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

DAVID C. LYONS
ROBERT L. THOMPSON**

Abstract

This paper tests the hypothesis that a significant part of the observed differences in corn yields among countries can be explained by differences in the corn-nitrogen price ratio. Evidence is provided that the farm level price of corn relative to the price of nitrogen fertilizer varies greatly among countires. The observed large differences reflect the price and international trade policies that exist in the respective markets for corn and nitrogen fertilizer. Pooled data from 14 of the largest 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 the observed corn yield differences among countries. This provides evidence that policies which distort corn and fertilizer prices have a significant effect on corn yields and in turn on the net trade positions of the various countries.

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 1973) and in a "massive disequilibrium" (Hayami and Ruttan 1970). They have argued that the resulting differences in price relatives among countries distrot the location of production of the various products and reduce the efficiency of global resource allocation. There is abundant evidence in the literature that farmers in all parts of the world readily respond to changes in product price relatives by reallocating their land area among crops (For reviews of the evidence, see for example, Krishna (1969) and Thompson (1975)).

* This study was carried out under Indiana Agricultural Experiment Station Project No. 45064, International Trade and U.S. Agriculture. The authors acknowledge the helpful comments and criticisms provided in the course of the study by L. F. Bauman, B. F. Jones, J. A. Sharples, G. E. Schuh, and J. W. Uhrig. However, any remaining errors or deficiencies are the responsibility of the authors.

** David C. Lyons is a student at the Indiana University Law School and Robert L. Thompson is Associate Professor in the Department of Agricultural Economics at Purdue University.

The aggregate effect of changes in factor-product price relatives on land productivity or crop yields has been less studied. 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 the world's third most important crop, corn.

In Table 1 the farm level price of corn relative to the price of nitrogen fertilizer is presented 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 there exist substantial policy distortions 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 nitrogen fertilizer are subsidized. In others, small or out-moded domestic industries which produce agricultural inputs are protected by import restrictions. A number of low income countries pursue a "cheap food" policy in which the prices of staple commodities are held at artificially low levels. Many high income countries artificially raise agricultural prices

TABLE 1 National Ratios of the Price of Corn to the Price of Nitrogen, 1961–1973

Country	Mean	Range
Yugoslavia	1.69	1.09–2.64
Thailand	.92	.65–1.16
Colombia	.67	.58– .85
Hungary	.58	.42– .72
Brazil	.52	.29– .66
Pakistan	.42	.29– .56
Canada	.41	.25– .70
United States	.38	.23– .85
France	.33	.27– .35
Italy	.32	.26– .43
Spain	.31	.27– .39
Mexico	.29	.20– .40
Bulgaria	.29	.27– .32
Egypt	.22	.17– .31
Philippines	.20	.16– .26
South Africa	.20	.16– .23

Source: F.A.O. (1975) for 1961–1970, supplemented with personal correspondence with F.A.O. for 1971–1973.

[1] Farm gate prices per 100 kg. of corn (sales price) and elemental nitrogen (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.

via minimum price programs and 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 2 (column 2) illustrates the striking differences which exist in corn yields among the 18 largest corn producing countries. Several of these large corn producing countries including Argentina, Thailand, and Yugloslavia have yields of only about the world average, which in turn is only about one-half of the U.S. average. The corn yield in Brazil, the third largest producer, is only about one-half of the world average (26.7 quintals/ha.). The average yields in Mexico, the Philippines, and Indonesia are all even lower, although these countries have much smaller total areas planted to corn. Of course, even in the absence of price distortions, one should not expect corn yields to be equal across countries due to differences in soils, climate, and technology. Evenson and Kislev

TABLE 2 Basic Corn Statistics for the 18 Largest Producing Countries, 1973–1975 Average

Country	Area	Yield	Production	Net Exports	Domestic Disappearance*
	(1000 hectares)	(quintals/ hectares)	(1,000 metric tons)		
U.S.	26197	51.9g	136134	33094	103040
P.R.C.	14000	21.59	30223	−837	31060
Brazil	10798	14.82	16000	1704	14296
U.S.S.R.	3545	30.72	10891	−6172	17063
South Africa	4486	20.99	9415	3081	6334
France	1942	47.59	9242	2774	6470
Mexico	7900	10.84	8567	−1726	10293
Yugoslavia	2332	36.70	8559	315	8244
Romania	3023	26.28	7946	−143	8089
Argentina	3119	25.22	7867	3633	4234
Hungary	1444	44.35	6404	1041	5363
India	6045	9.50	5742	—2	5744
Italy	898	57.28	5144	−4409	9553
Indonesia	2926	11.00	3217	165	3052
Canada	585	51.30	3001	−854	3855
Thailand	1128	23.05	2600	2165	435
Egypt	662	38.02	2517	−453	2970
Philippines	2951	8.39	2477	−99	2576

* Includes feed use, human consumption, industrial use, seed use, change in stocks and waste.

Source: 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.

have provided evidence that these all are significant factors in accounting for differences in corn productivity among the 49 countries in their sample. However, they ignored the possibility that differences in relative price among countries may also account for a significant part of the observed differences in corn yields.[2]

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 differences in this price ratio from other factors which vary systematically among countries on corn yields.

