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THE EFFECT OF DISTORTIONS IN RELATIVE PRICES ON CORN PRODUCTIVITY: A CROSS-COUNTRY STUDY

by

David C. Lyons

and

Robert L. Thompson

Department of Agricultural Economics
Purdue University
West Lafayette, Indiana 47907

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Pooled data from 14 large corn producing countries for 13 years show that the corn-nitrogen price ratio, as well as physical factors and technology, account for a significant part of corn yield differences among countries. Policies which distort corn and fertilizer prices have a significant effect on corn yields.

David C. Lyons is Legislative Assistant for Agriculture to Senator Lugar, Washington, D.C., and Robert L. Thompson is Assistant Professor, Department of Agricultural Economics, Purdue University.

THE EFFECT OF DISTORTIONS IN RELATIVE PRICES ON CORN PRODUCTIVITY: A CROSS-COUNTRY STUDY*

David C. Lyons and Robert L. Thompson**

The numerous policy-induced agricultural product and factor price distortions in different countries have led several recent observers to refer to world agriculture as being in "disarray" (Johnson) and in a "massive disequilibrium" (Hayami and Ruttan). They have argued that the resulting differences in price relatives among countries distort the location of production of the various products and reduce the efficiency of global resource allocation. In the research reported here an attempt was made to estimate the effect of policy distorted factor-product price relatives across countries on the yield of corn.

The farm level price of corn relative to the price of nitrogen fertilizer is presented in Table 1 for the 16 largest corn producing countries for which data could be obtained.[1/] Observe that the mean annual price ratio for 1961 to 1973 ranges from a low of 0.20 in the Philippines and South Africa to a high of 1.69 in Yugoslavia. These large differences in the ratio of the price of corn to the price of nitrogen provide *prima facie* evidence that substantial policy distortions exist in the respective markets for corn and nitrogen fertilizer. Many governments restrict trade in agricultural products and/or inputs via quotas, tariffs, or disequilibrium exchange rates. In some countries the prices of purchased inputs such as fertilizer are subsidized. In others, small or outmoded domestic industries which produce agricultural inputs are protected by import restrictions. If the world market were permitted to function freely and all countries allowed world prices to be reflected undistorted in their domestic markets, the relative prices of all goods and factors of production would be equal in all countries except for differences associated with transportation costs.

Table 1. Ratios of the Price of Corn to the Price of Nitrogen and Yields in the Major Corn Producing Countries

Country	Price Ratios 1961-1973 Mean	Price Ratios 1961-1973 Range	Corn Yield (Quintals/Hectares) 1973-1975 Mean
Yugoslavia	1.69	1.09 - 2.64	36.70
Thailand	.92	.65 - 1.16	23.05
Colombia	.67	.58 - .85	12.76
Hungary	.58	.42 - .72	44.35
Brazil	.52	.29 - .66	14.82
Pakistan	.42	.29 - .56	12.13
Canada	.41	.25 - .70	51.30
United States	.38	.23 - .85	51.97
France	.33	.27 - .35	47.59
Italy	.32	.26 - .43	57.28
Spain	.31	.27 - .39	38.56
Mexico	.29	.20 - .40	10.84
Bulgaria	.29	.27 - .32	39.53
Egypt	.22	.17 - .31	38.02
Philippines	.20	.16 - .26	8.39
South Africa	.20	.16 - .23	20.99

Sources: Prices; F.A.O. (1975) for 1961-1970, supplemented with personal correspondence for 1971-1973.
Yields; U.S. Department of Commerce, National Technical Information Service, "Foreign Production, Supply and Distribution of Grains and Cotton," Computer Tape No. PB 232 065, 1976; or U.S. Department of Agriculture, Foreign Agricultural Service, Foreign Agricultural Circular Grains, No. FG-9, May 1976.

Table 1 (column 3) also illustrates the striking differences which exist in corn yields among the same countries. Many countries with sizeable land areas planted to corn currently have yields below the world average. A small percentage increase in yield level (from whatever source) on their large land base could result in a substantial increase in total production and, in turn, the exportable surplus over domestic use. Of course, even in the absence of price distortions, one should not expect corn yields to be equal across countries, because there exist differences in soils, climate, and technology. Evenson and Kislev have provided evidence that these all are significant factors in accounting for cross-country differences in corn productivity. However, in their study of corn yields in 49 countries they ignored the possibility that differences in relative prices among countries may also account for a significant part of the observed differences in corn yields. It is hypothesized here that a significant part of the observed differences in corn yields among countries can be accounted for by differences in the corn-nitrogen price ratio. The objective of this study is to isolate the effects of this price ratio on corn yield from other factors which vary systematically among countries.

