The Impact of Chemical Restrictions on Agricultural Output and Input Markets

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I、Introduction

Chemical residues in food have become a major health consideration. Concern looms that new, more imposing legislation may be passed that restricts the type and amount of chemical fertilizers and pesticides that farmers may apply to crops. As an example, the EPA has propsed a ban of ethylene bisdithiocarbamate (EBDC), a fungicide, for 45 uses on crops by the spring of 1991. (Chitwood). Proponents of this new legislation argue that it will increase food quality and safety. Opponents argue that the reduction of chemical use will increase the cost of agricultural production. A study from The Fertilizer Institute suggests that a complete ban would boost consumer food costs by 45% and raise the general rate of inflation by 5%-7%. Other results of the study were that corn output would fall 40% and wheat 50% in association with a $5-billion loss in export sales (The Kiplinger Agriculture Letter).

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As Archibald points out in an article published in a recent issue of Choices, "Regulating Chemicals: A Public Policy Challenge", since this banning action involves several parties with conflicting interests -- agricultural producers, agribusinesses, chemical producers, and consumers -- evaluating the impact of chemical restrictions through a multi-market general equilibrium framework is essential to capture the effects in all sectors.

There have been recent studies addressing the effects of chemical restrictions in agriculture, (e. g., Dinan and Salassi, Helfand). However, these studies have been limited to partial equilibrium analysis. This study attempted to quantify the impact of chemical restrictions on output and input markets. A full equilibrium market framework was developed which allows interaction between different levels of markets in the U.S.

Gardner (1975, 1979, 1987) developed a sequence of theoretical works for comparative statics under multiple market equilibrium conditions. This study was based on the conceptual work of Gardner and earlier developments by Floyd. The technical relationships of agricultural production were estimated using a dual approach.

Ⅱ、Data

The data employ for this analysis are from the U.S. agricultural database developed by Capalbo, et al. The data set consists of annual data over the period 1948-83 on prices and quantities of agricultural outputs and inputs. Gross agricultural output was aggregated from two groups, crops and livestock products. Crops consist of small grains, coarse grains, other field crops, vegetables, and tree crops. The livestock group includes dairy and animal products. The commodities were aggregated using the Tornqvist approximation to the Divisia indexing procedure where the weights are the value shares of each commodity in the aggregation group. (Capalbo, et al.).

For the purpose of this study, inputs were divided into two categories, chemical inputs and nonchemical inputs. The chemical inputs consists of fertilizer and pesticides, while the nonchemical inputs includes labor, capital, land, structures, energy, and miscellaneous inputs.

In order to employ comparative static analysis under a full equilibrium framework, an output demand elasticity was needed. According to Tweeten the short run (1-2 year) elasticity of demand at the farm level for agricultural output has been estimated to be -0.25. For simplicity, this output demand elasticity estimate was adopted for the analysis.

Ⅲ、Theoretical Framework

To provide a full analysis of policies such as restrictions on input usage, relevant input markets must be included in the model. At least two categories of inputs are needed in order to analyze the consequences of a regulated and unregulated input category.

The simplest model that permits substitution in production is the single-output, two input model used by Hicks to investigate issues in labor economics. The development of this model as applied to agricultural price supports was accomplished by Floyd. The model consists of six equations : where fu and fv are the marginal products of factors, u, and v, respectively.

(1) $X = f(u,v)$ (industry production function),

(2) $f_u P_x = P_u$ (VMP = factor price),

(3) $f_v P_x = P_v$ (VMP = factor price),

(4) $u = g(P_u)$ (factor supply),

(5) $v = h(P_v)$ (factor supply), and

(6) $x = D(P_x)$ (product demand).