Since 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 can result in a substantial increase in total production and, in turn, the exportable surplus over domestic use. The secondary objective of the study is to estimate the effects of yield differences induced by the price distortions on net exports of corn in each of the countries studied.

In the next section a conceptual framework for analyzing cross-country differences in corn yields is outlined. This is followed by the statistical results of estimating a cross-country yield function. The results are then used to simulate the effects of price differences on yield and in turn on corn exports at historical area planted and domestic disappearance levels. Implications are drawn in the final section.

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:

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

where Y is physical output, T is the area of land in production, L is the flow of labor services and K_T represents land-saving or augmenting 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,

[2] In their analysis of cross-country differences in aggregate agricultural productivity, Hayami and Ruttan recognized the fact that relative product prices differ significantly among countries. However, rather than attempt to account for the "contribution" of this to observed productivity differences, they used a set of constant price weights (the cube root of the respective product prices in the U.S., Japan and India) to aggregate total agricultural output in each of the countries in their sample.

agricultural production may be considered to be a combination of two processes: a biological process, $f(T, K_T)$, and a husbandry function, $g(L, K_L)$. In this analysis we shall focus on the biological subfunction because of our interest in land productivity (or yield) and the fact that mechanical technology tends to be only mildly yield increasing.

The investigation of productivity at the level of the biological production process involves attempts to discover the relationship between quantities of nutrient inputs and physiological growth under given environmetal conditions.[3] In principle we could think in terms of a functional relationship which relates the yield of corn from a given area of land to the amount of nitrogen, phosphorous, potash, micronutrients, water, carbon dioxide, light, and heat *absorbed* by the plants. The functional relationship would tell us how much yield would change if the amount of any of the inputs absorbed changed.

The various inputs differ in their substitutability, and this would be reflected in the mathematical form of the response function. Moreover, in general different varieties of corn differ in their responsiveness to variation in one or more inputs. This implies that there would be a different response function for each variety, and that the output per unit of input would vary among the varieties for a given level of input or outputs. This is important, for an important goal of plant breeding research is to alter this relationship, especially in the direction of obtaining a larger response to given levels of plant nutrients and water.

In this framework we can think of the soil's role as that of physically supporting the plant and of providing a conduit for water and nutrients dissolved in the water to be absorbed through the plant's roots. Since soils differ in their capacity to do this, the yield of a crop grown in different soils, all other things held constant, may differ markedly.

For the physiological growth of a plant, water is required in its own right, as well as a conduit for nutrients required for plant growth. In nature this water is supplied by rainfall, which varies substantially across climatic zones and within climatic zones over time (annual weather). There is an optimum amount of water at each stage of plant growth. More or less at any stage represents a movement along the biological response curve. Different varieties of the same plant and different species of plants have differing demands for water and drought tolerance. Productivity of a given variety then varies with rainfall regimes as it does with soil types.

While the distribution of light is fairly uniform around the globe, its availability to plants does vary with the amount of cloud cover. This affects both the intensity of insolation as well as the environmental

[3] The discussion which follows draws heavily upon Lyons (1977, pp. 62–75) and Schuh and Thompson (1975, pp. 15–22).

temperature. Different species of plants have different optimum temperature conditions for growth. In addition, variation in day length is an important element in triggering various vegetative phases of certain varieties and species of plants (photoperiod sensitivity). Plants which are photoperiod sensitive require changes in day length to trigger certain physiological processes, such as flowering. Photoperiod sensitivity limits the degree to which certain plants can be moved across latitudes.

This brief discussion suggests that variable T in equation (1), which was called "land," really represents a vector of inputs in the biological production function including the inherent fertility of the soil and the climate above it. The forms of captial represented by K_T may 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 (embodied in improved seed). To this biological production relationship must be added husbandry practices, represented in equation (1) by subfunction $g(L, K_L)$. In a primitive agriculture the services of the land with some labor input for planting represent the principal inputs to which the crop output accrues. With some additional labor input for weeding and pest control, yields may be increased marginally, the returns to which accrue to that labor input. If a source of water for irrigation is available which can be tapped by gravity flow, additional output may be obtained by providing supplemental water in dry periods. Additional labor may also be expended to collect and spread manure, increasing the nutrient availability to the plants above that inherent in the soil.

The important point to remember in this context is that the underlying biological production function which relates plant uptake of nutrients, water, etc. is unchanged. We are merely adding a husbandry function through which greater labor input augments the naturally occurring availability of inputs or affects the timeliness of their delivery to the growing plants through the use of purchased inputs such as chemical fertilizers, lime, and irrigation pumps. The use of herbicides and insecticides may also increase crop output. Each of these can be thought of as contributing directly to output, in part by reducing crop damage and in part by replacing labor to the extent that they reduce the amount of time consumed in pulling weeds and manual insect control.

Mechanization is in some respects similar, whether it be animal or tractor powered. It can be argued that an important part of mechanization is purely a substitution for labor, permitting each member of the agricultural labor force to cultivate more land. In general, mechanization contributes little to land productivity growth in its own right, except as it may improve yields due to more timely operations.