Conceptual Framework

Any attempt to account for either temporal or cross-sectional differences in agricultural productivity must assume (explicitly or implicitly) the existence of some underlying production function. For present purposes, assume a separable two-stage production function with four inputs:

(1) $Y = F[(f(T,K_T), g(L,K_L)]$

where Y is physical output, T is the area of land in production, L is the flow of labor services, K_T represents land-saving forms of capital (embodying biological and chemical technology), and K_L represents labor-saving forms of capital (embodying mechanical technology). Assume that L and K_L, and T and K_T, respectively, are highly substitutable, however the substitution possibilities between subfunctions f and g are relatively low. That is, agricultural production is considered a combination of two separable processes: a biological process, $f(T,K_T)$, and a husbandry function, $g(L,K_L)$.

Variable T, land area,represents a vector of inputs in the biological production process including the inherent fertility of the soil and the climate above it. These impose certain constraints on potential yield in any given geographic area. The forms of capital represented by K_T either augment the naturally occurring availability of nutrients and water in the soil, as through chemical fertilizers or irrigation, or alter the form of the response function itself through plant breeding such that a larger response to given levels of plant nutrients and water is obtained.

To the biological production relationship are added husbandry practices, represented by subfunction $g(L,K_L)$, through which greater labor input, L, augments the naturally occurring availability of inputs or affects the timeliness of their delivery to the growing plants. Labor-saving technology, K_L, is in general embodied in machinery. To an important extent it is purely a substitution of capital for labor, which permits each member of the agricultural labor force to cultivate a larger land area, but which contributes little in its own right to greater land productivity, except as it may increase yields due to more timely operations.

In this analysis we shall focus on the biological subfunction because our interest is in land productivity. We shall assume that since mechanical technology tends to be only mildly yield increasing, the husbandry subfunction may be disregarded. This discussion based on the production function for corn suggests that cross-country differences in yield are associated with differences in soils, climate, technology, and management ability (or farmer education). This is where most previous cross-sectional productivity studies have stopped. Despite the fact that factor-product price relatives differ significantly among countries, previous studies have either assumed relative prices constant (e.g. Evenson and Kislev) or have employed a set of alien price weights for aggregating outputs and/or inputs (e.g. Hayami and Ruttan). However, no study known to the authors has explicitly attempted to isolate the effect of differences in relative prices among countries on observed productivity differences.

There exists abundant evidence in the literature that farmers around the world attempt to allocate resources in a profit maximizing manner (e.g. Schultz, Chaps. 2-3; Hopper, Yotopolous), i.e. to equate the value of the marginal product of each factor with its price in all uses. Assuming this is the case, distortions in factor-product price relatives will alter the marginal product and in turn the average product on any given response surface.

Statistical Analysis

Assuming profit maximizing behavior, corn yield in a given country at a given point in time, $\frac{Y}{T}$, is expressed as: $\frac{Y}{T} = G(\frac{P_C}{P_N}, Z)$, where P_C is the farmgate price of corn, P_N is the farm purchase price of nitrogen fertilizer,[2/] and Z is a vector of factors which shift the response surface among countries and through time. That is, Z positions the response surface, and P_C/P_N moves the profit maximizing level of fertilizer application and the associated yield level in and out along any given response surface.

The set of Z variables, arguments of the biological subfunction, includes soil properties, climatic factors such as temperature and rainfall, irrigation, diffusion of improved varieties, and rural education. Attempts to obtain time series data and to construct indices of the Z variables across as many of the principal corn producing countries as possible were unsuccessful. Therefore, in the absence of satisfactory data on the shifters on the corn response surface among countries, the only way to hold these factors more or less constant is via analysis of covariance estimates of the yield equation. In the present context, the function is estimated by ordinary least squares for the entire pooled sample of 14 countries and 13 years[3/] for which complete price data were obtained, with separate intercept terms for each country. The estimational equation is:

$$(2) \quad \ln(\frac{Y}{T}) = \ln A + b \ln(\frac{P_C}{P_N}) + \sum_{i=1}^{13} c_i \ln D_i + \ln \varepsilon,$$

where D_i is a 1-e dummy variable for each country other than the United States in the sample, i = 1, ..., 13. That is, A represents the U.S. intercept, and the estimates of c_i then capture the pervasive differences among countries in the omitted Z variables and shift the response curve of each other country relative to that of the U.S.[4/] We do not assume that all countries are drawn from the same universe, but rather, employ statistical procedures to sort out their similarities and differences.

