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THE OVERALL RATE OF RETURN TO AGRICULTURAL RESEARCH AND EXTENSION INVESTMENTS IN PAKISTAN: A Comment

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Nagy's estimation reveals a very high rate of return to research and extension in Pakistan's agriculture. This work demonstrates that this was due mainly to a mis-specified model, with the research and extension variable picking up the effect of omitted variables, namely water and fertilizer. Due to their importance in agriculture, it was not surprising to note that the inclusion of water and fertilizer results in a considerably lower rate of return to research and extension than shown by Nagy, at times even pushing it to a negative value.

In the summer 1985 edition of this Journal, Joseph G. Nagy attempts to identify and establish the contribution of the major sources of overall productivity growth in Pakistan's agriculture. Using a distributed lag model, the paper concentrates on estimation of the effect of expenditure on agriculture research and extension on agricultural productivity, and concludes that the marginal rate of return is 65 per cent.

The study, however, suffers from a series of problems, ranging from minor oversights to major conceptual drawbacks.[1]

A major problem in the specification of the model is its functional form. The basic estimable model [Equation (2) in Nagy] expresses the weather variable (W_t) in the semi-log form, but percentage area under high yielding variety (HYV_t) and research and extension expenditure (RE_t) variables in a double-log form. The expression of the latter two variables in this form is conceptually incorrect as this implies that given a zero value of

[1]For a discussion on the minor points, see Appendix.

any one[2], or both, variable(s), the value of the dependent variable i.e., productivity index (PI) will be zero.

An important omission in the specification of the model is that of some 'non-conventional' agricultural inputs, mainly fertilizer, which has been crucial to Pakistan's agricultural productivity in the last 20 years. Exclusion of fertilizer may have led to severe biases in the estimates of all the three models given in Nagy's work. The research and extension (RE) variable may be capturing the effect of fertilizer on agricultural productivity and therefore, the value of the marginal product and the internal rate of return to research and extension expenditures (MIRR) may be overstated.

The purpose of this exercise is to calculate the marginal product of, and the corresponding rate of return to, agricultural research and extension expenditures using Nagy's methodology and data but with improved specification of the model. To achieve this, all three of Nagy's models were re-estimated with the following modifications:

$$\text{Log (PI)} = \beta_0 + \beta_1 \text{ HYV} + \beta_2 \text{ W} + \beta_3 \text{ D65} + b_2 \text{ Z} \qquad (1)$$

$$\text{Log (PI)} = \beta_0 + \beta_1 \text{ HYV} + \beta_2 \text{ HYVSQ} + \beta_3 \text{ W} + \beta_4 \text{ D65} + b_2 \text{ Z} \qquad (2)$$

$$\text{Log (PI)} = \beta_0 + \beta_1 \text{ HYV} + \beta_2 \text{ HYVSQ} + \beta_3 \text{ FERT} + \beta_4 \text{ FERTSQ} + \beta_5 \text{ W} + \beta_6 \text{ D65} + b_2 \text{ Z} \qquad (3)$$

where: $Z = \sum_{i=0}^{k} (i^2 - ki - k - 1) \text{ Log (RE)}$; HYVSQ = HYV squared; FERT = fertilizer use; FERTSQ = FERT squared.

The estimated results of equations (1), (2) and (3) are given in Tables 1, 2, and 3 respectively.

Table 1 presents the results using Nagy's data but with the HYV variable expressed in non-log terms. Suprisingly, these results differ significantly from Nagy's estimates.[3] The MIRR calculated from our estimates are much higher i.e., ranging between 81.8 per cent and 90.0 per cent, than that calculated by Nagy (64.5 per cent). A minor decline in these rates occurs as a consequence of including the HYV variable in quadratic form (Table 2). However, the most intersting result emerges with the inclusion of

[2] HYV variable has zero values for 9 out of 20 sample years.

[3] Using HYV in log form, i.e., by adding one to the entire HYV series and then taking the logarithms, or by dropping the first 9 observations from the sample, yielded even more different results.