In addition to the input of physical labor, the human factor also provides an important management or coordination role in orchestrating the whole production process. Management skills are required to combine agricultural enterprises to make the most efficient use of a farm's endowment of land and labor. Welch has argued that the level of education of the farmer (broadly interpreted to include both formal schooling and vocational training of various kinds) has two basic effects in the production process. These include a worker effect, which enables the worker to obtain more output from the same bundle of resources, and an allocation effect, by means of which greater output is obtained from an improved allocation of resources. Viewed from this perspective, the contribution of education is in enabling the worker to acquire and decode new information. This effect of education gives rise to differences in observed productivity among farmers in the same sense that differences in availability of new production technology gives rise to observed differences in productivity.

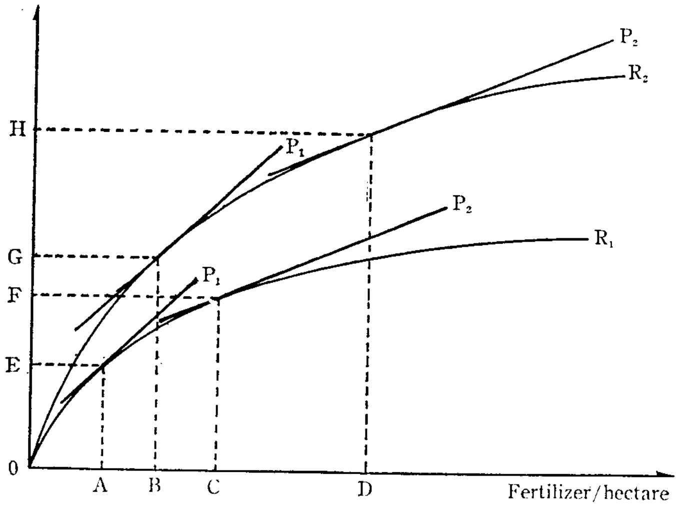
This discussion suggests that observed cross-country differences in corn yield are associated with differences in soils, climate, technology, and management ability (or farmer education). The soil and climate impose certain constraints on potential yield in any given geographic area. Technology here is biologcal and chemical in nature. The former, which is mainly based on plant breeding, includes higher yielding varieties, disease and drought resistence, and the like. Chemical technologies include fertilizer, lime, and pesticides. Irrigation may also be appropriately included here since it alters the availability of water to the growing plants. Management ability may influence the adoption of available technologies. As a result, we may think of a family of fertilizer response surfaces, in which the shifters include soils, climate, improved varieties, irrigation, and level of farmer education.

As indicated in the introduction to this paper, this is where most previous cross-sectional productivity studies have stopped. They have either assumed relative prices constant (e.g. Evenson and Kislev) or have employed a set of constant price weights for aggregating outputs and/or inputs (e.g. Hayami and Ruttan). However, none known to the authors have 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 1964, Chaps. 2–3; Hopper 1965; Yotopolous 1968), 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 product: factor price relatives will alter the marginal product and in turn the average product on any given response surface.[4]

[4] The relationship between average and marginal productivity of land, T, is: $Y/T = \partial Y/\partial T - Y[\partial(Y/T)/\partial T]$. That is, the average productivity of land, Y/T, for any given level of T, equals the marginal productivity at that level of T times the rate of change in average productivity at that level (Simonsen 1971, p. 246).

FIGURE 1 OPTIMUM RATES OF FERTILIZER APPLICATION UNDER DIFFERENT RESPONSE SURFACES AND PRICE RATIOS



This can be illustrated graphically in Figure 1 with two response curves, R_1 and R_2, which relate applications of nitrogen fertilizer to corn yields per hectare, holding the quantities of all other factors of production constant. Response curve R_2 may be higher than R_1 due to a higher yielding variety, more favorable rainfall, more fertile soil, a higher level of rural education, or the like. Two price lines, whose slopes equal two different ratios of the price of nitrogen to the price of corn, P_1 and P_2, are drawn tangent to the two response curves. The price of corn is higher relative to the price of nitrogen in P_2 than in P_1. Assuming that farmers seek to maximize profit, four different optimum levels of nitrogen use and corn yields result, A, B, C, and D, depending upon which price ratio and response curve one chooses.[5] This suggests that not only shifters of the response surface, but also distortions in the price of corn relative to the price of nitrogen may contribute to observed differences in corn yields among countries. We know of no study which has attempted to isolate the effects of relative prices from physical factors which vary systematically among countries.

Two possible approaches to analyzing observed productivity differences are suggested by the above framework. First, one could estimate a cross-country corn production function including as arguments all potential shifters of the response surface among countries. By assuming profit maximizing behavior, and parametrically varying the price of corn

[5] Herdt and Mellor utilized a similar diagram in comparing the fertilizer responsiveness of rice varieties and the optimum rate of fertilizer application in India and the United States.

relative to the price of nitrogen fertilizer, the effect on the yield could be calculated. This procedure is precluded, however, because the only crop specific input use data which exist across countries are for land. Alternatively, by assuming profit maximizing behavior, corn yield may be estimated as a function of the corn: nitrogen price ratio and a vector of factors which shift the response surface among countries, such as technology, climate and soils. To the extent that the production function is separable between the biologcal and husbandry subfunctions, we may limit the set of shifters here to arguments of only the biological subfunction. This is the procedure followed in the present study.

