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Market Price Response of World Rice Research

Yujiro Hayami[1], **Masao Kikuchi**[2] **and Kazuko Morooka**[3]

[1]*School of International Politics, Economics and Business, Aoyama Gakuin University, Shibuya, Tokyo 150 (Japan)*
[2]*International Irrigation Management Institute, Digana (Sri Lanka)*
[3]*International Rice Research Institute – Japan Library Office, Tuskuba (Japan)*

Abstract

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Using the total number of research publications as a proxy, the output of rice research in the world is estimated to be highly responsive in the short run to price fluctuations in the international rice market. The results suggest a danger of the inducement mechanism of public investment in the agricultural production infrastructure being misguided by cyclical price changes, thereby leading to recurrent food shortages and oversupplies in a cobweb-like manner.

Introduction

Market demand has been considered a major determinant of the rate of technological innovation (Griliches, 1957; Schmookler, 1966; Scherer, 1982). The Griliches–Schmookler theory of induced innovation has been founded on the presumed response of private entrepreneurs in the allocation of resources to inventive activities. However, market prices are also considered to have significant impact not only on private resource allocation by farm producers but also on public resource allocation by governmental and non-governmental organisations (Hayami and Ruttan, 1985). Scientific research on rice in the past, especially on its biological aspects, has been conducted predominantly in the public sector. In this paper an attempt is made to show how rice research has responded to changes in the international market price of rice, thereby providing evidence of market-price response in public resource allocation to research.

As a measure of rice research output, the total number of scientific publications on rice listed in the annual issues of the *International Bibliography of Rice Research* (IBRR), published by the International Rice Research Institute (IRRI), is used. The number of scientific publications has been used as a proxy

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for output in the research production function as well as an input for agricultural production functions (Evenson and Kislev, 1975; Evenson and Flores, 1978). This study represents an attempt to estimate the supply response of research product to price.

First, preliminary observations are made on the trend in the number of rice research publications in the world in comparison with the fluctuations in the international price of rice in order to establish a hypothesis. Then, the price response functions for research publications with various time-lag structures are specified and estimated. The results show that rice research output, as measured by the volume of scientific publications, is highly responsive to rice price.

Data and hypothesis

IBRR is intended to cover all publications on rice research in the world including botanical, agronomic, plant protection, production, economic and social aspects. The total number of publications reported in each annual issue includes not only those published in the year of that particular issue but also the publications that had been published but not recorded in previous years. For the purpose of analysing annual changes in rice research output, it was necessary to reclassify the publication data reported in the annual issues of IBRR by year of publication.

This recompilation was an easy task for the data between 1970 and 1978 because they had already been coded appropriately, and the enumeration of virtually all publications during the period had been finished. It was found that both the distribution of publications over the years of publication in each annual issue ('backward distribution') and over various issues for the same year of publication ('forward distribution') remained fairly stable for 1970–1978. For this reason, the total number of publications in the respective years of 1961–69 was estimated by assuming that the same backward distribution prevailed in the 1961–69 issues as was observed in the 1970–78 average distribution. Similarly, those of 1979–86 were obtained by adding to the numbers of publications in the respective years already listed in the annual issues the estimated number of publications left over to be listed in the future issues of IBRR. These numbers were estimated on the basis of the average forward distribution for 1970–78. The first issue of IBRR enumerates rice research publications for 1951–60, with the number totalling 7247 for the 10 years. For this period, the number of publications in each year was estimated based on a survey of a 30% random sample from all the publications compiled in the first issue.

Annual time-series of the total number of rice research publications in the world, thus obtained, are plotted in the upper part of Fig. 1. The series shows a sustained growth trend over the 35 years to 1985. The growth trend reflects