TABLE 1

Dependent variable, Log (PI)

Explanatory variables	Equation (1)	Equation (2)	Equation (3)
Constant	3.10100	3.104000	3.27300
	(6.89)	(7.38)	(11.03)
HYV	0.01560	0.014700	0.01530
	(4.05)	(4.04)	(4.42)
W	0.00023	0.000157	–
	(0.79)	(0.58)	–
D65	–	−0.163400	−0.17070
	–	(−1.82)	(−1.96)
Z	−0.00243	−0.002480	−0.00230
	(−3.97)	(−4.33)	(−4.89)
Distributed lag weights			
0	0.02430	0.02480	0.0230
1	0.04374	0.04464	0.0414
2	0.05832	0.05952	0.0552
3	0.06804	0.06944	0.0644
4	0.07290	0.07440	0.0690
5	0.07290	0.07440	0.0690
6	0.06804	0.06944	0.0644
7	0.05832	0.05952	0.0552
8	0.04374	0.04464	0.0414
9	0.02430	0.02480	0.0230
Sum of weights	0.53460	0.54560	0.5060
Adjusted R^2	0.69600	0.73500	0.7460
D.W. Statistic	0.43400	0.86900	0.9000
Degrees of freedon	16	15	16
Value of marginal product	6.21000	6.34000	5.8800
Present value of VMP (@ 10%)	4.16000	4.24000	3.9300
Present value of VMP (@ 15%)	3.51000	3.58000	3.3200
MIRR (%)	87.70000	90.00000	81.8000

Figures in parentheses are the t-statistics. Z = the weighted research and extension variable. MIRR = marginal internal rate of return.

TABLE 2

Dependent variable, Log (PI)

Explanatory variables	Equation (1)	Equation (2)	Equation (3)
Constant	3.24400	3.23700	3.40900
	(10.00)	(10.81)	(15.85)
HYV	0.04600	0.04300	0.04400
	(5.71)	(5.70)	(5.85)
HYVSQ	−0.00180	−0.00170	−0.00170
	(−4.01)	(−3.99)	(−4.03)
W	0.00021	0.00016	–
	(1.03)	(0.83)	–
D65	–	−0.12250	−0.13010
	–	(−1.90)	(−2.06)
Z	−0.00216	−0.00220	−0.00200
	(−4.86)	(−5.40)	(−5.93)
Distributed lag weights			
0	0.02160	0.02220	0.0200
1	0.03888	0.03996	0.0360
2	0.05184	0.05328	0.0480
3	0.06048	0.06216	0.0560
4	0.06480	0.06660	0.0600
5	0.06480	0.06660	0.0600
6	0.06048	0.06216	0.0560
7	0.05184	0.05328	0.0480
8	0.03888	0.03996	0.0360
9	0.02160	0.02220	0.0200
Sum of weights	0.47520	0.48400	0.4400
Adjusted R^2	0.84400	0.86700	0.8700
D.W. Statistic	0.77000	1.32000	1.4100
Degrees of freedom	15	14	15
Value of marginal product	5.52000	5.68000	5.1100
Present value of VMP (@ 10%)	3.69000	3.80000	3.4200
Present value of VMP (@ 15%)	3.12000	3.20000	2.8900
MIRR (%)	75.60000	78.20000	68.7000

Figures in parentheses are the t-statistics. Z = the weighted research and extension variable. HYVSQ = HYV squared.

the fertilizer variable, expressed in quadratic form (Table 3). It is not surprising to note that the MIRRs slip into negative values (although the estimates of the Z variable, and therefore the partial elasticities, are not significantly diffrent from zero). This verifies the belief that, in Nagy's analysis, the research and extension variable was capturing the effect of fertilizer on agricultural productivity and, therefore, the value of the marginal product and the internal rate of return were overstated.

Further, it appears as if the author is confused about the assumption of inverted 'U' shape of the partial production coefficients. Beginning with the assumption that "expenditures on research and extension will have a small impact on productivity increase in the current year of their expenditure but that the impact increases to a peak over time but then decays", the author expresses the partial production coefficients (α_i) as the second degree polynomial, i.e.,

$$\alpha_i = b_0 + b_1 i + b_2 i^2$$

However, the two assumptions are not necessarily the same or, that the latter is a specific form of the former, because, as given in Nagy's [equation (2)], α_i are the partial elasticities, whereas it is obvious that the former assumption concerns the marginal products rather than the elasticities. An inverted U-shaped distribution of MP_i does not necessarily imply that α_i would have the same, or even similar distribution, or vice-versa.