The omission of labor and capital, to reiterate, can be interpreted in either or both of two ways: (1) the analysis is restricted to the biological subfunction on the assumption that the husbandry subfunction is neutral with respect to yield per hectare, and/or (2) it is assumed that systematic differences among countries are picked up in the country-specific intercept terms (or the error term). Random year-to-year weather effects fall in the error term, ε. Also, due to lack of data on prices of competing crops and other inputs, neither is included. To the extent that these vary systematically among countries, their effect will also be captured by the country-specific intercept terms. The dummy variables should reduce the likelihood of specification bias in the estimate of b. Only if omitted variables are correlated positively with the corn: nitrogen price ratio will that coefficient be biased upwards (Griliches). Therefore, while it is regretable that cross-country shifters of the corn yield response surface could not be explicitly included due to lack of data, the importance of the omitted variables should not be exaggerated.

The statistical results are summarized in Table 2. Overall, the statistical results appear very satisfactory. The R^2 was .918 and all coefficient estimates are significantly different from zero at no less than the .0005 level, except for France and Italy's intercept shifters, which are significant at the .01 level, and Canada's intercept shifter, which is not significant at any accepted probability level. The significant negative signs for all countries but Canada's intercept shifters imply that the corn response surfaces of all those countries lie significantly below that of the U.S. They are ranked in Table 2 in decreasing order from Italy, which lies closest below the U.S., down to the Philippines, with the lowest response surface in the sample of 14 countries.

The estimated coefficient of the ratio of the price of corn to the price of nitrogen fertilizer is 0.22; it is significantly different from zero at the .0005 level. The significance of this coefficient is noteworthy because few previous crop supply studies have succeeded in estimating significant yield response to changes in relative product/factor prices. (One recent exception is the study of Houck and Gallagher). Here we find a very strong and significant effect. The likely explanation is that there exists a much greater variation in the observations on both yield per hectare and the price ratio when the data from the cross-section of countries is pooled, than within a sample of data from only one country.

Yield Simulations

We conclude that the estimated yield equation establishes a relationship between corn production and the price of corn relative to the price of nitrogen in the sample of 14 countries. The equation can be used to predict what the

Table 2. Statistical Results of Estimating the Cross-Country Corn Yield Equation

Variable	Parameter Estimate	t-statistic
A (constant)	4.09	46.04
P_C/P_N	0.22	3.13
Dummy Variables:		
Canada	0.01	0.12
Italy	-0.16	2.15
France	-0.17	2.26
Egypt	-0.27	3.39
Spain	-0.48	6.52
Hungary	-0.54	6.69
Yugoslavia	-0.89	6.88
Thailand	-1.02	10.45
South Africa	-1.07	12.78
Brazil	-1.34	17.29
Mexico	-1.48	19.97
Pakistan	-1.51	20.37
Philippines	-1.75	21.05
R^2	.918	

yield of corn would be in each country at any given price ratio, given its intercept. To estimate the change in corn yield in each country as the corn to nitorgen price ratio changes, the ratio was parametrically varied from 0.1 to 2.0 in units of 0.1. The range of price ratios used in these simulations brackets the ratios observed in the sample of countries. Over the period 1961 to 1973 the mean price ratio in each country ranged from a low of 0.20 in the Philippines and South Africa to 1.69 in Yugoslavia (Table 1). The calculated yield levels for selected price ratios are presented for each country in Table 3. These simulations suggest that there exists substantial corn yield response to changes in the price of corn relative to the price of nitrogen fertilizer in the sample of 14 countries. This suggests that policy-induced distortions in the price ratio do have a significant impact on observed corn yield differences among countries.

From a policy viewpoint the more interesting question is: given their respective response surfaces, what would be the corn yield in each country if the farmers in all countries confronted the same price ratio, rather than the different ones observed as a result of distortions due to differing national agricultural and fertilizer price policies. For purposes of comparison, consider the effects if all countries confronted a price ratio of 0.40, which was approximately the average price ratio in the U.S. over the period. (No suggestion is made here that relative prices were not distorted in the U.S. during the period). At a price ratio of 0.4, the predicted corn yield in Yugoslavia, which had the highest average price ratio (1.69) is only 20.0 quintals/ha. (60 percent of its observed 28.9 quintals/ha.). On the other hand, the predicted yields for South Africa and the Philippines, which had the lowest observed price ratios (0.20), were 16.8 and 8.5 quintals/ha., respectively, at a ratio of 0.4. These yields are 8.5 and 14.4 percent above their respective observed yields. The difference between their predicted yields at price ratio 0.4 is, of course, due to the fact that the Philippines' estimated response surface is much lower than that of

Table 3. Simulated Yields of Corn at Different Assumed Ratios of Corn to Nitrogen Fertilizer Prices