Statistical Analysis

The argument in the conceptual discussion suggests that corn yield in a given country at a given point in time, Y/T, can be expressed as: $Y/T = G(P_C/P_N, Z)$, where P_C is the farm gate price of corn, P_N is the purchase price of nitrogen fertilizer, and Z is a vector of factors which shift the response surface among countries and through time.[6] 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, and diffusion of improved varieties. Attempts to obtain time series data and to construct indices of these variables across as many of the principal corn producing countries as possible were unsuccessful.[7] Therefore, in the absence of satisfactory data on the shifters of 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 for the entire pooled sample of 14 countries and 13 years[8] for which complete price data were obtained, with separate intercept terms for each country. That is,

[6] While it is known that phosphorous is an important fertilizer element in corn production in certain countr es, e.g. France and Brazil, the initial inclusion of its price in the analysis below led to no significant results in the estimations, and it was dropped from the analysis.

[7] As an indicator of technology the percent of the area planted to improved varieties was defined. Complete data series on no country could be found. Boyce and Evenson report the number of corn research publications by country; however, their data are reported only in multiple year groupings which proved unworkable for our purposes. An attempt was made to construct annual rainfall and temperature indices for the corn growing period in each country. While it was possible to construct indices, they proved too crude in practice to contribute to the explanat on of observed cross-country yield differences.

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

(2) $$\frac{Y}{T} = A\left(\frac{P_C}{P_N}\right)^b \prod_{i=1}^{13} D_i^{c_i} \varepsilon,$$

where D_i is a 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 accordingly relative to that of the U.S.[9] 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 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, 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 will fall in the error term, ε. Also, due to lack of data on prices of competing crops and other inputs, neither are included. To the extent that these vary systematically among countries, their effect will also be captured by the country-specific intercept terms. Only if omitted variables are correlated positively with the corn:nitrogen price ratio will that coefficient be biased upwards (Griliches 1957). Otherwise, the dummy variables should reduce the likelihood of specification bias in the estimate of b. Therefore, while the omission of specific data on shifters of the corn yield response surface due to lack of data is regretable, the importance of the omitted variables should not be exaggerated.

The parameters of equation (2) are estimated by ordinary least squares in natural logarithms:

(3) $$\ln\left(\frac{Y}{T}\right) = \ln A + b \ln\left(\frac{P_C}{P_N}\right) + \sum_{1=1}^{3i} c_i \ln D_i + \ln \varepsilon.$$

(Each dummy variable takes on the value of 1 or e since ln 1=0 and *ln* e = 1.) The time series of 13 years of data on relative prices and yields in each of the 14 countries are pooled, making a total of 182 observations.[10]

The statistical results are summarized in Table 3. Overall, the statistical results appear very satisfactory The R^2 was .918 and all coefficient estimates are significantly different from zero at at least 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

[9] 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.

[10] Data sources were identified above in the footnotes to Tables 1 and 2.

any acceptable 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 decreasing order in Table 3 from Italy which lies closest below the U.S. down to the Philippines with the lowest response surface in the sample of 14 countries. It should be emphasized that while these results provide fairly strong evidence concerning the relative positions of the respective response surfaces, the dummy variables, of course, do not explain anything. Further data collection and analysis is needed to identify and estimate the relative importance of the factors accounting for the different positions of the surface in each country.

The estimated coefficient of the ratio of the price of corn to the price of nitrogen fertilizer is 0.22, and is signficantly different from zero at the .0005 level. This suggests that as the ratio of the price of corn to the price of nitrogen fertilizer rises by one percent, the average yield of corn per hectare increases 0.22 percent. 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. Here we find a very strong and significant effect. The likely explanation is that there exists a much greater variation in both the yield per hectare and in the price ratio when the data from the cross-section of countries is pooled, than within a sample of data from only one country.[11]

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 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 nitrogen price ratio changes, the ratio was

[11] It should be borne in mind that this partial analysis of covariance specification forces each country to have the same price coefficient (while permitting each to have its own intercept). In principle, the assumption of a common price coefficient across countries is a testable hypothesis—either by estimating a separate response equation for each country, or by estimating a full analysis of covariance model in which country-specific slope shifters are also included. The latter, which is equivalent to estimating a separate function for each country, was attempted here. The price coefficient increased from 0.22 to 0.28; however, certain estimated intercept and slope shifters took on implausibly large values (both positive and negative). It appears that likely measurement errors in the observations are too large to permit estimation of the influences of variables for countries within which the ranges of data variation are relatively small. While the full analysis of covariance estimation provided mixed evidence on whether the price coefficient is uniform across all countries in the sample, we conclude that this basic assumption cannot be adequately tested with the presently available data. All that can be claimed is that differences in corn productivity among countries can be explained well with this assumption.