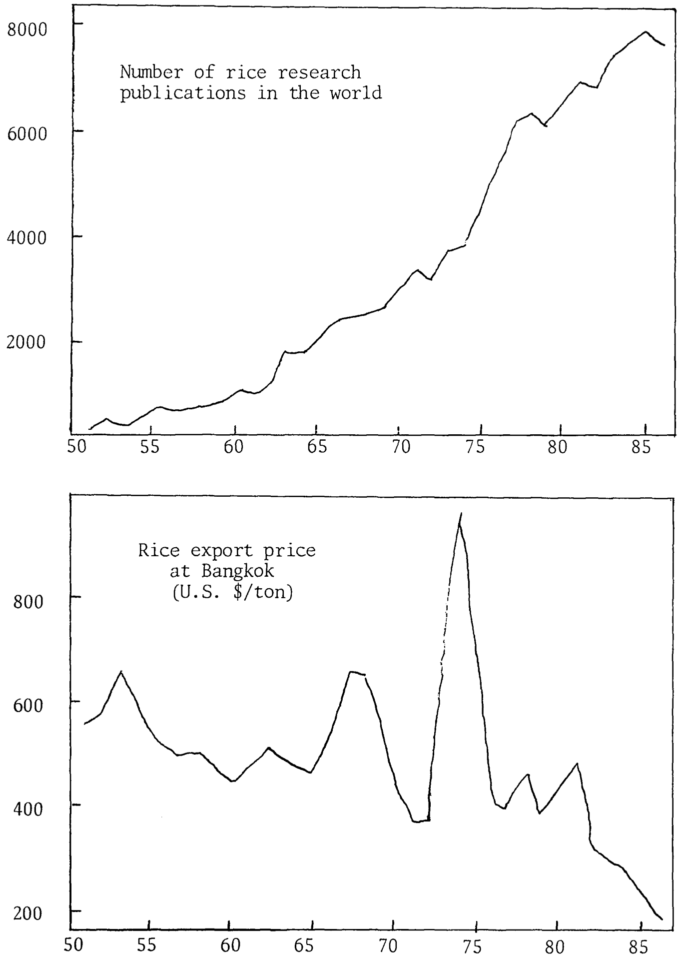

Fig. 1. Movements in the total number of rice research publications in the world and the export price of Thai rice (f.o.b. Bangkok, 5% broken, milled) deflated by the unit value index of manufacturing exports (1980 = 100), 1951-1986.

cumulative increases in investments in research, not only on rice but also on agricultural and related sciences in general, presumably based in part on a growing public awareness of the high social rate of return to research and development. This growth trend was not unique to rice and agriculture but common to all industries during "the Epoch of Modern Economic Growth" (Kuznets, 1966) or "the Second Economic Revolution" (North, 1981). Indeed, cumulative increases in agricultural productivity based on the sustained growth in agricultural research capacity should be one of the major factors underlying the long-run decline in the real price of rice and other food crops over the past 100 years (Johnson, 1984).

However, the growth rate in rice research publications has not been stable in the short run. The estimated growth was very rapid at an average compound rate of 11.1% per year for 1955–63, declined to 5.5% for 1963–69, jumped to 10.3% for 1969–78, and declined sharply to 2.4% for 1978–86.

Such fluctuations in growth trend appear to be explained, to a significant extent, by fluctuations in rice prices in the international market as shown in the lower part of Fig. 1. The price series from IRRI (1986) drawn in this diagram is the export price of Thai rice (f.o.b. Bangkok, 5% broken, milled) as a typical indicator of international market prices, deflated by the unit value index of manufacturing exports prepared by the World Bank (1987). The export price index of manufacturing commodities is used as a deflator because its movement is more stable than that for the prices of primary commodities and, therefore, is considered more appropriate for the purpose of characterising the pattern of rice price fluctuations.

The deflated price of rice fluctuated widely. Especially conspicuous are the sharp increases for 1953–54 triggered by the Korean War, for 1966–68 due to a severe drought in the Indian subcontinent, and for 1973–75, the 'World Food Crisis' period. It appears that the acceleration in rice research output in the late 1950s and the mid 1970s, as measured by the number of publications, represents responses to high rice prices in these periods. On the other hand, the market deceleration in rice research output that has occurred since the end of the 1970s seems perhaps to be explicable by the slump in the international rice market following the so-called World Food Crisis.

It appears reasonable to hypothesise that underlying such responses in research output to price fluctuations have been the actions of various governments and non-profit organisations in reallocating their budgets in response to price-influenced changes in the rate of return to the production of public goods.

Regression analysis

As a test of the above hypothesis, regression equations are estimated that relate the total number of rice research publications (Q) to the export price of rice at Bangkok deflated by the price index of manufacturing export (P). The basic functional specification employed is as follows:

$$\ln Q = a_0 + a_1 \ln P + a_2 t + e$$

where the a's and e are regression coefficients and an error item, respectively. The exponential time trend is introduced to represent the cumulative effect of past research investments on research infrastructure and on the advancement of scientific knowledge.