In this regard, equations (2) and (3) were re-specified as follows:

$$\text{Log (PI)} = \beta_0 + \beta_1 \text{ HYV} + \beta_2 \text{HYVSQ} + \beta_3 \text{ W} + \beta_4 \text{ D 65} + b_2 \text{ Z1} \qquad (4)$$

$$\text{Log (PI)} = \beta_0 + \beta_1 \text{ HYV} + \beta_2 \text{ HYVSQ} + \beta_3 \text{FERT } \beta_4 \text{ FERTSQ} + \beta_5 \text{ W} + \beta_6 \text{ D65} + b_2 \text{ Z1} \qquad (5)$$

where: $Z1 = \sum_{i=0}^{k} (i^2 - ki - k - 1)$ (RE).

The estimated results of equations (4) and (5) are given in Tables 4 and 5 respectively. It may be noted that with the research and extension variable stated in linear terms, the pattern of analysis remains the same.

In conclusion, one may reiterate that Nagy's model suffers from specification problems and the impact of investment in research and extension on agricultural productivity is grossly overstated.

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TABLE 3

Dependent variable, Log (PI)

Explanatory variables	Equation (1)	Equation (2)	Equation (3)
Constant	4.366000	4.395000	4.579000
	(20.37)	(18.01)	(18.08)
HYV	−0.022800	−0.024100	−0.026200
	(−1.87)	(−1.79)	(−1.74)
HYVSQ	0.001800	0.001900	0.001500
	(2.88)	(2.64)	(1.99)
FERT	0.002100	0.002200	0.002000
	(6.72)	(5.70)	(4.83)
FERTSQ	−0.000002	−0.000002	−0.000002
	(−3.66)	(−3.41)	(−2.60)
W	0.000210	0.000220	–
	(2.10)	(2.05)	–
D65	–	0.011500	−0.003100
	–	(0.29)	(−0.07)
Z	−0.000068	−0.000010	0.000140
	(−0.20)	(−0.02)	(0.31)
Distributed lag weights			
0	0.000680	0.0000960	−0.001430
1	0.001224	0.0001728	−0.002574
2	0.001632	0.0002304	−0.003432
3	0.001904	0.0002688	−0.004004
4	0.002040	0.0002880	−0.004290
5	0.002040	0.0002880	−0.004290
6	0.001904	0.0002688	−0.004004
7	0.001632	0.0002304	−0.003432
8	0.001224	0.0001728	−0.002574
9	0.000680	0.0000960	−0.001430
Sum of weights	0.014960	0.0211200	−0.031460
Adjusted R^2	0.966000	0.9630000	0.954000
D.W. Statistic	2.080000	1.9900000	2.480000
Degrees of freedom	13	12	13
Value of marginal product	0.170000	0.0200000	−0.370000
Present value of VMP (@ 10%)	0.116000	0.0160000	−0.240000
Present value of VMP (@ 15%)	0.098000	0.0140000	−0.210000
MIRR (%)	−27.650000	−45.7400000	−18.000000

Figures in parentheses are the t-statistics. Z = the weighted research and extension variable. HYVSQ = HYV squared, FERTSQ = FERT squared.

TABLE 4

Dependent variable, Log (PI)