TABLE 3 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	

parametrically varied from 0.1 to 2.0 in units of 0.1. The calculated yield levels for selected price ratios are presented for each country in Table 4. 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).

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. Table 4 focuses attention on the more interesting question from a policy viewpoint: 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

TABLE 4 SIMULATED YIELDS OF CORN AT DIFFERENT ASSUMED RATIOS OF CORN TO NITROGEN FERTILIZER PRICES

(quintals per hectare)

P_C/P_N	U.S.	Canada	Mexico	Brazil	France	Hungary	Spain	Italy	Yugo-slavia	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

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 South Africa.[12] These results illustrate that both the position of the corn response surface and the ratio of the price of nitrogen are significant in accounting for observed differences in corn productivity among countries. In the next section implications are drawn from this for world trade in corn.

Effect of Price Distortions on Net Exports

As indicated in the introduction to this paper, a number of countries with large land areas planted to corn have relatively low yields. A small percentage increase in yields, whether from a shift in the response surface or from a change in relative prices, could result in a large absolute increase in total producton and, in turn, the exportable excess over domestic disappearance.[13] In this section, the yield simulations presented in Table 4 are used as the basis for analyzing the effect of distortions in the corn: nitrogen price ratio on the excess supply of corn from the respective countries. For sake of illustration it is simply assumed that the area planted to corn and the volume of domestic disappearance in each country remain constant at the mean annual levels observed during 1960–75.[14] This procedure should produce an underestimate of the export supply response to changes in the price of corn relative to the price of nitrogen since an increase in the price of corn relative to other products would be expected to increase the area planted to corn and to decrease the quantity of corn consumed domestically. The results are presented in Table 5. The bottom row of figures in the table presents the 1960–75 mean observed net exports of corn from each country in the sample. This is presented to facilitate comparison and to judge the plausibility of the calculated levels.

These simulations suggest that there exists substantial corn export supply response to the price of corn relative to the price of nitrogen in

[12] The yield levels simulated here should not be interpreted as forecasts of corn yields at any certain 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.

[13] Given the large market share of the United States in the world corn market, many other countries could increase their corn exports by a fairly large percent without appreciably lowering the export price received.

[14] This procedure was followed by Timmer and Falcon (1975a) in their study of the Southeast Asia rice economy. The data collection, which would have been necessary to econometrically estimate the price elasticities of area response and of domestic demand in each country studied was beyond the scope and resources of this study. (See, for example, Timmer and Falcon (1975b)).

the sample of 14 countries and that even traditionally deficit countries might attain self-sufficiency in corn in response to a higher price of corn relative to nitrogen. Table 5 shows that in the export simulations, every country in the sample except Spain, Italy, and Yugoslavia becomes a net exporter of corn at some price of corn relative to the price of nitrogen fertilizer less than 1.7 on the basis of yield response alone.

The same information contained in Table 5 is presented graphically in Figure 2 in the form of excess supply curves for corn in each country. The shapes of the respective excess supply curves are determined by differences in the intercept of the yield response function, as well as in the area planted to corn and the volume of domestic consumption. The curves of countries with relatively small areas but large consumption, such as Italy and Spain, rise rapidly and they do not become net exporters at any price ratio despite their relatively high response surfaces. On the other hand, exports from a country like Brazil with a very low response surface, but a very large area and small domestic consumption rise rapidly as the price ratio increases.

The price ratio at which each country switches from being a net importer to being a net exporter provides a crude measure of the competitive position of the respective countries in the world market.[15] For those countries which only become self-sufficient in corn at relatively high price ratios to become corn exporters would almost certainly require shifting their response surfaces upward. Countries which have been very close to self-sufficient at historical prices would find that a marginal increase in the price ratio would turn them into net exporters instead of net importers.

The average aggregate level of net exports from the 14 countries in the sample during the period 1960–1975 was 17,248,000 M.T. According to the simulations this level of net exports would occur at a price ratio of .426 if the farmers in all countries confronted this price ratio. As shown in Table 1, 10 of the 14 countries had average prices below this during 1961–1973. They were: the U.S., Canada, Mexico, France, Spain, Italy, Pakistan, Philippines, Egypt, and South Africa. Only Brazil, Hungary, Thailand and Yugoslavia had higher average relative prices.

By increasing the relative price ratio 14.8 percent from 0.426 to 0.50, the calculated level of total net exports from the 14 countries increases

