DYNAMIC ANALYSIS OF RETURNS TO RESEARCH II: AN APPLICATION TO KENYAN MAIZE

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INTRODUCTION

This paper applies the dynamic, returns to research methodology developed in Choe and Oehmke to Kenyan maize data. This application has two objectives: First, to provide an empirical test of this methodology, in a developing country, and where the research system has been relatively well-studied so that the reader will be able to develop an intuitive feel for the accuracy of the results from the dynamic analysis. Second, to gain insight about the effect of research on production. Two questions are of particular interest: What is the time lag between research expenditures and the impact on production? What effect does interruption or curtailing of research programs have on their efficiency?

The latter question is of particular importance in Kenya. Real Kenyan research expenditures in maize have declined since the mid-1970's (Karanja). This decline has been absorbed largely through declining operating budgets. Over the same period, the output of the maize research system may have declined, with a decrease in the number of new varieties released, and possibly smaller yield increases associated with those new varieties that are released (Karanja, 1990). The dynamic assessment methodology can be used to determine how the decline in expenditures affected the rate of growth of maize production.

SPECIFYING THE REDUCED FOR MODEL

Identification Tests

The first step in time-series econometric modeling is to determine if each of the series is stationary. The presence of nonstationarity and the algebraic manipulations needed to restore stationarity will influence model specification.

Results of the Dickey-Fuller test shows evidence of nonstationarity (presence of a unit root) of all series. A unit root is not rejected at the 0.05 significance level for any series, with test statistics of -1.85 for research expenditures, -1.75 for yields and -1.70 for area planted (AP) (sample size of 37).[1] Plots of each series (Figure 1) are supportive of these findings when the series are increasing, as indicated by the consistent upward trend in each of the series. However, research expenditures do exhibit a strong decline between 1976 and 1985. The turning from an increasing series to a decreasing series is not indicative of stationarity, and this will be taken into account in the econometric estimation.

None of the series indicate the presence of a second unit root. A second unit root is rejected by Dickey-Fuller test at the .05 significance level for any series with test statistics of -5.34 for research expenditures, -5.4 for yields and -8.06 for area planted (sample size of 31).

The next step is to test for cointegrating relationships among the series. The Johansen-Juselius test finds more than one cointegrating relationship among the variables. A single cointegrating relationship is found when one or two years of lagged variables are included in the estimated relationship. When 3 to 5 lags are included, a second cointegrating relationship is found. The cointegrating relations vary with the choice of lag structure: neither of the two relationships found with 3 to 5 lags is equivalent to the relationship found with 1 to 2 lags. This result is not surprising in light of the small number of observations available (Kunst, 1989).

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[1] The critical value at the 5 percent level is approximately -2.98.

The presence of cointegrating relationships indicates that the error correction model is the preferred reduced form for estimation. However, it is very difficult to choose the appropriate number of cointegrating relationships, particularly since the estimated relationships vary. Alternatively, a vector autoregression in levels of the variables is chosen. Justification for choosing the VAR in levels as the reduced form when cointegration is apparent is found in Robertson and Orden (1989) and Choe (1991). The VAR results will be consistent with the results from the appropriate ECM.

Including Structural Change in the VAR

A plot of real research expenditure by time shows an upward trend from 1955 to 1975, and then a downward movement from 1976 to 1985. The downward movement is the result of stagnant or declining nominal funds granted by donor agencies in the late 1970's and early 1980's, coupled with inflation. It is possible that these changes are part of a structural economic change in the late 1970s that affected the way in which Kenya was able to generate maize research funds.

Two methods are available to indicate whether the shift from increasing to declining research expenditures is the symptom of an underlying structural change. Chow suggests dividing the sample at the time when the structural change is thought to have occurred, and then to estimate the model on each subsample. If the parameter estimates from the subsample regressions are approximately equal to those obtained from the regression on the whole sample, then the model is consistent across the sample and no structural change occurred. Mazon introduces one or more variables which take on the value 0 prior to the time at which the structural change is thought to have occurred, and appropriate values after that time.[2] If one or

[2] For changes in the intercept, in each regression a single dummy variable is used. Including interactions between the dummy variable and the predetermined variables allows the effects of the predetermined variables to change over time.

more of these variables is statistically significant, then a structural change is said to have occurred. Because of the small sample of available data on Kenyan maize research, partitioning into subsamples is not feasible and so Mazon's methods are adopted.