In order to justify these equations as a representation of a one-output, two-input industry, the following assumptions apply: (1)the output market is competitive, (2) the input markets are comptitive, (3) producters maximize profits, and (4) all firms are identical. Since the analysis entails agriculture production, the first three assumptions seem reasonable. The last assumption may be taken to mean that all units of inputs, u and v, respectively, have the same characteristics and that only one least-cost technology is available. These conditions imply that at competitive equilibrium, all producers will be observed at the minimum of their average cost function so that the industry production function (1) is linear homogeneous.

Since the analysis pertains to changes in the system, equation (1)-(6) were totally differentiated, converted to elasticity form, and simplified assuming constant return to scale[1]. The resulting equations are

(7) $EX = K_u Eu + KvEv$ (where $K_u = uPu / XPx$, $K_v = XPx$),

(8) $EPu = (-K_v/\sigma)Eu + (K_v/\sigma)Ev + EPx$,

(9) $EPu = (-K_u/\sigma)Eu + (K_u/\sigma)Eu + EPx$,

(10) $Eu = e_u EPu$

(11) $Ev = e_v EPv$, and

(12) $EX = \eta\ EPx$,

where η is the elasticity of product demand.

The system of linear equations, (7)-(12), contains six mutually determined percentage change variables, EX, Eu, Ev, EPx, EPu, and EPv, (e. g. Eu= du/u), and six parameters, K_u, K_v, σ, η, e_u, and e_v). Writing these equations in matrix form in preparation for solving via Cramer's rule, the right hand side is a column of zeros reflecting a static equilibrium system (Gardner, 1989, p. 98).

Now, consider a policy of a ban on chemical factors of production such that the quantity of u is directly controlled. The system of equations (7)-(12) was modified by dropping equation (1), the supply function of u, and dividing all equations by Eu. After some algebra the following results were obtained (Gardner, 1989, p. 97):

$$(13)\ \frac{EPu}{Eu} = \frac{e_v + Ku\,\delta - K_v\,\eta}{\delta\,\eta + e_v(K_u\,\eta - K_v\,\sigma)} \quad \text{and}$$

$$(14)\ \frac{EPx}{Eu}=\frac{K_u(e_s+\sigma)}{\sigma\eta-e_s(K_s\sigma-K_u\eta)}\ \text{and}$$

Dividing (13) by (14) gives the effect of an increase in a policy determined commodity on the input price, given that the product price change was achieved through input quantity controls. The expression is

$$(15)\ \frac{EPu}{EPx}=\frac{e_v+K_u\sigma-K_s\eta}{(\sigma e_s)K_u}\quad \text{and}$$

The effects of an input restriction on different variables are shown in table 1. The signs of all of the expressions are unambiguous except for the effect on Pv and v. Here the sign depends on whether δ is greater than or less than $-\eta$. As indicted in table 1, values for η, K_u, K_s, e_v, and δ are needed in order to derive the impact of a chemical input restrictions on output and the relevant markets.

Ⅳ、Statistical Model and Estimation

A translog cost function was formulated and estimated in order to obtain values for shares, K_u and K_v; and the elasticity of substitution between the chemical input and nonchemical input, σ_{12}.

The one-output-two-inputs translog cost function is C is cost, y is output, w_1 is the price of the chemical input, and w_2 is the price of the nonchemical input. This translog (dual) cost function can be regarded as a quadratic approximation to the unspecified "true" cost function (Ray). In this context, $b_{ij}=b_{ji}$ for all i and j.

$$(16)\ \ln C=a_0+\sum_{i=1}^{3}a_i\ln x_i+1/2\sum_{i=1}^{3}\sum_{j=1}^{3}b_{ij}\ln x_i\ln x_j;\ \text{where } x=(w_1,w_2,y),$$

Linear homogeneity of the cost function in input prices was maintained through restrictions on the parameters. Share equations were derived and utilized to estimate the elasticity of substitution between inputs.

To avoid singularity in the variance-covariance matrix when estimating a complete system of share equations, one of the equations is dropped. Since there are two inputs in this analysis, only one equation was estimated in conjunction with the theoretical assumption of homogeneity to obtain paramcter values for the cost function.