It is to be expected that the effects of price changes on research output involve substantial time lags. In this analysis, in addition to the Koyck–Nerlove model of a distributed lag with the inclusion of the lagged dependent variable (Q_{t-1}), the Almon polynomial-lag model is also used (Johnston, 1984, pp. 352–358).

Results of the regression analysis based on 36 annual time-series observations (1951–86 as listed in the Appendix) are shown in Table 1. Equation (1) in Table 1 reports the ordinary least-squares estimates of a simple model with the price variable of 1-year lag (P_{t-1}) and the time trend (t) as the only two explanatory variables. The estimated coefficients of price and time trend are found to be statistically different from zero at the 1% significance level. The coefficient of determination adjusted for degrees of freedom ($\bar{R}^2$) is 98%. However, the Durbin–Watson statistic indicates the likely prevalence of serial correlation among the residuals.

A trial to incorporate possible distributed lag effects through the Koyck–Nerlove model using the same set of observations is reported in equation (2) in Table 1. Inclusion of the lagged dependent variable (Q_{t-1}) resulted in a

TABLE 1

Regression estimates of the price response of rice research publications based on the 1951-86 annual time-series data[a]

Equation no.:	(1)	(2)	(3)	(4)
ln P		Koyck-Nerlove	Almon (q=2)[b]	
			Without e.p.c.	With e.p.c.
P_t			0.125 (2.60)**	0.076 (5.49)**
P_{t-1}	0.257 (2.87)**	0.147 (1.93)*	0.143 (5.43)**	0.126 (5.49)**
P_{t-2}			0.143 (4.38)**	0.151 (5.49)**
P_{t-3}			0.125 (3.51)**	0.151 (5.49)**
P_{t-4}			0.089 (2.41)*	0.126 (5.49)**
P_{t-5}			0.034 (0.57)	0.076 (5.49)**
[Sum]			[0.659]	[0.706]
ln Q_{t-1}		0.594 (4.07)**		
t	0.089 (35.6)**	0.034 (2.62)**	0.090 (36.2)**	0.090 (37.2)**
Degrees of freedom	33	31	27	29
$\bar{R}^2$	0.9793	0.9858	0.9845	0.9845
D.W.[c]	1.01	2.24	0.97	0.87

[a] Regression equations are estimated by the ordinary least-squares method. Student t-statistics are shown in parentheses with * and ** indicating the estimated coefficients significant at 5% and 1%, respectively.

[b] q stands for the degree of polynomial assumed for the Almon-lag distribution; e.p.c. stands for the end-point constraints.

[c] Durbin–Watson statistics.

slight improvement in the goodness of fit in terms of $\bar{R}^2$ as well as a significant reduction in the residual serial correlation. The coefficient of price turns out to be positive and significant at the 5% level, while those of the time trend and the lagged dependent variables are significant at the 1% level. The long-run elasticity of rice research publications with respect to price is estimated to be 0.36.

Another approach to incorporate the lagged price effect is to apply the Almon polynomial-lag model. The ordinary least-squares method was used for various combinations of the degree of polynomial and the order of the lags. Since differences in $\bar{R}^2$ were negligibly small among the estimated equations over the ranges of the polynomial from first to third degree and of the lag orders from 4 to 6 years, the combination of their median was chosen.

The results using the Almon lag thus estimated are reported in equation (3) in Table 1, which has a lag distribution extending over the prior 5 years with a second-order polynomial, for which no end-point constraint is imposed. As was to be expected, the effect of rice price in inducing rice research is found to be distributed in an inverted-U shape. The estimated coefficients of all the lagged prices are positive, and those up to the 4th year are statistically significant at the 1% or 5% level. The long-run price elasticity calculated as the sum of the current and the lagged price effects turns out to be 0.66, which is almost twice as large as that estimated from the Koyck–Nerlove model. A comparison of equations (2) and (3) shows that the Koyck–Nerlove and the Almon models have almost the same goodness of fit in terms of $\bar{R}^2$, though the latter is subject to significant serial correlation of its residuals. The estimated coefficient of the time trend in the Almon model is positive and significant at the 1% level, and its magnitude is not too dissimilar to its long-run coefficient estimated from the Koyck–Nerlove model.