Introducing dummy variables into the structural equation results in

$$By_t = \sum_{i=1}^{p} B_i y_{t-i} + \gamma DV_i + Au_i \tag{1}$$

where $y_t = (RE_t, YD_t, AP_t)'$ and DV_t represents a sequence of dummy variables for $i = 1, \ldots, p$. The reduced form and moving average representations of (1) are

$$\begin{aligned} y_t &= \sum_{i=1}^{p} C_i y_{t-1} + \delta Z_t + v_t \\ y_t &= \sum_{i=0}^{\infty} D_s u_{t-s} + \sum_{s=0}^{\infty} \theta_s Z_{t-s} \end{aligned} \tag{2}$$

where $C_i = B^{-1} B_i$, $\delta = B^{-1}\gamma$, and $v_t = B^{-1} Au_t$. The structural form corresponds to the conceptual representation of interaction among research expenditures, yields and areas planted. It cannot be estimated directly. The reduced form eliminates all but one endogenous variable from each equation, and puts the resulting equations in a form to be estimated. The time paths of the endogenous variables can be determined from these equations. However, they are inappropriate for comparative statics. The moving average representation allows for comparative statics by representing the endogenous variables as the result of the past (infinite)

history of shocks (or of a finite history of shocks and an initial condition).[3] These shocks can then be artificially manipulated to trace out the time paths of the variables under the assumption that a different, counterfactual history occurred. The comparison of these histories and the consequent projections of the time paths of the variables of interest constitutes the equivalent of comparative statics exercises, and allows for policy analysis.

An alternative form of comparative statics exercise is an historical decomposition. The historical decomposition of $y_{t+\tau}$ can be written as

$$y_{t+\tau} = \sum_{s=0}^{t-1} D_s U_{t+\tau-s} + \left[\sum_{s=\tau}^{\infty} D_s U_{t+\tau-s} + \sum_{s=0}^{\infty} \theta_s DV_{t+\tau-s} \right] \tag{3}$$

The first right-hand-side term of (3) represents the part of $y_{t+\tau}$ due to innovations in periods $t + 1$ through $t + \tau$. The second term (in braces) represents the forecast of y_t based on information available at time t, including knowledge of the structural change, and is called the base projection. If the dummy variable is set equal to zero, so that there is no structural change, the base projection will be changed. The difference between the alternative base projections is the part of y_t attributed to the dummy variable, and is the measured effect of the structural change. Since there is no asymptotic distribution theory available when dummy variables are

[3] To obtain the moving average representation, lag equation (1) one period, so that y_{t-1} is represented as a function of variables at time t-2 and earlier. Use this equation to eliminate y_{t-1} from equation (1). Repeating this procedure ad infinitum removes all y variables from the right-hand-side of (1), resulting in (2). In practice, induction is used to reduce the number of steps.

used, Monte Carlo methods are used to find the significance of these variables.[4] The dummy variable technique will provide measures of the impact of declining external funding after 1978 on Kenyan maize sector.

RESULTS

Estimation

The reduced form equation (2) was fitted to natural logarithms of data to stabilize their variances (Kunst). The lag lengths were chosen on the basis of final prediction error (FPE) and information criteria (Judge et al. pp. 686-687). The FPE and Akaike's Information Criterion didn't reach optima within the seven lags tried. The Schwartz criterion was minimized at a lag length of zero. The zero lag model is overfitted, so Sim's likelihood ratio test statistic is used to test the significance of the extra parameters. At the 5 percent level, the zero lag model is rejected in factor of the one lag model (test statistic of 112, prob(112) < 0.0001). The one lag model is not rejected when compared to the two lag model (test statistic of 12.2, prob(12.2) = 0.20). However, Nicklesburg found that the lag selection criteria tends to underfit models, particularly in small sample exercises. Considering this argument, a lag length of two is chosen for the analysis.

The hypothesis that the error terms from the different equations are mutually orthogonal is not rejected, based on a likelihood ratio test (test statistic 2.14, prob(2.14) = 0.54) and a lag range multiplies test (test statistic 1.98, prob(1.98) - 0.58) (p. 476-477, Judge et al.). These results indicate that the error terms from the estimation of equation (2) are uncorrelated across

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[4] Kloek and Kijk provide grounds for the use of Monte Carlo methods to estimate posterior moments of both structural and reduce form parameters. One hundred random samples are drawn from the posterior distribution of the VAR coefficients (assumed to be Normal-Inverse Wishart (see Zellner)). Then the historical decompositions are generated in each draw and the first moment and the standard errors are computed with the 100 different historical decompositions.

equations. This situation occurs when the matrix $B^{-1}A$ is diagonal, under the assumption that the u_t are uncorrelated. Hence the structural form, equation (1), is also a reduced form consistent with equation (2).

Regression Results

The estimated VAR model and summary statistics are shown in table 2. The statistics indicate that the model does a good job of representing the autocorrelation structure of the variables although most of the individual coefficients are not significant. The R^2 values are high and the Q test shows no autocorrelation of residuals. The Q test on squared residuals indicates no ARCH (Autoregressive Conditional Heteroscadasticity) effect in variances. The dummy variable was significant with a negative coefficient in research expenditure equation, implying that the decreased external funding may have reduced the research activity.

