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Estimates of Supply Conditions for 8 Commodities

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Preliminary

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1. Introduction

Estimates of demand elasticity are abundant. Estimates of supply elasticity are exceedingly scarce.[1] Yet few would deny the usefulness of estimates of supply elasticities for many concrete applications. Using a simple two equation model and annual data for the US going back to the beginning of the century, this study attempts to estimate the parameters that reveal the supply elasticities for 8 commodities whose quality has stayed the same over the sample period.

There are also good theoretical reasons for attempting to fill Clapham's empty boxes. Because theoretical analyses of the status of the core for an industry places the nature of the supply conditions at the center of the stage, it is necessary to learn more about the cost blade of Marshall's scissors. According to the theory of the core, an industry has a nonempty core only if the industry total cost function (ITCF) is subhomogeneous so that the industry has nondecreasing returns to scale. This means that the marginal industry total cost function (MITC) is either equal to or below the industry unit cost. In the neoclassical competitive equilibrium the MITC is the industry supply schedule. Hence under the first alternative a perfectly elastic supply schedule implies a nonempty core.

Two criteria determine the suitability of a commodity for estimation of its supply conditions in this study. The first is the availability of a long series of annual data. The second is that the quality of the commodity has remained constant over the period for which data are available.

Two exogenous variables are crucial for this study. The first is a measure of the general price level. The Consumer Price Index is the longest time series available for this purpose. The second is a measure of permanent income. Annual expenditures on consumption serve as a proxy for permanent

income. Briefly, the main reason is this. The amount that people spend on their consumption depends on their future prospects, their expected wealth. Consumption outlays are available for each year starting in 1929 and are available for a scattered selection of years beginning in 1900. Hence the sample period cannot begin before 1900. The commodities and the number of years for which there are observations in the samples are as follows:

67 for corn, cotton, potatoes and wheat;

65 for eggs;

61 for Douglas fir;

56 for electricity;

51 for cement.

The second major constraint is imposed by the desire to study commodities of constant quality during the sample period. Many raw materials satisfy this requirment especially among agricultural commodities. I chose corn, cotton, Douglas fir, eggs, potatoes and wheat. The two nonagricultural commodities in the sample are electricity and Portland cement. Supply conditions differ markedly between these two groups. The agricultural commodities are produced by many quite small firms. During the sample period the number of agricultural firms (farms) has been decreasing and the firm size increasing. Even so, by the end of the sample period, 1988, it remains accurate to describe these as small firm industries. In contrast, the electricity industry has relatively few large firms subject to State and Federal regulation. It is the prevailing belief that there are economies of scale in generating electricity. The Portland cement industry contains many firms that operate in regional markets. Cement is rarely shipped more than 300 miles. This fact alone does not, of course, explain the regional nature of the cement industry. Nothing prevents a cement firm from operating plants

widely scattered throughout the U.S. Nevertheless, each regional market contains relatively few firms. The industry adhered tenaciously to basing point pricing a practice at variance with a neoclassical model of competition (Stigler, 1949). A long legal battle between the Federal Trade Commission and the firms in the industry stretching over more than 4 decades finally culminated in Federal victory and, presumably, this pricing practice no longer occurs. Complications are also present in agriculture. Since 1933, the Federal government has been an active participant in corn, cotton and wheat via the various programs aimed at supporting prices and limiting output. Federal loan programs allow farmers of corn cotton and wheat to obtain nonrecourse loans from the government at so much per unit. If the farmers do not redeem these loans then the government takes title to the collateral. These programs put a floor on prices because they allow farmers in effect to sell their output to the government at the support prices. Either the market price is above the support level and clears the market, or the market price is at the support level and the government accumulates stocks of the commodity at the support price. In either case, the average price received by farmers, the price variable in the regressions, presumably lies on the farmers' supply schedules. The effects of these programs on output are more difficult to guage. Even after 1933, these programs limited acreage planted but did not directly control production. The only commodities in the sample to which it would seem that the neoclassical model of perfect competition may apply are Douglas Fir, eggs and potatoes.

Supply conditions take as given the inputs that cannot or do not vary for at least the time spanned by a sample observation, one year. If the firms can produce other products with the same facilities as they can use to produce the given product, then the supply of this commodity is not

constrained by fixed inputs specialized to it. Thus perhaps only the total agricultural cropland can be said to be specialized for producing agricultural outputs. For instance, if producers of corn can also readily produce soybeans then there are no inputs committed to corn for periods even as long as the corn growing season. This point of view seems especially well founded for a commodity like eggs for which the specialized input, hens, may live less than one year depending on the economic prospects for eggs and poultry. Production conditions for Douglas fir suggest that all the inputs are highly mobile on very short notice. For these reasons there is no attempt to include measures of any fixed inputs for Douglas fir and eggs. A possible candidate for fixed inputs for corn, cotton, potatoes and wheat is acreage planted. The results for these 4 commodities are reported in two ways: first, assuming high substitutability among such agricultural products so there is no measure of fixed inputs in the model; second, assuming acreage planted (or harvested) is a proxy for inputs committed for one year (in the Appendix). This Appendix also describes some salient trends in these 4 commodities that are pertinent to the role of acreage harvested as a proxy for fixed specialized inputs.

For Portland cement and electricity the situation is different because there are specialized facilities. Measures of industry capacity are available for Portland cement and electricity. It is important to realize that these are measures of the physical capacity of the production facilities. They have no connotations about optimality nor do they refer to the scale of output at which unit costs might be a minimum. For cement, capacity simply refers to the size of the kiln in which the product is made. For electricity, it refers to the peak load capacity of a generator. Both

measures owe more to the laws of physics and chemistry than to the laws of economics.

2. Estimation of Model Parameters

1. Demand

According to the standard theory, the quantity demanded, q, of a commodity varies inversely with its relative price, p, holding real income, y, constant. The total quantity demanded depends on the size of the population, denoted by h (for humans). The relative price of the commodity is defined to be its nominal price divided by an index of the price level. I use the Consumer Price Index (CPI) to estimate the price level. However, as many studies have shown, the CPI suffers from many shortcomings. For present purposes the most serious are these. The CPI keeps old commodities in its sample for too long and brings new commodities in too late. Nor is this all. In addition it fails to correct prices of the commodities in its sample for changes in product quality. These practices bias the price index upward to the extent that existing products improve in quality and new products drop rapidly in price before they enter the CPI sample. Because of these errors it is advisable to make the price level index a separate variable in the demand equation. All the variables in the model are in (natural) logs. P denotes the log of the nominal price of the commodity, Q the log of quantity, and Π the log of the CPI. The price level appears as a separate exogenous variable in the demand equation. One can test the hypothesis that the coefficient of Π is equal in size and opposite in sign to the coefficient of P (see below sec.3).

The total demand for the product depends on some appropriate measure of total real permanent income. The reasons for a reluctance to deflate the nominal price of the commodity by the CPI apply to nominal income as well. The research distinguishing between permanent and transitory income suggests that total consumption is a better measure of permanent income than is total

income itself (Friedman, 1957). Therefore, Y_N, the log of nominal income, is represented by the log of nominal consumption. The demand equation of the model is as follows:

(1) $$Q = \alpha_o + \alpha_1 P + \alpha_2 Y_N + \alpha_3 \Pi + \alpha_4 H + u.$$

H denotes the log of total population and u is a random residual.

2. Industry Total Cost Function

Because the title of the preceding subsection is "Demand," it would seem that "Supply" ought to be the title of this one. However, the longer title more accurately represents the underlying theory. This theory assumes that an industry is organized so that each given rate of output is produced at the minimum total cost. The function relating this minimum total cost to output is called the Industry Total Cost Function (ITCF). The derivative of this function with respect to output is the Marginal Industry Total Cost (MITC) and it underlies the industry supply schedule. At the optimal levels of industry inputs, production of a given rate of output occurs at the least total cost. Therefore, the input that describes how to make the commodity, the stock of knowledge, is also an endogenous variable that depends on the desired scale of operation. The state of technology underlying the ITCF is not given and is a function of the expected demand. The distinction between the short run and the long run ITCF depends on which inputs are held constant. At an instant in time all inputs may be given and the given outputs of the firms in the industry may be sold on the market for whatever price they can fetch. Ultimately, all inputs can adjust in order to satisfy the given demand conditions at the least total cost. In a competitive industry with growing demand, the shifting demand traces out the long run MITC. The output at an efficient industry equilibrium maximizes the net benefit of producing and selling the commodity. Hence it is that rate of

output at which the marginal industry total cost equals the marginal benefit. Write MITC as a function of the output, q, and k, the stocks of the inputs that are fixed for the time period to which the ITCF refers.