The purpose of estimation was to compute the elasticities of substitution using estimated parameters. The allen partial elasticities of substitution from the translog model, are obtained as follows (Ray):

$$\sigma_{ij} = \frac{b_{ij} + k_u k_v}{k_u k_v}$$

The supply elasticity of the nonchemical input is estimated by simply regressing lnv on lnPv. Results of estimation follow.

V、Empirical Results

The chemical input share equation was estimated using restricted least squares. All of the coefficients are significant at 5% level. The estimated and calculated coefficients for the cost equation are reported in table 2.

The elasticity of supply for the nonchemical input was estimated to be 0. 0026, which, of course, is inelastic. Such a low elasticity may have resulted since this input category contains land and machinery which are commonly considered to be quasi-fix or fixed inputs in a short-run situation. The elasticities of substitution were calculated and are reported in the Appendix. Except in the earlier years over the range of the data, σ as positive indicating a substitute relationship between the two inputs.

For purposes of this analysis, the last sample observation in the data set was chosen to evaluate a hypothetical restriction on the chemical input for all of the relevant markets. Using the derived formulas depicted in table 1, the results are summarized in table 3.

The results show that, a one percent reduction in the chemical input resulted in a 0.28 percent increase in the agricultural output price and a 0.07 percent decrease in the output. As expected, the equilibrium price for chemical inputs increased. The large magnitude (over 7%) of the increase was due to the low substitution effect between the two inputs and the fairly high demand elasticity for the chemical input. As for the nonchemical input market, there was a negative effect on the quantity of the nonchemical input as well as its equilibrium price.

The effect of the chemical restriction on the nonchemical input can be decomposed into two parts. First, a reduction in the chemical input led to a decrease in output. This caused a decrease in the derived demand for the nonchemical input (demand effect). Second, a reduction in the chemical input led to substitution of the nonchemical input (substitution effect). The net effect depends on which force is stronger.

The results suggest that the output demand effect dominated the input substitution effect. This is consistent with the low estimate of σ (for 1983, the estimate was only 0.01246). A weak substitution effect combined with a low elasticity of supply for the nonchemical input resulted in a large decrease in the nonchemical input price.

In summary, the total effects on the three markets after the chemical restriction were that all prices increased except for the nonchemical input and all equilibrium quantities decreased. Thus, given this scenario, consumers of agricultural output and the chemical input would have experienced a loss in consumer surplus. Although a higher output price resulted, production cost increased, so producers of agriculture output faced a decrease in rents. This result is consistent with Gardner's statement, "The input regulation that we do observe, such as on quantities of pesticides, appears designed to aid neither farmers not input suppliers. This is clear from a ban on a chemical, since cutting quantity to zero cannot increase rents for either its consumers or producers, although it can inrease rents of other farm inputs. "(Gardner, 1987. p. 103). The results of this study showed that even the producers of other farm inputs suffered loss due to the low substitution effect between the two inputs.

Ⅵ、Conclusion

Archibald (p.20) may be correct in her statement that "Policy and regulatory decisions about the use of chemicals in food production and processing are unavoidable." However, the results of this study reflect the dangers of such restrictions in that large social costs may result. Careful action and evaluation about the benefits and costs of policy alternatives among different sectors and interest groups must to be emphasized in order to reduce social transaction costs.

Footnotes

1. If production technology reflects constant returns to scale (CRTC), then all second partials of the production function can be eliminated by means where σ is the elasticity of substitution between u and v (Allen, p. 343, following from the assumption that the production function is linear homogeneous). A CRTC production function also implies that the sum of factor payments exhausts the value of output (XPx= uPu+ vPv).

$$f_{uu}=\frac{-vf_uf_v}{ux\sigma} \quad \text{and} \quad f_{uv}=f_{vu}=\frac{f_uf_v}{\sigma x},$$