Because the null hypothesis of zero price effect in the end points of the lag distribution in equation (3) is accepted at the 5% significance level according to the F-statistic of 1.02, the Almon model was re-estimated with end-point constraints. The results reported in equation (4) in Table 1 with end-point constraints are found to be largely the same as those of equation (3) without end-point constraints.

Finally, a hypothesis is tested that the secular increase in rice research capacity depends on the accumulation of past research output. For testing this hypothesis, the simple time trend is replaced by a geometrical aggregation of past research publications (Q_{t-i}) with the Almon-lag weights. The equation that gives the best statistical fit is chosen from among the various combinations of the degrees of polynomial and the orders of time lag for the two explanatory variables, after deleting the cases in which negative and significant weights are estimated for past research publications. The results are reported in Table 2; equations (5) and (6) in Table 2 report the cases with and without the end-point constraints, respectively. The end-point constraints are statis-

TABLE 2

Regression estimates of the response of rice research publications to price and past research, based on the 1951-86 annual time-series data[a]

Equation no.:	(5)	(6)
$\ln P$	Almon ($q=2$)	
	Without e.p.c.	With e.p.c.
P_t	0.001 (0.028)	0.040 (4.57)**
P_{t-1}	0.054 (3.47)**	0.067 (4.57)**
P_{t-2}	0.078 (4.25)**	0.080 (4.57)**
P_{t-3}	0.075 (3.63)**	0.080 (4.57)**
P_{t-4}	0.043 (1.67)	0.067 (4.57)**
P_{t-5}	−0.016 (−0.35)	0.040 (4.57)**
[Sum]	[0.235]	[0.374]
$\ln Q$	Almon ($q=4$)	
	Without e.p.c.	With e.p.c.
Q_{t-1}	0.344 (1.73)	−0.016 (−1.04)
Q_{t-2}	0.176 (1.62)	−0.021 (−0.843)
Q_{t-3}	0.059 (1.21)	−0.017 (−0.577)
Q_{t-4}	−0.011 (−0.426)	−0.005 (−0.178)
Q_{t-5}	−0.040 (−1.26)	0.013 (0.517)
Q_{t-6}	−0.034 (−1.07)	0.034 (1.99)*
Q_{t-7}	−0.002 (−0.07)	0.057 (4.76)**
Q_{t-8}	0.044 (1.85)*	0.079 (4.72)**
Q_{t-9}	0.092 (2.85)**	0.097 (3.63)**
Q_{t-10}	0.125 (3.37)**	0.108 (3.01)**
Q_{t-11}	0.126 (3.24)**	0.107 (2.65)**
Q_{t-12}	0.076 (1.01)	0.092 (2.42)*
Q_{t-13}	−0.046 (−0.27)	0.058 (2.25)*
[Sum]	[0.909]	[0.586]
Degrees of freedom	14	18
$\bar{R}^2$	0.9894	0.9871
D.W.	1.28	1.67

[a] See footnotes to Table 1.

tically acceptable at the 5% significance level according to the F-statistic of 2.53.

By substituting the accumulated past research publications for the exponential time-trend formulation, the estimated price effects decrease by about one-half but remain positive and significant for most of the prior 5 years with the quadratic lag distribution. In equations (5) and (6), the Almon-lag weights for past research publications are distributed over as long as 13 years with the fourth-degree of polynomial. The estimated coefficients are statistically nonsignificant for the first several years and become positive and significant after the 7-year lag in the case of equation (5), and after the 5-year lag in the case of equation (6). Such results seem to reflect the long gestation period needed for research results to become effective inputs to current knowledge production.

The values of $\bar{R}^2$ for equations (5) and (6) are slightly larger than those of equations (3) and (4). The Durbin–Watson tests are inconclusive for equations (5) and (6) at the 1% level, while significant positive serial correlation is indicated for equations (3) and (4). However, evidence is not conclusive on whether the exponential time trend or the accumulation of past research publications is the better proxy for the secular increase in rice research capacity. This is because the addition of the time variable to equations (5) and (6) results in implausible and nonsignificant estimates of not only the coefficient of this variable but also the coefficients of prices and past research publications, presumably due to multicollinearity.