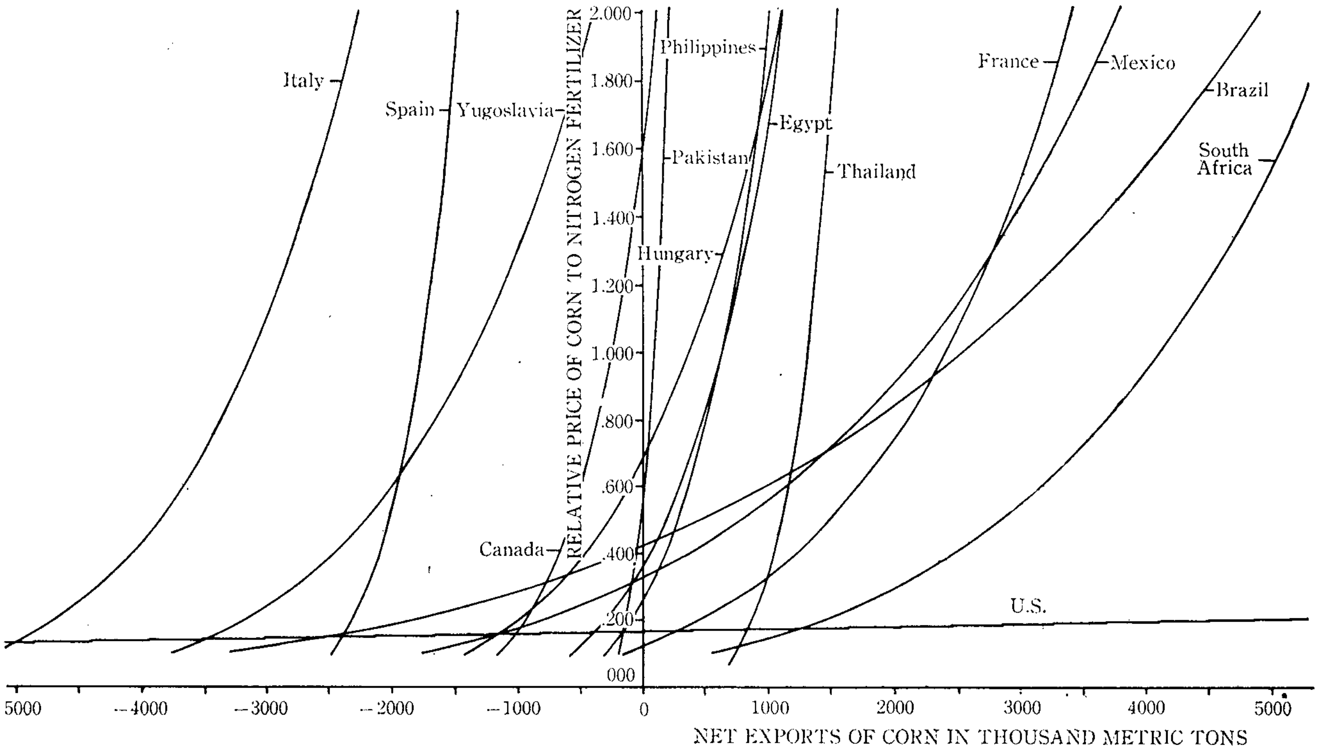
[15] This is only an absolute advantage argument and implies nothing about the locus of comparative advantage in corn production. One approach to analyzing comparative advantage would be via a large mathematical programming model of world agriculture which permits simultaneous resource adjustments among all products. A much simpler approach would be through calculation and comparison of the domestic resource costs of corn production in each country. See Evenson and Valentini for treatments of the role of technological change in shifting the locus of agricultural comparative advantage.

TABLE 5 SIMULATED NET EXPORTS OF CORN AT DIFFERENT ASSUMED RATIOS OF CORN TO NITROGEN FERTILIZER PRICES

P_C/P_N	U.S.	Canada	Mexico	Brazil	France	Hungary	Spain	Italy	Yugoslavia	Pakistan	Thailand	Philippines	Egypt	South Africa	Total (14 Countries)
								(1000 Metric Tons)							
.20	4704	−934	−762	−1817	476	−984	−2306	−4661	−3149	−129	877	−85	−280	1442	−7608
.40	21406	−669	385	−129	1220	−457	−2099	−4063	−2459	−42	1045	193	74	2475	16880
.60	32424	−494	1141	984	1711	−109	−1963	−3669	−2003	16	1156	376	307	3156	33033
.80	40859	−360	1720	1836	2087	157	−1859	−3367	−1655	60	1242	516	485	3677	45398
1.00	47780	−250	2195	2536	2395	376	−1773	−3120	−1369	96	1311	631	631	4105	55544
1.20	53692	−156	2601	3133	2659	562	−1700	−2908	−1124	127	1371	729	757	4471	64214
1.40	58879	−74	2957	3657	2890	726	−1635	−2723	−910	154	1423	816	866	4791	71817
1.60	63517	0	3275	4126	3096	872	−1578	−2557	−718	178	1470	893	964	5078	78616
1.80	67723	67	3564	4551	3284	1005	−1526	−2407	−544	200	1513	963	1053	5338	84784
Mean 1960–1975 Net Export (actual)	18139	−648	−122	769	1924	249	−2095	−4160	189	−28	1330	−23	−226	1950	17248

* Positive levels are exports; negative levels are imports.

FIGURE 2 Simulated Excess Supply Curves



31.9 percent from 17,248,000 to 22,748,000 metric tons. If the ratio increases 20 percent further from 0.50 to 0.60, calculated net exports rise 45.2 percent more to 33,033 metric tons. These results suggest that there exists considerable potential for increased net exports in response to changes in the price of corn relative to the price of nitrogen.

