–11.84	–0.94
Zero Residue	0.33	0.16	17.33	1.37
Substitute for high poisonous chemical	0.11	0.29	33.54	2.65

Note: The results are calculated through the spatial error model of agricultural chemical hedonic price. The average price per mou P_0 of agricultural chemical is 7.92 Yuan/mou. Semi-elastic coefficient of average price per mou to a certain characteristic = EXP (the estimate of regression coefficient) – 1; the extent of impact = (semi-elastic coefficient of average price per mou to certain characteristic) × P_0

price level changed measured in Yuan when a certain characteristic is included.

We selected five characteristics with significant impacts on the price. When we compare the rate of the change of the average price per1 mou (that is the definite value of the semi-elastic coefficient of the average price per 1 mou to a certain characteristic), we may acquire the following rank (from a big impact to a small impact): "substitute for highly poisonous chemical", "hypertonicity", "zero residue", "rainfastness" ,"internal absorption".

Most of the agricultural chemicals have a quality time of 2 years or 3 years. When other factors remain the same, we may find that the average price per 1 mou for an agricultural chemical with 2 years of quality time is 126.18% of the price of the one with 3 years of the quality time. We may see a significant difference between the two.

When we keep other factors constant, we may find that the 1% increase of the sales volume standard may result in a 0.71% drop of the average price per 1 mou. At the average level, the change of 1% in the unit may cause a 0.06 Yuan/mou change.

Given that other selected characteristics have no significant impact on the average chemical price per 1 mou, we may conclude that, for the medium or low toxic agricultural chemicals, "substitute for high poisonous chemical" ,"hypertonicity", "zero residue", "rainfastness" and "internal absorption" are the main factors of price determinations in addition to the basic characteristics like form, function, and marketing time.

CONCLUSIONS

This paper studies the agricultural chemical price determination in the export-oriented vegetable production areas in China, using a hedonic price model with the spatial econometric estimations. The data are from the agricultural retail shops of Anqiu, the Shandong Province. The results show that the medium or low toxic agricultural chemicals, substitutes for highly poisonous chemicals, hypertonicity, zero residue, rainfastness, chemicals without internal absorption feature, shorter time to expiration, lower sale volume standard, newer products in the market, and non- solid forms all enjoy higher prices. When other factors remain the same, there is no significant difference in price between the medium toxic agricultural chemicals and low toxic ones. Also, the factors like different packages, the effective time, plant accessibility, causing pollution or not, with biological factors or not, having a certificate/patent or not, do not have any significant impact on the agricultural chemicals price.

The information of this paper can help agricultural chemical manufacturers to make decisions in order to maximize their profits. According to the relative impact of a certain characteristic on the corresponding increase of price, we may obtain the following rank: "substitute for high poisonous chemical", "hypertonicity" ,"zero residue" ,"rainfastness". When those characteristics are included, agricultural chemicals can be charged a higher price. When the added cost is less than the corresponding increase in price, manufacturers make more profit by including these characteristics. The characteristic of "internal absorption" has a negative impact and the manufacturers in the vegetable-export base should consider reducing the output of agricultural chemical with this characteristic.

The result of no significant price difference between the biological chemicals and the traditional agricultural chemicals also needs some attention. The cost of the biological chemicals is relatively higher. Under this circumstance, the biological chemical manufacturers will have no motivation for the biological chemical production, which can be detrimental to the development of the industry of biological chemicals in the long run. The same concern is raised for the less-polluting agricultural chemicals production. This will exert a negative impact on our long term environmental protection.

In addition, the existence of the spatial interdependence found in this analysis confirms the China's substantive advance in the technology for disseminating information and the development of transportation in the recent years. In the past decades, China has achieved a great progress in the infrastructure construction, like highways, rural roads, telecommunication, etc. For example, China had 508 million mobile phone users by July, 2007 (Gao 2007), which means that two Chinese people share one mobile phone. Therefore, a quick transmission of information generates a comparatively equal price formation.

Several suggestions can be derived from this analysis for the policy makers: First, manufacturers should be encouraged to conduct a more innovative research and to develop substitutes for highly poisonous by the less-polluting ones. Subsidies can be provided to the manufacturers for compensating the costs and reducing the high price so that farmers are more willing to adopt the safer chemicals. Second, the national standards for agricultural chemicals should be promptly formulated; especially for those promising chemicals like biological chemicals. Third, environmental education should be further promoted to enable farmers to understand the relationship among food safety, farmers' own health, the quality of environment, and the short-term and long-term effects of pollution.

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