(Quintals Per Hectare)

$\frac{P_C}{P_N}$	U.S.	Canada	Mexico	Brazil	France	Hungary	Spain	Italy	Yugoslavia	Paki-stan	Thai-land	Philip-pines	Egypt	South Africa
.20	41.93	41.93	9.54	10.98	35.37	24.43	25.94	35.73	17.22	9.26	15.12	7.29	32.01	14.38
.40	48.83	48.83	11.12	12.79	41.20	28.46	30.22	41.61	20.05	10.79	17.61	8.49	37.28	16.75
.60	53.39	53.39	12.15	13.98	45.04	31.11	33.04	45.50	21.92	11.79	19.25	9.28	40.76	18.31
.80	56.88	56.88	12.95	14.89	47.99	33.15	35.20	48.47	23.36	12.56	20.51	9.88	43.42	19.51
1.00	59.74	59.74	13.60	15.64	50.40	34.81	36.97	50.91	24.53	13.20	21.54	10.38	45.60	20.49
1.20	62.18	62.18	14.16	16.28	52.46	36.24	38.48	52.99	25.54	13.74	22.42	10.81	47.47	21.33
1.40	64.33	64.33	14.64	16.84	54.27	37.49	39.81	54.82	26.42	14.21	23.20	11.18	49.11	22.07
1.60	66.25	66.25	15.08	17.35	55.89	38.61	40.99	56.45	27.21	14.63	23.89	11.51	50.57	22.72
1.80	67.99	67.99	15.48	17.80	57.36	39.62	42.07	57.93	27.92	15.02	24.52	11.81	51.90	23.32
Average 1960-1975 Yields	47.53	48.83	10.36	13.67	41.35	32.92	30.29	42.29	28.89	10.96	21.50	7.42	33.28	15.44

South Africa.)[5/] These results illustrate that both the position of the corn response surface and the ratio of the price of nitrogen to the price of corn are significant in accounting for differences in corn productivity among countries. Domestic price and trade policies which distort prices in the corn and fertilizer markets therefore have a significant effect on corn yields. Losses in the efficiency of global agricultural resource allocation may result.

FOOTNOTES

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**David C. Lyons is Legislative Assistant for Agriculture to Senator Lugar, Washington, D.C., and Robert L. Thompson is Assistant Professor, Department of Agricultural Economics, Purdue University.

1. Farm gate prices per 100 kg. of corn (sales price) and 100 kg. of elemental nitrogen (farm purchase price) in domestic currency are employed. This avoids any problem of selecting an appropriate exchange rate for comparisons among countries. Prices for each crop year are those prevailing at the time the crop was planted.

2. It is known that phosphorous is an important fertilizer element in corn production in certain countries, e.g. France and Brazil. However, when the price of corn relative to the price of P_2O_5 was included in the initial specification of equation (3), its coefficient was not significant at any acceptable probability level, and it was dropped from the analysis.

3. United States, Canada, Mexico, Brazil, France, Spain, Italy, Hungary, Yugoslavia, Egypt, South Africa, Pakistan, Thailand, and the Philippines, for 1961 to 1973.

4. This procedure was utilized by Timmer and Falcon in their cross-country study of Asian rice production and trade. It was originally used in the agricultural economics literature to correct for "management bias" in production functions due to the omission of this nonobservable input. See Griliches and Mundlak.

5. The yield levels simulated here should not be interpreted as forecasts of corn yields at any given price level. Rather, they should be considered as suggestive of the potential yield levels in each country at different price ratios. Year-to-year variability in weather conditions alone would surely negate the predictions in any given year. Rather, the purpose is analytical and should only be taken as suggestive of the relative magnitudes among countries.

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Biographical Information

David C. Lyons, a native of Indiana, is Legislative Assistant for Agriculture to Senator Lugar, Washington, D.C. He completed his Master of Science degree at Purdue in May 1977 and was employed at Purdue as a technician in grain and livestock marketing research until June 1978. He received his Bachelor of Science degree from Purdue in December 1974. This paper reports part of the results of Lyons' M.S. thesis.

Robert L. Thompson is an Assistant Professor in the Department of Agricultural Economics at Purdue University. His principal area of responsibility is in international trade research. He also teaches a graduate course in international agricultural trade and an undergraduate course in world agricultural development. A native of New York State, Thompson received his B.S. from Cornell University in June 1967. His graduate work was done at Purdue University, where he received the M.S. degree in January 1969 and the Ph.D. degree in May 1974. His international experience includes study in Denmark, work with the agricultural extension service in Laos, and teaching agricultural production economics in Brazil. Thompson served as Lyons' major professor in carrying out the research reported here.