(1) $\quad MITC = f(q, k).$

Because the model uses logs of all variables, a convenient specific form of f is given as follows:

(2) $\quad f(q, k) = B\, q^{\beta_1} k^{\beta_2}.$

It is plausible to suppose that the equilibrium price is proportional to but not necessarily equal to Marginal Industry Total Cost.

(3) $\quad p = MITC\ x.$

If the ITCF is convex then the MITC must be nondecreasing so that β_1 is nonnegative. The factor of proportionality, x, can represent the effects on the price of movements along a shorter run MITC than f. Fluctuations of demand result in short run equilibria such that markets clear at prices equal to short run industry marginal cost. The factor x can also represent departures from marginal cost pricing of industry output. It may be that the price equals unit cost so that if the MITC is below the IUTC (Industry Unit Cost Function) then x is greater than one. Therefore, because of either demand or cost factors,

(4) $\quad p = f(q, k)\ x.$

Taking logs and substituting from (2) gives

(5) $\quad \log p = \beta_o + \beta_1 Q + \beta_2 K + X + v,$

in which v denotes a random residual. If X is a proxy for shorter term marginal cost then write

(6) $\quad X = \gamma_o + \gamma_1 Q + \gamma_2 K.$

Possibly, $\gamma_1 > 0$ and $\gamma_2 < 0$. Substituting X given by (6) into (5) yields

(7) $\log p = (\beta_o + \gamma_o) + (\gamma_1 + \beta_1) Q + (\gamma_2 + \beta_2) K + v.$

This shows that the coefficients of Q and K are the sums of the shorter and longer term effects. However, the nature of the available data may prevent disentangling these effects so that it may be necessary to remain content with estimates of the sums. Because p is the relative price, $\log p = P - \Pi$. Hence (7) becomes

(8) $P = \beta'_o + \beta'_1 Q + \beta'_2 K + \Pi + v,$

in which the primed coefficients denote the corresponding sums in (7). Equation (8) is the relevant supply side of the model.

3. The Reduced Form

In this model the endogenous variables are price and quantity. The reduced form equations express these variables as functions of the exogenous variables that are Π, Y_N, and H. In addition because the data are annual figures the stock of capital that is specialized to the production of the commodity is exogenous as well. Even if the industry produces several commodities, the prices and quantities of these would be endogenous so that introducing them explicitly into the model would not help us estimate the structural parameters. The reduced form equations obtained by solving (1.1) and (2.8) for Q and P are given as follows:

(1) $Q = c_o + c_1\Pi + c_2 Y_N + c_3 H + c_4 K + \xi,$

(2) $P = d_o + d_1\Pi + d_2 Y_N + d_3 H + d_4 K + \eta.$

In case it is assumed that no inputs are specialized for the production of the given commodity during a year, K is absent from both equations. However, if K should appear in the reduced form equations but is omitted, then the least squares estimates of the coefficients of (1) and (2) would not be consistent. More generally, the absence of any pertinent exogenous variable

from the estimated reduced form regressions prevents the claim that least squares estimates of these regressions are consistent. Because one can always say that some such variable has been left-out, this kind of empirical work does not rest on a purely objective foundation. Some untestable prior beliefs always remain.

By expressing the coefficients of (1) and (2) in terms of the structural parameters of (1.1) and (2.8), it is not difficult to verify that the reciprocal of the supply elasticity is

(3) $\beta_1' = d_2/c_2 = d_3/c_3$

because

$$d_2 = \beta_1'\alpha_2/(1 - \alpha_1\beta_1') \quad \text{and} \quad c_2 = \alpha_2/(1 - \alpha_1'\beta_1');$$

$$d_3 = \beta_1'\alpha_4/(1 - \alpha_1\beta_1') \quad \text{and} \quad c_3 = \alpha_4/(1 - \alpha_1\beta_1').$$

Also, the demand elasticity (cf. (1.1) satisfies

(4) $\alpha_1 = c_4/d_4,$

because

$$c_4 = \alpha_1\beta_2'/(1 - \alpha_1\beta_1') \quad \text{and} \quad d_4 = \beta_2'/(1 - \alpha_1\beta_1').$$

Note that the random residuals of the reduced form equations would be correlated even if the residuals of the structural equations are uncorrelated. This can be verified from the two equations as follows:

(5) $\xi = (u + \alpha_1 v)/(1 - \alpha_1\beta_1')$ and $\eta = (v + \beta_1' u)/(1 - \alpha_1\beta_1')$

The simplest hypothesis at the outset concerns the deflator, Π. If the correct relative price were the nominal price divided by the CPI and if "real" income were nominal income divided by the CPI then in equation (1.1) it would follow that

(6) $\alpha_3 = -\alpha_1 - \alpha_3.$

This would yield testable implications about the reduced form coeficients as follows:

(7) $\quad c_1 + c_2 = 0 \quad$ and $\quad d_1 + d_2 = 1.$

Also, one must say something about the nature of the probability distributions supposed to generate the random shocks in order to perform statistical tests of the hypotheses in (7). The usual assumption is normality. My tests of the hypotheses in (7) follow convention. The Section Results describes the results.

We shall focus our attention on the estimates given by (3) and (4) for two reasons. First, they relate directly to fundamental parameters of the structural relations and, second, they are relatively simple functions of the reduced form regression coefficients. Even so, estimates of confidence bounds for these important parameters are not straightforward. Moreover, as is plain from (3), the structural parameter β_1' is overidentified and the two estimates are correlated because each uses ratios of coefficients from the same pair of equations.

4. Confidence Bounds for Estimates of Ratios

This section describes a new way of obtaining confidence bounds for the structural parameters. Consider two correlated random variables, x and y with means μ_x, μ_y and standard deviations σ_x, σ_y. These random variables correspond to estimates of the regression coefficients of the same exogenous variable in the pair of reduced form equations (3.1) and (3.2). In (3.3), x corresponds to, say, d_2 and y to c_2 . Let

(1) $\quad X = (x - \mu_x)/\sigma_x \quad$ and $\quad Y = (y - \mu_y/\sigma_y.$

(Note that X and Y in this section do <u>not</u> refer to natural logs.) Thus X and Y have mean zero and standard deviation one. The ellipse defined by

(3) $$X^2 - 2\rho_{xy} X Y + Y^2 = c,$$

in which

(4) $$c = 2(1 - \rho^2)\ell$$

gives an iso-probability contour for a bivariate normal distribution (Uspensky, 1937, pp.308-12). This ellipse covers a fraction of the bivariate distribution as determined by ℓ. The correlation between the two estimates is $\rho_{xy} = \sigma_{xy}/\sigma_x\sigma_y$. The ratio estimator is $z = x/y$. The extreme values of the ratio included by this ellipse is given by the rays from the origin tangent to the ellipse as shown in Figure 1. This is <u>not</u> the same as the area of the bivariate distribution between the extremal rays. One way to obtain confidence bounds on z is to find the extrema of z on the ellipse defined by (3). This may furnish confidence level bounds under suitable conditions for some values of ℓ. The Lagrangian for the extremum problem is defined by

(5) $$z + \lambda(X^2 - 2\rho X Y + Y^2 - c)$$

(dropping subscripts from ρ causes no ambiguity). If a solution exists it must satisfy the first-order conditions as follows:

(6) $$(1/y) + (2\lambda/\sigma_x)(X - \rho Y) = 0$$

(7) $$-(x/y^2) + (2\lambda/\sigma_y)(Y - \rho X) = 0.$$

Complications can arise that are most easily understood with the help of diagrams. Figure 1 shows the ellipse for a given ℓ. The center of the ellipse is at the point M whose coordinates are μ_x, μ_y. The orthogonal lines A_1A_2, B_1B_2 are the principal axes of the ellipse. The length of these axes is proportional to the standard deviations of x and y. A solution of the extremum problem is given by the rays through the origin that are tangent to