Explanatory variables	Equation (1)	Equation (2)	Equation (3)
Constant	4.02700	4.04500	4.15000
	(26.37)	(28.92)	(50.43)
HYV	0.04810	0.04550	0.04580
	(6.50)	(6.60)	(6.68)
HYVSQ	−0.00190	−0.00180	−0.00180
	(−4.71)	(4.79)	(−4.78)
W	0.00022	0.00016	–
	(1.14)	(0.93)	–
D65	–	−0.11800	−0.12600
	–	(−1.99)	(−2.16)
Z1	−0.00014	−0.00014	−0.00013
	(−5.43)	(−6.05)	(−6.57)
Distributed lag weights			
0	0.001415	0.0014430	0.0013260
1	0.002547	0.0025974	0.0023868
2	0.003396	0.0034632	0.0031824
3	0.003962	0.0040404	0.0037128
4	0.004245	0.0043290	0.0039780
5	0.004245	0.0043290	0.0039780
6	0.003962	0.0040404	0.0037128
7	0.003396	0.0034632	0.0031824
8	0.002547	0.0025974	0.0023868
9	0.001415	0.0014430	0.0013260
Sum of weights	0.030800	0.0308000	0.0286000
Adjusted R^2	0.864000	0.8870000	0.8880000
D.W. Statistic	0.870000	1.4800000	1.5600000
Degrees of freedom	15	14	15
Value of marginal product	7.840000	8.0000000	7.3500000
Present value of VMP (@ 10%)	5.240000	5.3500000	4.9200000
Present value of VMP (@ 15%)	4.430000	4.5100000	4.7700000
MIRR (%)	119.700000	123.1000000	109.5000000

Figures in parentheses are the t-statistics. Z1 = the weighted research and extension variable (linear).

TABLE 5

Dependent variable, Log (PI)

Explanatory variables	Equation (1)	Equation (2)	Equation (3)
Constant	4.382000	4.3890000	4.5140000
	(46.57)	(43.04)	(48.90)
HYV	−0.022000	−0.0230000	−0.0250000
	(−1.68)	(−1.57)	(−1.53)
HYVSQ	0.001700	0.0018000	0.0015000
	(2.61)	(2.33)	(1.72)
FERT	0.002100	0.0021000	0.0020000
	(6.26)	(5.20)	(4.34)
FERTSQ	−0.000002	−0.0000020	−0.0000020
	(−3.55)	(−3.25)	(−2.44)
W	0.000220	0.0002200	–
	(2.15)	(2.08)	–
D65	–	0.0093000	−0.0068000
	–	(0.23)	(−0.15)
Z1	−0.000007	−0.0000037	0.0000048
	(−0.29)	(−0.13)	(0.15)
Distributed lag weights			
0	0.000070	0.0000370	−0.0000480
1	0.000126	0.0000666	−0.0000864
2	0.000168	0.0000888	−0.0001152
3	0.000196	0.0001036	−0.0001344
4	0.000210	0.0001110	−0.0001440
5	0.000210	0.0001110	−0.0001440
6	0.000196	0.0001036	−0.0001344
7	0.000168	0.0000888	−0.0001152
8	0.000126	0.0000666	−0.0000864
9	0.000070	0.0000370	−0.0000480
Sum of weights	0.001540	0.0008140	−0.0010600
Adjusted R^2	0.966000	0.9630000	0.9540000
D.W. Statistic	2.060000	1.9900000	2.4600000
Degrees of freedom	13	12	13
Value of marginal product	0.390000	0.2100000	−0.2700000
Present value of VMP (@ 10%)	0.260000	0.1400000	−0.1800000
Present value of VMP (@ 15%)	0.220000	0.1200000	−0.1500000
MIRR (%)	−17.120000	−25.6900000	−22.4000000

Figures in parentheses are the t-statistics. Z 1 = the weighted research and extension variable (linear). HYVSQ = HYV squared. FERTSQ = FERT squared.

APPENDIX

Equation (1), specifying the productivity model, includes the term π, which, as is written, seems meaningless. If it is to denote the product of the lagged values of RS_t and EX_t, then the equation should be as follows:

$$P = A\ \pi\ RS_{t-i}^{\alpha_{1i}}\ EX_{t-i}^{\alpha_{2i}}\ HYV_t^{\alpha_3}\ ED_t^{\alpha_4}\ e^{\alpha_5 W_t}$$

Similarly the subscript for the term RE in equations (2) and (A.7)[4] in Nagy, should be t-i and not t-1 as is printed.

It is claimed that the data for the dependent variable, PI (productivity index) has been obtained from Wizarat (1981). However, a comparison of PI series of the two studies reveals different figures for the year 1969-70, i.e., 133. 6 in this study as opposed to 144.6 in Wizarat's study.[5]

Editor's note:

[4] The original draft also used t-1 in (A.7).

[5] In our exercise, however, we will use 133.6 so as to remain consistent with Nagy's data.