2. When a production function exhibits constant return to scale, the coefficient of cost fiexibility η equals one:

$$\eta=\frac{\partial \ln C}{\partial \ln y}=1.$$

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Table 1. Formulations for the on Different Variables from a Chemical Restrictio

Effect on :	
x	$\dfrac{\eta K_u(e_v+\sigma)}{\sigma\eta-e_v(K_v\sigma-K_u\eta)}$
Px	$\dfrac{K_u(e_v+\sigma)}{\sigma\eta-e_v(K_v\sigma-K_u\eta)}$
Pu	$\dfrac{e_v+K_u\sigma-K_v\eta}{\eta\sigma-e_v(K_u\eta-K_v\sigma)}$
Pv	$\dfrac{K_u(\sigma+\eta)}{\sigma\eta-e_v(K_v\sigma-K_u\eta)}$
v	$\dfrac{K_ue_v(\sigma+\eta)}{\sigma\eta-e_v(K_v\sigma-K_u\eta)}$

Table 2. Coefficients of The Cost Function

Parameter	Coefficient	t-ratio
b_1	0.206	21.265
b_2	0.794	21.265
b_{11}	0.518	14.947
b_{12}	−0.518	−14.947
b_{22}	0.518	14.947

Table 3. Results of a Hypothetical 1%Restriction on Chemical Inputs

Market	% change
Output market	
Price	0.2837
Quantity	−0.0709
Chemical input market	
Price	1.2404
Quantity	−1.000
Nonchemical input market	
Price	−4.4747
Quantity	−0.0140

Appendix

Estimated Elasticities of Subetitution

Year	σ
1949	−0.2564
1950	−0.2031
1951	−0.1882
1952	−0.2418
1953	−0.1386
1954	−0.2353
1955	0.0216
1956	0.0247
1957	−0.0399
1958	−0.0470
1959	−0.0332
1960	0.0038
1961	0.0591
1962	0.1057
1963	0.1616
1964	0.1954
1965	0.1888
1966	0.1956
1967	0.2639
1968	0.1903
1969	0.1169
1970	0.0653
1971	0.1568
1972	0.1900
1973	0.1650
1974	0.3335
1975	0.3702
1976	0.3053
1977	0.2662
1978	0.1984
1979	0.1542
1980	0.1520
1981	0.0872
1982	0.0099
1983	0.0124

禁止農藥使用對於農業產出及因素投入市場影響之分析——美國農業之實例

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摘要

食物上的殘餘農藥所造成食品安全上的顧慮，以及化學農藥使用所造成地下水源的污染，使得農業由單純的生產產品供給者變爲一個健康與環境污染的威脅者。美國的環保署最近正大力促導禁止農藥使用的立法通過。關於此一法案，其支持者認爲如此可以確保食品及環境的安全；而反對者則認爲農業的生產成本將因而提高，消費者將因此負擔更高的食物支出而導致通貨膨脹，並危及美國農產品出口的外匯收入。

由於此禁止法案直接影響經濟體系中各利益相衝突的團體—農民、農產品加工者、農藥生產者，以及消費者，因此本研究乃利用一個多層市場全面均衡的理論架構，以及對偶性經濟理論來實際衡量此一農藥禁止使用法案對於美國農業產出及其它因素投入市場的影響。大部份農藥禁止使用影響之研究均受限於局部均衡的架構，無法考慮各市場間互動與回饋的效果。此研究根據全面均衡的架構，並利用超越性對數成本函數來計算出因素之間的替代彈性，以及其它相關參數，並將”影響程度”予以量化及分析。

實證結果顯示在現行的消費偏好與生產技術條件下，此一法案之施行將導致大幅社會成本的發生。在農產品以及農藥兩層市場中的消費者將面臨消費者剩餘的減少。在非農藥投入因素的市場上，其生產者也將因因素之間替代彈性較低，而面臨生產者剩餘減少的情況。因而對於此一政策施行利弊的考量，需予以妥善的評估，以期降低社會轉接中的成本。

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