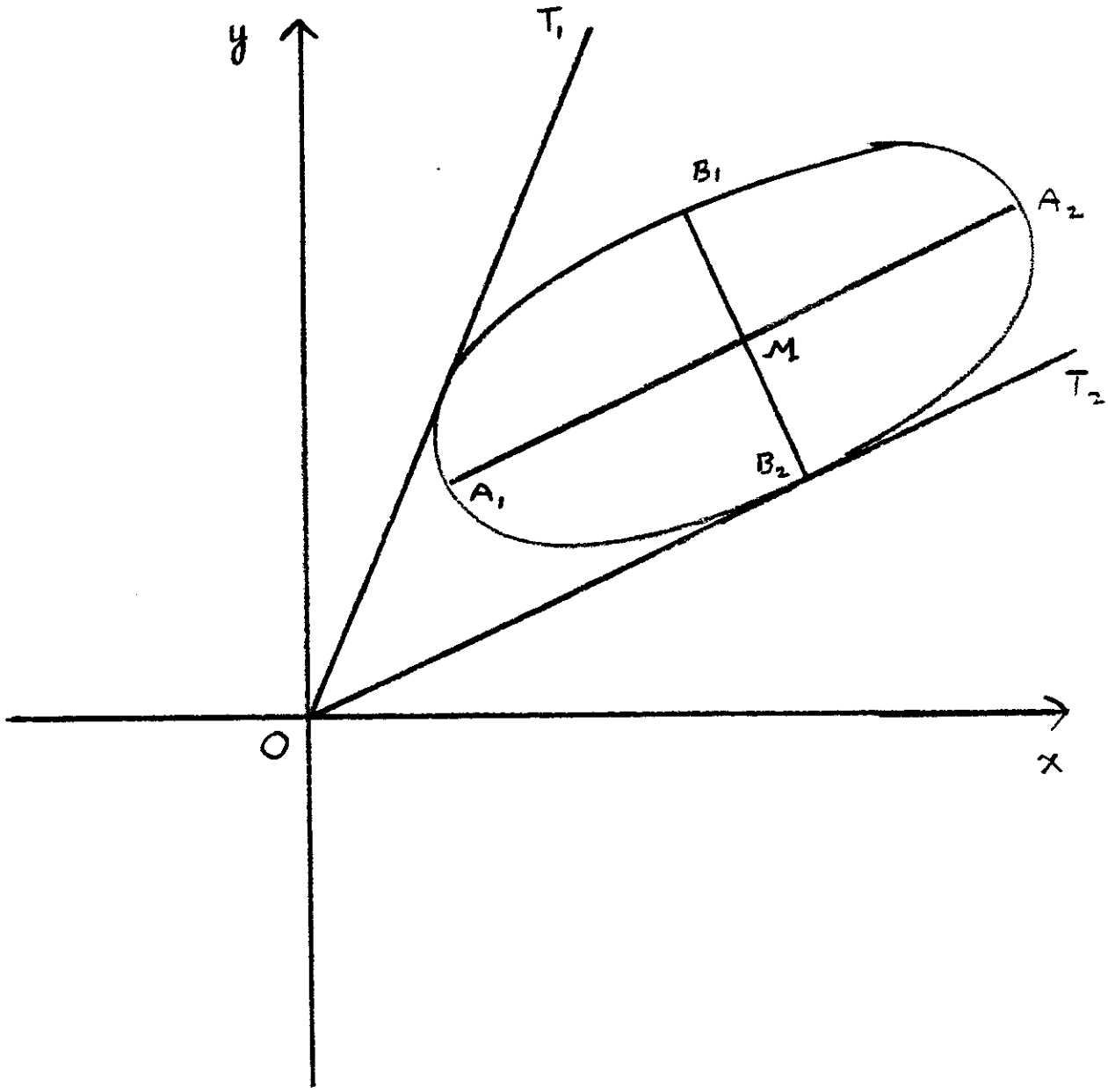

FIGURE 1

the ellipse. Figure 1 shows the two tangents, T_1 and T_2. T_1 gives the upper confidence bound and T_2 the lower confidence bound. Note that the ray connecting the origin to M (this ray is not shown in the diagram) lies between these two bounds. Therefore, the point estimate given by the ratio of the means is bracketed by the ratios given by the slopes of the two tangents. The probability level corresponding to the ellipse is the confidence level of the bracket. There is a family of ellipses, all centered on M and generated by choosing various values of ℓ, that determines the confidence level. Thus, $\ell = 3$ gives a 95% confidence bound. Various other values of ℓ and the corresponding confidence levels are as follows:

ℓ	.5	.75	1	1.5	2	2.5
Conf Level %	39	53	63	78	86	92.

For large enough ℓ, the ellipse becomes tangent to the y-axis and the upper bound of the extremum is infinite. For still larger values of ℓ, the ellipse intersects the y-axis and the solutions of the necessary conditions do not give the extrema, the confidence bounds for the ratio. Figure 2 shows an ellipse that intersects both axes. Plainly, no rays from the origin are tangent to this ellipse. This means there are no finite extrema and, consequently, the necessary conditions are meaningless. A necessary condition for an extremum problem is valid if an extremum exists. However, an extremum may not exist as shown by Figure 2. The closer is M to the origin, the smaller the ℓ that can give confidence bounds on the ratio. This is reasonable. Thus if one of the means is close to zero, one cannot hope to obtain confidence bounds for the ratio. In case extrema do exist for a suitably chosen value of ℓ, they can be found by solving the following equation:

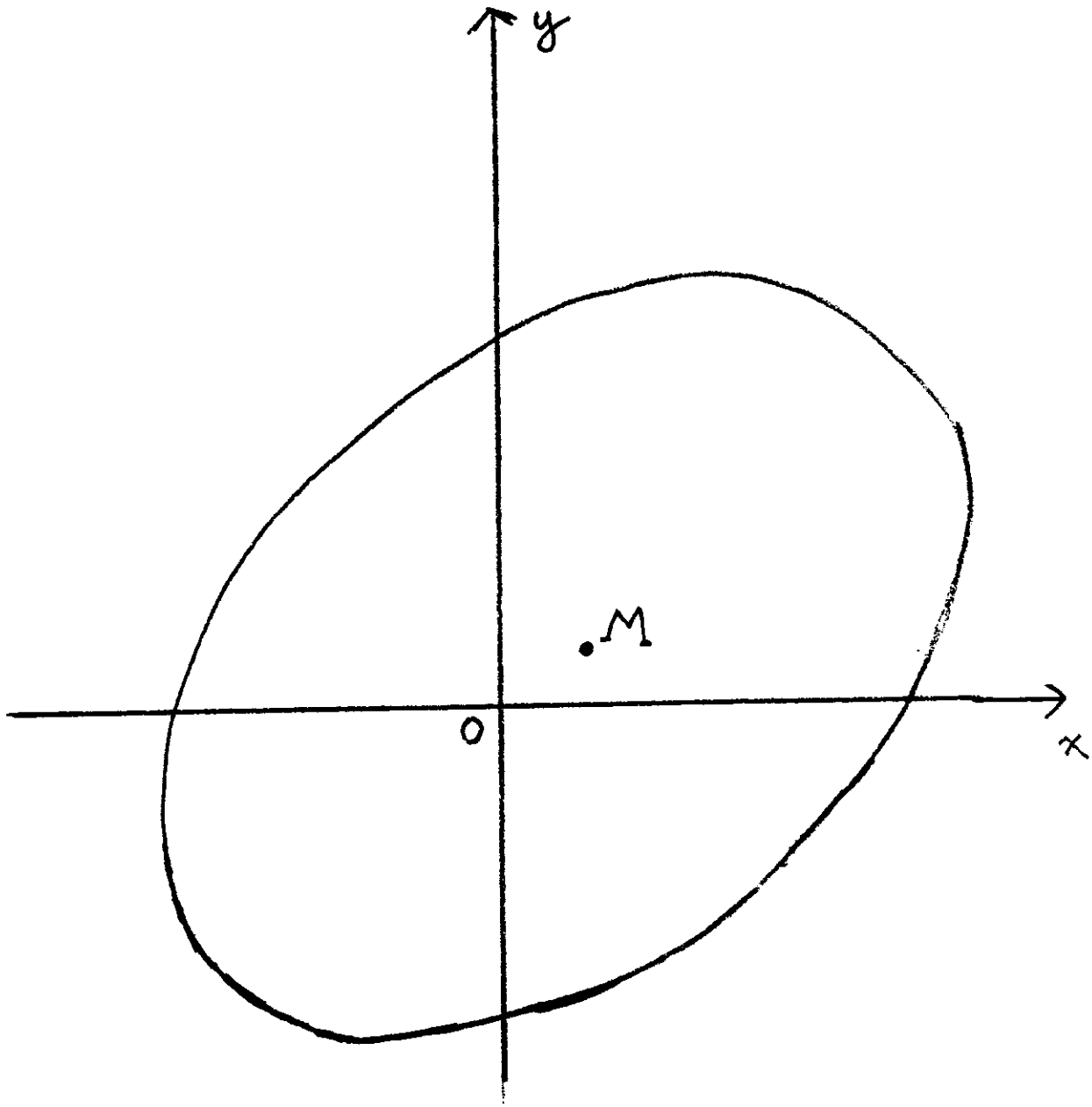

FIGURE 2

(8) $$(\mu_x/\sigma_x)(X - \rho Y) + (\mu_y/\sigma_y)(Y - \rho X) + c = 0$$

together with (3) for pairs (X, Y). Equation (8) comes from the necessary conditions (6) and (7) by eliminating the Lagrangian multiplier. It is a valid equation provided the tangents do bracket the point estimate given by the ratio of the means, the coordinates of M. The bounds are given by

(9) $$z = (\mu_x + X\,\sigma_x)/(\mu_y + Y\,\sigma_y).$$

The relation between ℓ and the confidence level B is

(10) $$B = 1 - e^{-\ell} \Longleftrightarrow \ell = -\log(1 - B).$$ (Uspensky, p.312)

Now μ_x, μ_y, σ_x and σ_y directly refer to the estimated reduced form regression coefficients and their standard errors. The correlation between the errors of the estimated coefficients across equations is $\rho_{xy} = \sigma_{xy}/\sigma_x\sigma_y$. Let

(11) $$S_\xi^2 = E(\xi^2),\ S_\eta^2 = E(\eta^2),\ \text{and}\ S_{\xi\eta} = E(\xi\,\eta)$$

so that these are the variances and covariances of the residuals of the reduced form equations. Let m^{11} refer to the leading element of $Z'Z^{-1}$ where $Z'Z$ is the moment matrix of the exogenous variables.

(12) $$\sigma_x = S_\xi \sqrt{m^{11}} \qquad \sigma_y = S_\eta \sqrt{m^{11}} \qquad \sigma_{xy} = m^{11} S_{\xi\eta}.$$

Therefore,

(13) $$\rho_{xy} = S_{\xi\eta}/S_\xi S_\eta.$$

The correlation between the errors of estimate of regression coefficients equals the correlation between residuals of the reduced form regressions.

3. The Results

The results in this section assume there are no specialized inputs used to produce the agricultural commodities. The firms producing these commodities can use their resources to produce several commodities. Hence no estimate of K appears in the reduced form regressions for corn, cotton, Douglas fir, eggs, potatoes or wheat. However, Section 5, the appendix, reports results using acreage harvested as a proxy for specialized inputs for corn, cotton, potatoes and wheat. K does appear as an exogenous variable for cement and electricity.

The results of testing hypotheses about the deflator are in Table 1. If the demand and MITC equations were homogenous of degree zero in the nominal price and the CPI, and if the CPI were the correct deflator for nominal consumption then $c_1+c_2=0$ and $d_1+d_2=1$. Table 1 shows the actual sums, the F-ratios and the probability of getting these or larger F-ratios on the hypothesis that the sums do equal 0 and 1 respectively. In all but 4 cases these hypotheses can be rejected decisively. In two cases the probabilities of getting F-ratios at least as large as the actual values are as much as about .8 - the c's for cotton and the d's for cement. It is only for potatoes that the results are consistent with the hypotheses about the deflators with high probability.

Table 1

Tests of Hypotheses about the CPI Deflator

Commodity	$c_1+c_2 \stackrel{?}{=} 0$	$d_1+d_2 \stackrel{?}{=} 1$
Corn		
Sum	0.479	0.487
F-ratio	28.201	10.249
Prob	0.000	0.002
Cotton		
Sum	-0.037	0.757
F-ratio	0.091	1.739
Prob	0.764	0.014
Wheat		
Sum	0.453	0.605
F-ratio	34.500	5.105
Prob	0.000	0.027
Douglas Fir		
Sum	0.564	-0.366
F-ratio	14.670	3.487
Prob	0.005	0.067
Eggs		
Sum	-0.232	0.546
F-ratio	14.581	18.615
Prob	0.00032	0.0000

Potatoes

Sum	0.0533	0.9078
F-ratio	0.955	0.293
Prob	0.332	0.590

Electricity

Sum	-0.141	1.536
F-ratio	15.994	26.203
Prob	0.000	0.000

Cement

Sum	1.067	0.969
F-ratio	26.300	0.062
Prob	0.000	0.804

Table 2 gives the two point estimates of b_1, the reciprocal of the supply elasticity, and confidence bounds. In every case, the confidence band does bracket the point estimate so that the extremum problem used to derive the confidence bands does have a unique solution. For the 6 agricultural products, 4 of the pairs of point estimates are positive and two pairs, cotton and eggs, are negative. However, the upper value of the 95% confidence bounds for cotton exceeds 6 and the upper value of the 86% confidence bound for eggs is about 3.5 so that the confidence bounds for both these estimates cover zero. A value of zero for b_1 means an infinitely elastic supply. Hence the results for cotton and eggs are consistent with an infinitely elastic supply for these two commodities. Even though the point estimates of b_1 for potatoes and Douglas fir are both positive, like eggs and cotton, the 95% confidence bands for Douglas fir and potatoes cover zero. Hence like eggs and cotton these results are also consistent with an infinitely elastic supply schedule for Douglas fir and potatoes. It is only for corn and wheat that the confidence bands are well inside a positive interval. However, even for these two commodities the lower bound of the interval is not far from zero. It is reasonable to conclude, therefore, that the supply schedule for corn and wheat is highly elastic albeit perhaps not infinitely elastic. It should be noted that the high multicollinearity among the exogenous variables raises the estimates of σ_x and σ_y which in turn widens the estimated confidence bounds.

The cement and electricity regressions include the same 3 explanatory variables as the agricultural commodities and in addition include estimates of the productive capacity of these industries. Hence there are 4 exogenous variables for these regressions. The pairs of point estimates of b_1 for

these two commodities are negative indicating downward sloping Industry Unit Total Cost curves for electricity and cement on the hypothesis that the price approximates unit costs for these commodities. It is not possible to compute 95% confidence bounds for electricity because the ellipse for both ratio estimates intersects the y-axis. Table 2 gives a 53% confidence bound (ℓ=.75) for one of the point estimates and a 63% confidence bound (ℓ = 1) for the other. Notice that the 95% bound for cement covers zero while the 86% bounds are negative. Hence these results support the hypothesis of a downward sloping IUTC curve for both cement and electricity at fairly high confidence levels.

Table 2

Estimates of b_1, Reciprocal of Supply Elasticity, and 95% Level Confidence Bounds

Commodity	d_2/c_2	d_3/c_3
Corn		
Point Est	1.624	1.503
Conf Bnds	0.375 6.194	.270 6.157
Cotton		
Point Est	-2.426	-2.671
Conf Bds	-.339 7.204	-.402 6.092
Douglas Fir		
Point Est	1.693	0.645
Conf Bds	.802 3.342	-.677 2.382
Eggs		
Point Est	3.067	-3.948
Conf Bds	1.833 3.494*	-16.539 -1.394
Potatoes		
Point Est	2.015	7.370
Conf Bds	-.0462 4.994	-15.979 2.872
Wheat		
Point Est	1.963	2.321
Conf Bds	.558 5.588	.676 8.059
Electricity		
Point Est	-3.254	-6.271
Conf Bds**	-40.517 -.736	-14.543 -4.088
Cement		
Point Est	-.332	-.402

Conf Bds†	-1.372	.0350	-2.731	.0517
	-1.008	.-.0236	-1.597	-.0192

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* The first pair gives the 86% bounds (ℓ=2) and the second pair the 95% bounds.