Although it is difficult to choose one specification of regression over others in terms of statistical criteria, all the estimated equations reported in Tables 1 and 2 unanimously support the hypothesis that rice research publication activities in the world have fluctuated in the short run in response to price fluctuations in the international rice market along a secular trend.

Conclusion

Our analysis has shown that the output of rice research, as measured by the total number of rice research publications in the world, has been responsive to the fluctuations in rice price in the international market. The results are consistent with the results of studies by Griliches (1957), Schmookler (1966) and others on the influence of product market conditions on inventive activities. The results are also consistent with the Hayami–Ruttan hypothesis that both government and non-profit organisations are guided to reallocate public resources in response to changes in the rate of return to the production of public goods corresponding to price changes.

We are keenly aware of the highly provisional nature of this pilot exercise. As it stands, the analysis is overly aggregative and, therefore, some critical information that may be obtained from disaggregated data (e.g., separation between basic and applied research publications) may be missed. The model specification may be too simple and naive without due consideration of other possibly influential factors. Too, the data series of rice research publications by year of publication is still provisional.

Despite these limitations, the results of this study on rice research, together with those of our earlier study on irrigation (Hayami and Kikuchi, 1978), suggest rather strongly a danger of the inducement mechanism for public investments being misguided by cyclical price changes due to such ad-hoc and possibly irrelevant causes as weather fluctuations. If the high food prices in the late 1960s and early 1970s induced the acceleration in public investment in food production infrastructure, and consequently caused the oversupply and depressed prices of food commodities in the 1980s, the deceleration in public investment since the late 1970s has been meeting the pre-condition for food shortages in the future. Rather than responding to recurrent 'world food crises' and 'agricultural depressions' in a cobweb manner, national governments and international agencies should base their investment decisions on the long-run need for food.

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Appendix

Rice research publications, rice price and unit value index of manufacturing exports in the world

Year	Rice research publications (No.)		Rice export price at Bangkok (US$/t)	Unit value index of manufacturing export (1980 = 100)	Deflated rice export price (US$/t)
	Listed in each issue of IBRR[a]	Recompiled by year of publication[b]			
1950			137	22.6	606
1951	727	455	144	26.1	552
1952	727	631	156	27.3	571
1953	727	523	175	26.6	658
1954	727	680	158	26.0	608
1955	727	839	142	26.5	536
1956	727	858	137	27.4	500
1957	727	873	137	28.0	489
1958	727	904	142	28.5	498
1959	727	1009	132	28.1	470
1960	727	1179	125	28.7	436
1961	1054	1162	137	29.2	469
1962	954	1280	153	29.7	515
1963	1948	1949	143	29.2	490
1964	1738	1881	138	29.8	463
1965	1985	2138	136	30.0	453
1966	2355	2444	163	31.1	524
1967	2780	2583	206	31.4	656
1968	2737	2669	202	31.2	647
1969	2855	2686	187	32.8	570

Appendix (continued)

Year	Rice research publications (No.)		Rice export price at Bangkok (US$/t)	Unit value index of manufacturing export (1980 = 100)	Deflated rice export price (US$/t)
	Listed in each issue of IBRR[a]	Recompiled by year of publication[b]			
1970	2550	3074	144	34.8	414
1971	2766	3506	129	36.7	351
1972	2974	3275	147	40.0	368
1973	3248	3831	350	46.4	754
1974	3831	3998	542	56.5	959
1975	4415	4927	363	62.8	578
1976	4712	5470	254	63.7	399
1977	5237	6310	272	70.0	389
1978	5685	6472	368	80.5	457
1979	7027	6200	334	91.2	366
1980	4713	6571	434	100.0	434
1981	6750	7065	483	100.5	481
1982	6081	6925	293	99.1	296
1983	6800	7578	277	96.6	287
1984	7058	7750	255	94.9	269
1985	7498	7999	216	95.8	225
1986	8011	7808	211	113.9	185

[a] The figures for 1951-60 are the simple average of the total number of publications (7274) listed in the first issue of the IBRR that covers the 10-year period.

[b] For this column, see the text.

t, metric tonne = 1000 kg.

Sources: IRRI (1986) and World Bank (1987).

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