It is of particular interest to the U.S. to examine the implications of the model for producing countries which compete in the export market. Eight countries in the sample had average price ratios lower than in the U.S.: Mexico, France, Spain, Italy, Pakistan, Philippines, Egypt, and South Africa, and five had higher price ratios over the period: Canada, Brazil, Hungary, Yugoslavia, and Thailand. Of these, France, Thailand, and South Africa have been important competing exporters. This suggests that France and South Africa would be larger net exporters if their farmers confronted the same price ratio as American corn growers. Thailand and Brazil would be smaller net exporters at American prices.

The area in corn production in Brazil is second only to the corn area of the U.S. One would expect that with such a large area in corn production Brazil would become an important exporter if its average yield increased significantly. These results suggest that this is unlikely to happen at the U.S. price ratio without shifting Brazil's corn response surface upwards.

Philippine and Egyptian farmers confronted very low prices of corn relative to prices of nitrogen, and both countries were marginal importers over the period. At the U.S. price ratio the model suggests both would be marginal exporters. Yugoslav farmers confronted the highest price of corn relative to the price of nitrogen in the sample, about 4.5 times the U.S. price ratio; at U.S. prices Yugoslavia would be a large importer. Hungarian relative prices are also higher than in the U.S., and it has historically been a minor exporter of corn. At U.S. prices, the model suggests Hungary would be a net importer.

Note that at the highest price ratios in Table 1, after the U.S., the next largest net exporters of corn in order are: South Africa, Brazil, Mexico and France, followed at a substantially lower volume by Thailand, Hungary and the Philippines. That is, at the highest yields, which accompany the higher price ratios, the countries with the largest areas planted to corn become the largest exporters.

Before leaving this section, it needs to be emphasized that, as with the yield simulations, the levels of net exports generated and presented in Table 5 should not be interpreted as forecasts of the levels of trade at the respective relative prices, but should only be considered as suggestive of the size of the potential levels of net exports from each country, given different price ratios of corn to nitrogen fertilizer.

Conclusions

The results indicate that the price of corn relative to the price of nitrogen fertilizer is a significant factor in accounting for observed differences in corn productivity among countries. This implies that government policies which change the price of corn relative to the price of nitrogen fertilizer do affect the level of corn production and in turn the volume and direction of trade. The results are consistent with previous studies which demonstrate that the position of the corn response surface differs significantly among countries. This study was unable to estimate the relative importance of the specific shifters of the response surface among countries. However, to the extent that the shift elements can be brought under man's control through investment and research, government policy may raise corn productivity and net exports at a given price ratio.

REFERENCES

Boyce, James K., and Robert E. Evenson, 1975, *Agricultural Research and Extension Programs* (New York: Agricultural Development Council).

de Janvry, A., 1973, "A Socioeconomic Model of Induced Innovations for Argentine Agricultural Development," *Quart. J. Econ.*, 87: 410–435.

Evenson, Robert E., 1975, "Agricultural Trade and Shifting Comparative Advantage," *Trade, Agriculture and Development*, eds. G. S. Tolley and P. S. Zadrozny, pp. 181–200, Cambridge, Mass.: Ballinger Publishing Co.

Evenson, Robert E. and Yoav Kislev, 1973, "Research and Productivity in Wheat and Maize," *J. Polit. Econ.*, 81: 1309–29.

Food and Agriculture Organization of the United Nations, 1975, *Agricultural Producer Prices 1961—1970*, Rome.

Food and Agriculture Organization of the United Nations, *Production Yearbook*, Roome, 1960–1974 issues.

Griliches, Zvi, 1957, "Specification Bias in Estimates of Production Functions," *J. Farm Econ.*, 39: 8–20.

Hayami, Yujiro and Vernon W. Ruttan., 1970, "Agricultural Productivity Differences Among Countries," *Amer. Econ. Rev.*, 60: 895–911.

Herdt, Robert W. and John W. Mellor, 1964, "The Contrasting Response of Rice to Nitrogen: India and the United States," *J. Farm Econ.*, 46: 150–160.

Hopper, W. David, 1965, "Allocation Efficiency in a Traditional Indian Agriculture," *J. Farm Econ.*, 47: 611–624.

Johnson, D. Gale, 1973, *World Agriculture in Disarray*, London: Fontana/Collins.

Krishna, Raj, 1969, "Agricultural Price Policy and Economic Development," *Agricultural Development and Economic Growth*, eds. H. M. Southworth and B. F. Johnston, pp. 497–540, Ithacay Cornell University Press.

Lyons, David C., 1977, "The Effect of Relative Prices on Corn Production and Exports: A Cross-Country Study," M. S. Thesis, Purdue University.

Lyons, David C. and Robert L. Thompson, "The World Corn Economy in Perspective," *Agric. Exps. Ysas. Bull.*, No. 163, Purdue University, June 1977.

Mundlak, Yair, 1961, "Empirical Production Function Free of Management Bias," *J. Farm Econ.,* 43: 44–56.