** The first pair give the 53% confidence bound (ℓ = .75) and the second pair gives 63% confidence bound (ℓ=1).

† The second line gives the 86% confidence bounds (ℓ=2).

Because the cement and electricity regressions include measures of capacity, the model implies it is also possible to estimate the elasticity of demand, $a_1=c_4/d_4$, for these two commodities (see (2.3.4)). Table 3 gives the point estimates and confidence bounds.

Table 3

Estimates of the Demand Elasticity, a_1, and Confidence Bounds

Commodity		
Electricity	86% Confidence Bounds (ℓ=2)	
Point Est	-.891	
Conf Bnd	-.630	-1.622
Cement	63% Confidence Bounds (ℓ=1)	
Point Est	-3.233	
Conf Bnd	-.364	6.546

Compared to most estimates of demand elasticities, these are fairly high.

Table 4 contains selected statistics for the reduced form equations that are the basis of the results given in the three preceding tables.

Table 4

Selected Statistics for the Reduced Form Regressions

Commodity	Coefficients* (Standard Errors)			Correlation of Residuals	R^2
Dependent Variable	Π	Y_N	H	K	
Corn					
Q	-.255 (.240)	.734 (.188)	-1.598 (.419)	-.529	.859
P	-.705 (.424)	1.192 (.332)	-2.402 (.739)		.756
Cotton					
Q	.432 (.329)	-.472 (.258)	.980 (.574)	.111	.154
P	-.387 (.489)	1.145 (.383)	.980 (.853)		.766
Douglas Fir					
Q	-2.059 (.380)	1.693 (0.322)	-3.055 (0.782)	.173	.436
P	-2.302 (.716)	2.866 (.605)	-1.972 (1.473)		.950
Eggs					
Q	-.5748 (.1661)	.3430 (.1352)	.6895 (.3211)	.6113	.872
P	-.5056 (.2877)	1.0518 (.2343)	-2.7220 (.5562)		.798

Potatoes						
Q	-.2919	.3452	-.2987		-.4858	.803
	(.1451)	(.1138)	(0.2531)			
P	.2122	.6956	-2.2014			.734
	(.4528)	(.3551)	(0.7900)			
Wheat						
Q	-.214	.668	-1.293		-.102	.905
	(.202)	(.158)	(.352)			
P	-.705	1.311	-3.001			.723
	(.464)	(.364)	(0.811)			
Electricity						
Q	-.298	.157	-.728	1.225	-.559	.999
	(.142)	(.123)	(.325)	(.095)		
P	2.047	-.511	4.565	-1.374		.928
	(.422)	(.364)	(.965)	(.281)		
Cement						
Q	-.244	1.311	-4.051	.909	.299	.915
	(.416)	(.338)	(1.301)	(.304)		
P	1.404	-.435	1.630	-.281		.939
	(.246)	(.200)	(2.122)	(1.566)		

* The regressions also include constant terms but since these coefficients and their standard errors play no role in the analysis they are not shown in the table.

It must be noted that the estimated serial correlation of the residuals is fairly high especially for the price regressions. Therefore, it would seem to be possible to improve the efficiency of the estimates by transforming the data in order to remove this serial correlation. However there are good reasons for not doing this. Some of the time series have gaps. There is no complete series for nominal consumption or income prior to 1929 and data are missing for these variables for almost every other year in the sample from the starting point to 1929. It would greatly reduce the degrees of freedom to do the usual transformations in order to remove the serial correlation of the residuals.

4. Conclusions

A necessary condition for a nonempty core is that the Marginal Industry Total Cost Function is not above the Industry Unit Cost Function. A sufficient condition for this is that the Marginal Industry Total Cost be infinitely elastic. In the case of the 6 agricultural commodities the hypothesis of an infinitely elastic supply lies well within the confidence bounds of the point estimates. For electricity and cement the point estimates of b_1 are negative. If the price approximates unit cost in these industries, it follows that unit costs are a decreasing function of output indicating the presence of nondecreasing returns to scale. This would also mean that marginal cost pricing would fail to cover total cost and that a neoclassical competitive equilibrium could not exist for these two industries although there is an implication of a nonempty core for cement and electricity.

5. Appendix

1.Equilibrium with Uncertainty about Demand and Cost Conditions

A brief description of the economic theory underlying the empirical estimates is given here. It is an extension of a theory more fully described in (Telser,1978, chap. 3). The function B(q,v) defines the ex post monetary benefit from a rate of consumption q. The variable v denotes a random disturbance affecting the demand. B is expressed as follows:

$$(1) \qquad B(q, v) = \int_0^q b(\xi, v)d\xi.$$

It may be regarded as the area under the demand curve b(.). The Industry Total Cost Function, G(q,k,u) is defined as follows:

$$(2) \qquad G(q,k,u) = \int_0^q g(\xi, k, u)d\xi,$$

in which u is a random disturbance and k represents the inputs that must be chosen ex ante. For instance, u includes the effects of the the weather. The function g(.) stands for the marginal industry cost. Assume that the random variables u and v are independent. Let ϕ and ψ denote their respective probability density functions. The ex post net benefit is

$$(3) \qquad \gamma = B(q, v) - G(q, k, u).$$

It is the net benefit after the realization of the random variables u and v. The ex ante net benefit is the expected value of γ, namely

$$(4) \qquad E(\gamma) = \int \gamma \, \psi(v) \, \phi(u) \, du \, dv.$$

The optimal q maximizes the ex post net benefit in (3) so it is an implicit function of u, v and k. Conditional on the optimality of the ex post q, the optimal k maximizes the ex ante net benefit (4). Therefore the optimal k depends on the parameters of the pdf's for u and v but not on the actual realizations of the random shocks. In other words, k, the fixed inputs, is

optimal for the long run while q is optimal for the short run. To show how q can be optimal if it is subject to random shocks requires a closer look at the ex post equilibrium.

The current output is not entirely at the mercy of random effects. Although the Industry Total Cost Function is subject to random disturbances, firms can partially offset these by choosing appropriate levels of those inputs they can vary in the short run. For instance, inventories of the final product serve this purpose. After the realization of the random variables u and v, the price adjusts so that the quantity purchased equals the marginal benefit. Formally, the ex post net benefit is a maximum with respect to q if q satisfies the following equation:

(5) $$B_q - G_q = 0.$$

Let p denote the price. Equation (5) asserts there is an optimal equilibrium if

(6) $$p = B_q = G_q.$$

Assume that the price always satisfies (6) so that the quantity is always optimal ex post. If the fixed inputs, k, are optimal, there is an ex ante equilibrium given by the first-order conditions for maximizing the expected net gain as follows:

(7) $$\int\{[B_q - G_q]\partial q/\partial k - G_k\}\psi\,\phi\,du\,dv = 0.$$

By virtue of (5), this reduces to

(8) $$\int G_k\,\psi\,\phi\,du\,dv = 0.$$

Hence the equilibrium value of the fixed inputs must satisfy (8). Note that k does not depend on the actual value of q, u or v and instead it depends on the parameters that determine the pdf's of u and v together with the

parameters of the demand function. The latter enter via the dependence of the ex post equilibrium value of q on the demand conditions as shown by (5).

2. Necessary Conditions for a Nonempty Core

This section sketches those results that are pertinent for the material in the text about the status of the industry's core. Let t denote an n-vector in the nonnegative orthan of R^n. The coordinates of t are nonnegative real numbers that represent how many persons of each of the n types belong to the grand coalition. Let f(s) be the function giving the return that a coalition $s \leqq t$ can assure itself under the most adverse conditions. There is a nonempty core if a y exists capable of satisfying the two conditions as follows:

(1) $\quad y\ t = \Sigma_{i=1}^{n} y_i t_i = f(t);$

(2) $\quad y\ s \geq f(s) \qquad$ for all s: $0 \leqq s \leq t$.

We seek conditions on f so that it will admit a nonempty core for arbitrary nonnegative t in R^n. This means f is to be totally kind (for more information about kind characteristic functions see Telser, 1978, sec.4.4 and 1987, chap. 4, prt. 1, sec. 5).

Wherever f has a gradient it is straightforward to show that y can satisfy the core constraints (1) and (2) for arbitrary t only if

(3) $\quad y \leqq \nabla_t f(t).$

It follows that $t\ y = f(t) \leq t\ \nabla_t f(t)$. The latter inequality is equivalent to superhomogeneity of f. A function f is said to be superhomogeneous if for all $\lambda \geq 1$,

(4) $\quad f(\lambda t) \geq \lambda\ f(t).$

Hence at any t where the gradient of f exists, inequality (4) is equivalent to

(5) $\quad t\,\nabla_t f(t) \geq f(t).$

These results apply to an industry that makes m different products. Let $B^i(q^i)$ denote the benefit a type i person obtains from a bundle of m goods given by the coordinates of the m-vector q^i. The total cost to the coalition t of furnishing its members with the total of the m goods given by $Q = \Sigma_i t_i q^i = t\,q$ is given by the function G(Q). This total cost function corrsponds to the Industry Total Cost Function. The optimal $\{q^i\}$ for the coalition t maximizes the following expression:

(6) $\quad t\,B(q) - G(Q).$

By definition, this maximum equals f(t). Ignoring nonnegativity conditions on q^i, innocuous in the present treatment, the optimal q^i must satisfy the following first-order necessary condition:

(7) $\quad \nabla_q B(q) - \nabla_Q G(Q) = 0.$

The optimal q is an implicit function of t by virtue of (7).

To derive the necessary condition for a nonempty core in this case we need the gradient of

(8) $\quad f(t) = \max_{\{q\}} \{t\,B[q(t)] - G(Q)\}.$

with respect to t.

$$\nabla_t f(t) = B + \nabla_q B\ (dq/dt) - \nabla_Q G\ (dQ/dt)$$

and

$$dQ/dt_i = q + t_i\ dq/dt_i.$$

Therefore,

$$t\,\nabla_t f(t) = t\,B + t[\nabla_q B - \nabla_Q G](dq/dt) - Q\,\nabla_Q G$$

$$= t\,B - Q\,\nabla_Q G$$

$$= t\,B - G + G - Q\,\nabla_Q G$$

$$= f(t) + G - Q\,\nabla_Q G.$$

According to (5), for a nonempty core it is necessary that

(9) $$t\,\nabla_t f(t) - f = G - Q\,\nabla_Q G \geq 0.$$

However,

(10) $$G(Q) \geq Q\,\nabla_Q G$$

is true for arbitrary Q if and only if G is a subhomogeneous function of Q. This completes the proof of the following

PROPOSITION. The core of the industry is nonempty only if the Industry Total Cost Function is subhomogeneous.

This Proposition gives a necessary condition for a nonempty core under very weak restrictions on B and G. If each benefit function is an increasing concave function of q, so that the demand functions are downward sloping, and if the cost function G is convex in Q then subhomogeneity of the cost function is also sufficient for a nonempty core. (Telser, 1987, chap.4, prt. 3,sec.2, prop. 1).

3. Estimates of the Model for 4 Agricultural Commodities with Acreage Harvested as an Exogenous Variable

Suppose we take the acreage planted of a commodity as a proxy for the fixed inputs used to produce it. Although acreage planted may be more closely correlated to the relevant fixed inputs than is acreage harvested, figures on planting are not available for as long a period as acreage harvested. Hence in order to have as long a time series as possible, let us use acreage harvested as representative of the fixed inputs instead of acreage planted. Sometimes acreage harvested is considerably smaller than acreage planted owing to adverse weather conditions. Output is more closely correlated, though certainly not perfectly correlated, to acreage harvested than it is to acreage planted. Acreage planted varies less over time than does acreage harvested. This is shown by the fact that the standard deviation of acreage planted is smaller than of acreage harvested (Figures 3-14 show high correlations between plantings and harvestings). However, in addition to the fact that data giving acreage harvested are available since 1866 and for a much shorter period for acreage planted, there is one advantage in favor of acreage harvested, the acreage harvested figures are probably more accurate than the acreage planted figures.

Even granting that it may be better to use acreage planted as a proxy for the specialized fixed inputs, it must be admitted that producers can choose which crop to raise from among several alternatives. Few inputs are specialized to one crop. Perhaps the only specialized input is the total agricultural cropland and it may impose only a weak constraint on the production of a particular commodity. This means there are good reasons for omitting entirely any variable to represent specialized inputs for a single crop. Nor is this all. Figures 3 - 14 show upward trends in the production

of corn, cotton, potatoes and wheat while there are downward trends in the acreage harvested. Therefore, what may be the most specialized of the inputs, land, has become increasingly less important during the sample period as less specialized inputs replace it perhaps largely in response to Federal programs in agriculture.

Having said all this, as Table 5 shows , the point estimates of b_1 are not much affected by the addition of the variable the log of acreage harvested. The main effect of introducing this variable is to widen the confidence bounds on the point estimates of b_1 because the standard errors of the estimated coefficients tend to increase. Probably this is as a result of the greater multicollinearity among the explanatory variables resulting from the addition of acreage harvested. Note that although the R^2 for cotton is much higher with the addition of acreage harvested, there is little effect on the estimates of b_1. In particular the point estimates still bracket zero as is the case in Table 2.

The pertinent statistics for the regressions are in Table 6. Consider the regressions with P as the dependent variable. For these regressions, the coefficient of acreage harvested is nearly zero relative to the estimated standard error. These coefficients do not furnish a basis for reasonable estimates of the demand elasticity for these 4 commodities. Not only are the point estimates implausible but also the confidence bands are of very little use. These results differ considerably from those for cement and electricity in which it is found that the coefficients of capacity imply a reasonable estimate for the demand elasticity. Therefore, the estimates of capacity for cement and electricity probably lie closer to the correct figures than is true for the 4 agricultural commodities. It is, therefore, plausible to

conclude that acreage harvested is either not a good proxy for the specialized inputs or that the specialized inputs of the 4 agricultural commodities are of little quantitative importance.

Table 5

Estimates of b_1 the Reciprocal of the Supply Elasticity, for Corn, Cotton, Potatoes and Wheat from Regressions that Include Acreage Harvested

Commodity	d_2/c_2		d_3/c_3	
Corn				
Point Est	1.112		1.473	
Conf Bnds	0.189	3.172	0.252	5.372
Cotton*				
Point Est	4.289		-4.518	
Conf Bds	1.746	152.2	-1136	-1.776
Potatoes				
Point Est	1.006		5.529	
Conf Bds	-0.3780	3.392	0.8422	153.19**
Wheat				
Point Est	1.682		2.282	
Conf Bds	0.000	31876	0.000	280475

* The bounds for cotton are at the 63% level (ℓ=1).

** These bounds are at the 88% level (ℓ = 2.1).

Table 6 contains selected statistics for the reduced form equations that are the source of the results given in Table 5.

Table 6

Selected Statistics for the Reduced Form Equations

Commodity	Coefficients* (Standard Errors)				Correlation of Residuals	R^2
Dependent Variable	Π	Y_N	H	Hvt		
Corn						
Q	-.827 (.272)	1.086 (.199)	-1.620 (.385)	.833 (.233)	-.588	.883
P	-.736 (.528)	1.208 (.386)	-2.386 (0.746)	.0621 (.452)		.755
Cotton						
Q	-.543 (.275)	.316 (.217)	.602 (.424)	.739 (.0997)	.0443	.552
P	-.646 (.557)	1.354 (.440)	-2.721 (.860)	.193 (.202)		.769
Potatoes						
Q	-.6850 (.1167)	.6751 (.0928)	-.3973 (.1834)	.4184 (.0546)	-.6670	.899
P	.2314 (.5082)	.6795 (.4041)	-2.1966 (.7982)	-.0205 (.2378)		.734
Wheat						
Q	-.656 (.163)	.859 (.122)	-1.268 (.268)	.631 (.0886)	-.393	.947
P	-1.066 (.480)	1.446 (.359)	-2.892 (.789)	.572 (.261)		.743

Notes

* I am grateful to Yair Mundlak for helpful comments on the preceding draft of this paper. Scott Lyden assisted me by gathering some of the figures. The Center for the Study of the Economy and the State helped support this research.

1. For an excellent survey of the various estimates of supply elasticities for agricultural products and a history of the problem, see Mundlak (1985).