Schuh, G. Edward and Robert L. Thompson, "Assessing Agricultural Progress and the Commitment to Agriculture," Mimeographed, Bureau for Program and Policy Coordination, U. S. Agency for International Development, Washington, Jan. 24, 1977.

Schultz, T. W., 1964, *Transforming Traditional Agriculture.,* New Haven: Yale University Press.

Simonsen, Mario Henrique, 1971, *Teoria Microeconomica,* 2nd ed., vol. 1, Rio de Janeiro: Fundacao Getulio Vargas.

Thompson, Robert L., 1975, "Agricultural Price Policy as a Factor in Economic Development," *Agricultural Policy: A Limiting Factor in the Development Process,* ed. M. Alexander, pp. 71–85, Washington: Inter-American Development Bank.

Timmer, C. Peter and Walter P. Falcon, 1975 a, "The Political Economy of Rice Production and Trade in Asia," *Agriculture in Development Theory,* ed. L. G. Reynolds, pp. 373–408, Haven: Yale University Press.

Timmer, C. Peter and Walter P. Falcon, 1975b, "The Impact of Price on Rice Trade in Asia," *Trade, Agriculture, and Development,* eds. G. S. Tolley and P. A. Zadrozny, pp. 57–89, Cambridge, Mass.: Ballinger Publishing Co.

U.S. Department of Agriculture, 1976, "Reference Tables on Wheat, Corn, and Total Coarse Grain Supply-Distribution for Individual Countries," Foreign *Agric. Circular-Grains,* No. FG9–76, May 1976.

U.S. Department of Commerce, 1976, "Foreign Production, Supply and Distribution of Grains and Cotton," National Technical Information Service Computer Tape No. PB 232 065.

Valentini, Rubens, 1972, "Technology and International Trade in Agricultural Products: A Test of Some Hypotheses," Ph.D. Thesis, Purdue University.

Welch, Finis, 1970, "Education in Production," *J. Polit. Econ.,* 78: 35–59.

Yotopoulos, P. A., 1968, "On the Efficiency of Subsistence Agriculture," *Food Res. Inst. Studies*, 8: 125–135.

빈 면

JOURNAL OF RURAL DEVELOPMENT

Vol. IV No. 1 **June 1981**

發行兼編輯人	金 甫 炫	發行處	韓國農村經濟研究院	
印 刷 人	柳 健 洙	印刷所	三和印刷株式會社	
1981年 6月 30日 印刷			1981年 7月 6日 發行	

定期刊行物 登錄 바—790(1978. 10. 17)

INFORMATION FOR CONTRIBUTORS

The JOURNAL OF RURAL DEVELOPMENT is devoted to problem-oriented research and policy studies in the field of agricultural and rural development in Korea and overseas. Its purpose is to contribute to the wider understanding of questions of rural economics, sociology and public administration related to rural development by publishing the results of original research, international comparative studies, and articles analysing various experiences in this field. The emphasis is on conceptual and/or empirical work with relevance for public policy. Contributions are invited from all over the world and the Editorial Board reviews articles submitted and decides on their suitability for publication.

1. Two copies should be submitted. All copy should be typed double space including quotations (indented matter), footnotes and references. Maximum length is 25–30 pages unless there is prior approval from the editor.
2. In a covering letter the author should state that the article being submitted has not been published nor is being considered for publication elsewhere.
3. An abstract of 100–150 words should accompany manuscript on a separate sheet.
4. Articles should contain a final section in which the author sets out his main conclusions in a way which will be at least broadly intelligible to the non-specialist reader.
5. Measurement should be metric.
6. Tables and figures should be numbered consecutively and should bear a descriptive title. In table, vertical rules should not be used.
7. REFERENCE

In text: All references to monographs, articles, and statistical sources are to be identified in the text by last name of author, year of publication, and pagination where appropriate, all within parenthesis.

(a) When author's name is in the text: Samuelson (1968). When author's name is not in text: (Friedman 1956).

(b) Pagination follows year of publication: (Heady 1949, pp. 837–850).

(c) For more than one reference to an author in the same year, distinguish them by use of letters (a,b) attached to the year of publication: (1968a).

(d) Enclose a series of references with a single pair of parentheses, separated by semicolons: (Hartley 1977; Johnson 1973; Kuznets 1968).

At the end of the paper: List all items alphabetically by author and within author(s), by year of publication, under the heading of "References."

(a) Books
Forrester, J. W., 1971, *World Dynamics*, Cambridge, Mass: Wright-Allen Press, Inc.

(b) Article in edited anthology
Parsons, H., 1958, "The Value Problem in Agricultural Policy," pp. 285–299 in *Agricultural Adjustment Problem in a Growing Society*, edited by E. O. Heady and et al., Ames, Iowa: Iowa State College Press.

(c) Journal article
Choe, Y. B., 1978, "Toward an Idea of Agricultural Economics: A Critique on the Idea of the Applied Economics of Agriculture," *Journal of Rural Development* 1 (Nov.): 1–21.

8. Footnotes should numbered consecutively throughout the paper.
9. Authors will receive 30 free offprints and additional offprints may be obtained at cost price if ordered before publication.