Nerlove (1957) is a well known source for estimates of supply schedules for agricultural commodities. His model attempts to explain acreage planted as a function of the expected price of the commodity planted. However, acreage planted is an input and in the standard theory the equilbrium input is at the level where the expected value of its marginal product equals its price. In this case the price is an imputed rental of the land. A supply schedule ought to relate <u>output</u> to the product price, not an input such as land.

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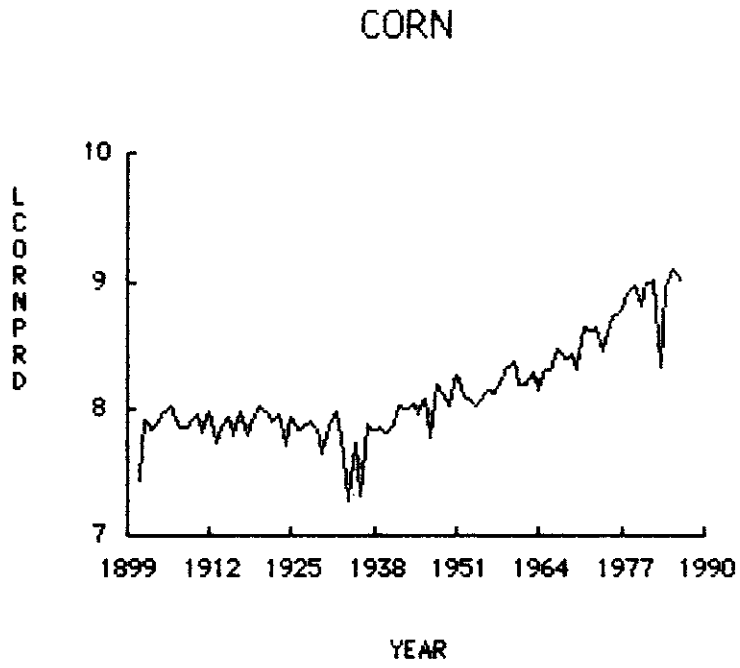

CORN
LCORNPRD
10
9
8
7
1899
1912
1925
1938
1951
1964
1977
1990
YEAR

Figure 3

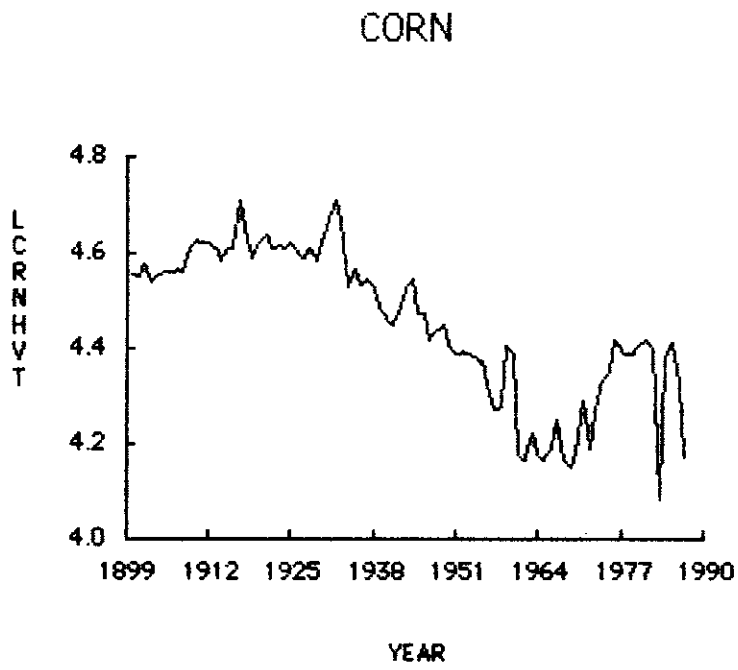

CORN
LCRNHVT
4.8
4.6
4.4
4.2
4.0
1899
1912
1925
1938
1951
1964
1977
1990
YEAR

Figure 4

Corn

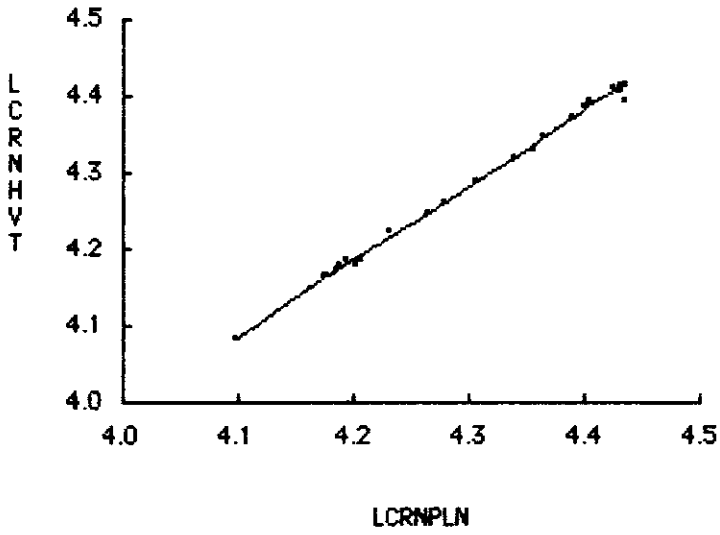


Figure 5

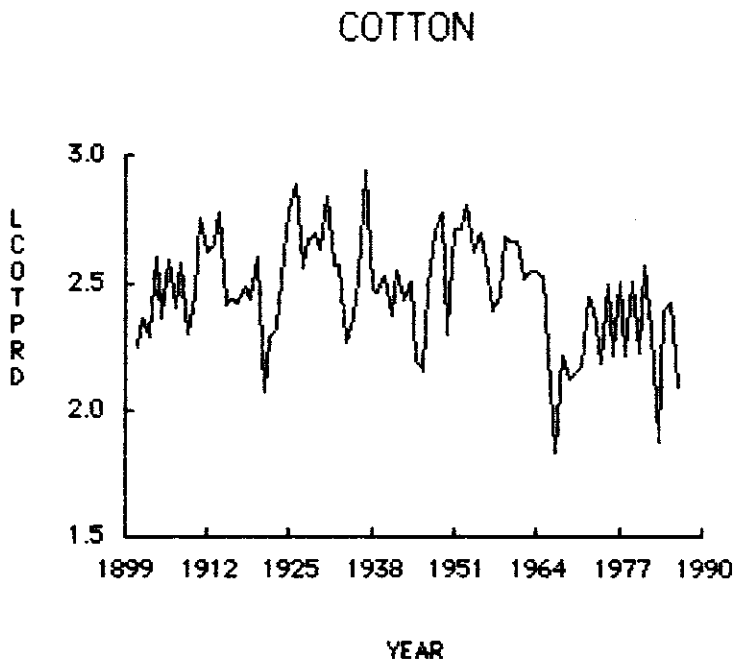

COTTON
LCOTPRD
3.0
2.5
2.0
1.5
1899
1912
1925
1938
1951
1964
1977
1990
YEAR

Figure 6

COTTON

Figure 7

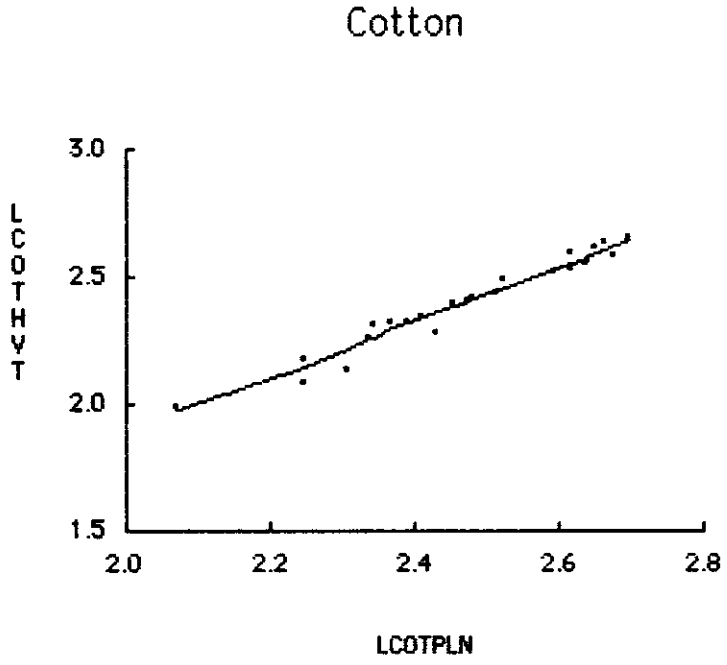


Figure 8

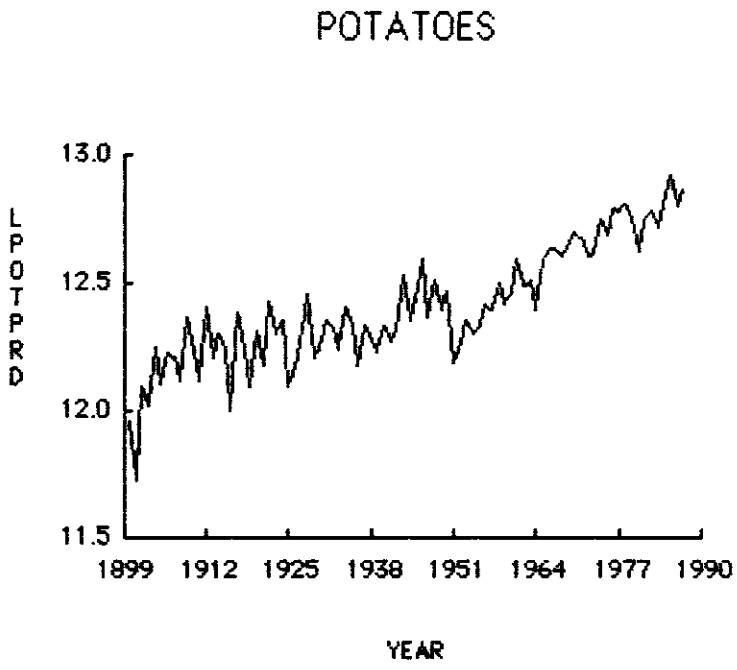

POTATOES
13.0
12.5
12.0
11.5
LPOTPRD
1899
1912
1925
1938
1951
1964
1977
1990
YEAR

Figure 9

POTATOES

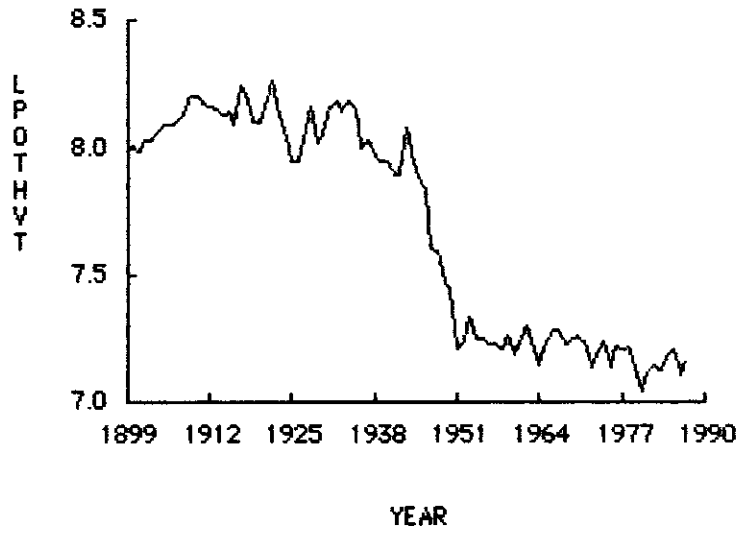


Figure 10

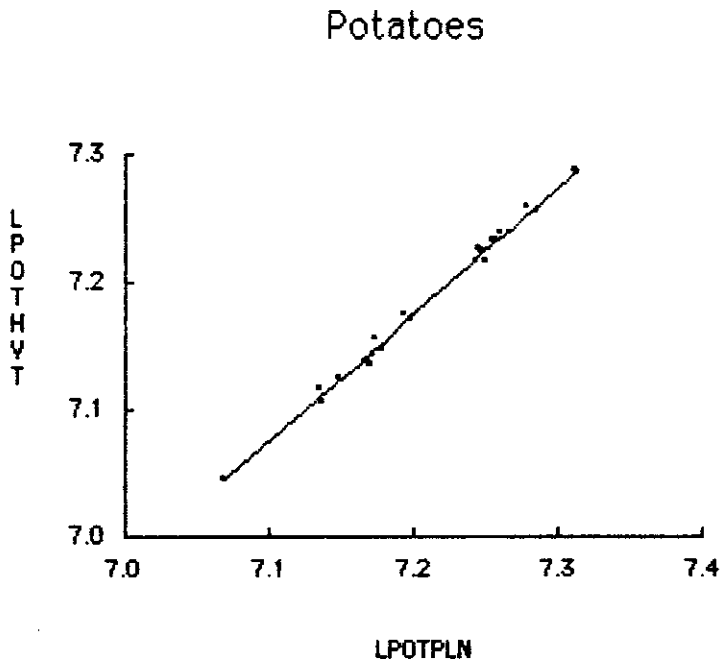
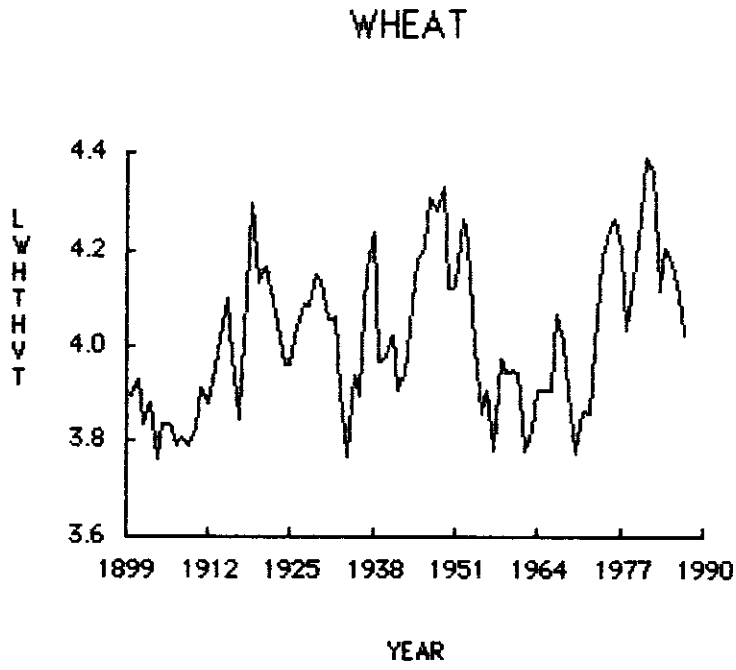


Figure 11

WHEAT

Figure 12


WHEAT
LWHTHVT
4.4
4.2
4.0
3.8
3.6
1899
1912
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1938
1951
1964
1977
1990
YEAR

Figure 13

Wheat

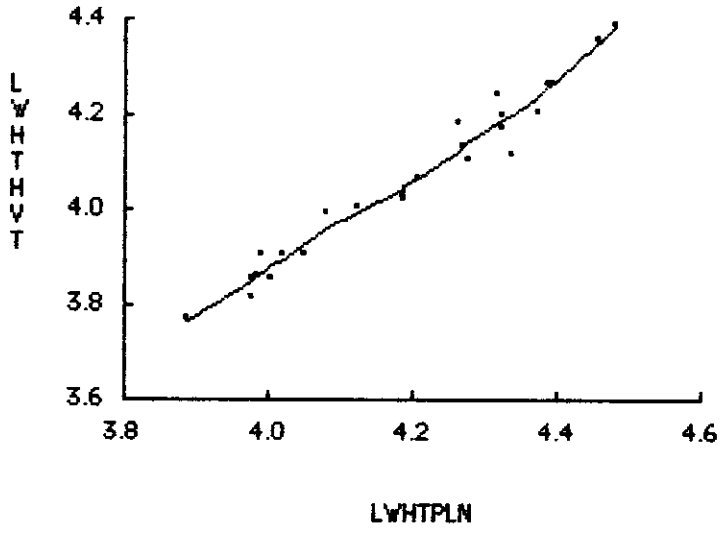

Figure 14