The F values for each variable set (yield, area and research expenditures) with corresponding significance levels are given in table 3. The F values indicate that the current value of each variable is explained mostly by its own past values. The table does not show feedback among the variables except, that past values of area are important in explaining research expenditures. Significance of the coefficients individually or as sets provides little evidence on the dynamic interactions among the variables. The F values imply only a Granger-type causality within sample periods (Bessler, 1984). The statistics (F and t values) implies only the ability of the autoregressive parameters in explaining the ways in which each variable evolves through time given past values. The autoregressive parameter itself can't be used to trace the impact of a variable on others because specific shocks have both direct and indirect effects on the evolution (Orden, 1986).

Impulse Response Weights

The impulse response weights are given by the elements of the matrices D_s appearing in equation (2). These weights show the response of each of the three variables to unexpected shocks in one of the variables. All shocks are normalized to one standard deviation of the sample for the variable in question.

Response of Research Expenditures

The responses of current and future research expenditures to unexpected, 1% increases in research expenditures, yields and area planted are depicted in Figure 2. The immediate effect of an unexpected increase in research expenditures on these same expenditures is, tautologically, an increase equal to the size of the shock. Hence the height at time $t = 0$ of the graph in Figure 2 (upper), 1%, equals the size of the unexpected increase in research expenditures. The consistently positive values indicated by the graph show that increases in research outlays are persistent over time. After one year, expenditures increase an additional 0.4 % over what they would have been in the absence of the shock, and such increases persist for at least nine years. After 10 years no more increases occur. However, the earlier increases are permanent and research expenditures remain at a permanently higher level. The permanent response to an unexpected increase in research expenditures is the sum of the responses in each year. Consequently, an unexpected increase in research funding has positive and permanent effects on future research funds.

Research shows no immediate response and a slight negative response after one year to an unexpected increase in yields (Figure 2 middle). In the second year the response becomes positive, continues to rise until the sixth year, and remains positive after 11 years. Although the first, negative response is unexpected, the persistent positive response afterward indicates that increasing yields generate additional funds for the research program.

The response of research to an unexpected increase in the area planted is to increase in the first year after the shock, and to continue to increase every year for at least 11 years (Figure 2 bottom). The magnitude of these increases peaks in year five, and tapers off gradually after that, but remains strong in year 11.

Response of Yields

The responses of yields to an unexpected increase in research expenditures is depicted in Figure 3 (upper). At time $t = 0$, there is no effect on yield. This is consistent with the idea that research is an intertemporal activity, and some lag occurs before impacts occur. The magnitudes of the impacts increase until a peak is reached three years after the initial expenditures, and then impacts decline to a zero level after seven years. These lag lengths are somewhat shorter than the usual literature on research, which finds lags of 7 to 30 years before research has substantial impacts. However, it is important to note that the lag lengths presented here are interpreted to be the time it takes for an unexpected increase in funding in a currently productive research program to have an impact, <u>not</u> the length of time it takes for a new program to generate useful results (which is expected to be longer).

An unexpected increase in yields causes additional positive increases in yields for at least another 11 years (Figure 3 middle). This response is consistent with persistent technical shocks (but also perhaps with other types of shocks). For example, the unexpected discovery of a new, yield-increasing management technique may cause a current increase in yields, and future increases in yields as farmers become more proficient at the technique.

Yields show no immediate response to an increase in area planted, but show positive responses of increasing magnitude from one to three years after the shock (Figure 3 bottom). Additional increases of a smaller magnitude continue at least until 11 years after the shock. The positive response to an increase in area planted is intuitively plausible in light of the land

constraint and land subdivision faced by Kenya. Increases in area planted come not from use of previously idle, marginal land, but largely from replacement of other crops by maize. In high-potential areas, this occurs primarily as populations increase from generation to generation. As the patriarch passes the land down to his children, the land is subdivided and each new household has a smaller holding than did the patriarch's household. Each new household tries to provide for their own consumption of maize on a smaller land area, thus shifting land from the production of other crops into maize. Because this is high-potential land, increasing the area planted to maize would not decrease average yields. Because each household derives its income from a smaller land holding, the land is farmed more intensively, increasing yields of all crops. Consequently it is plausible that maize yields are positively related to area planted.

Response of Area Planted

The area planted to maize does not respond immediately to an unexpected increase in research expenditure, but does show a positive response after one year (Figure 4 upper). It is possible that this response reflects the perception that the increased expenditures will increase the profitability of growing maize, although the magnitude of this response is small. Responses in the third year and beyond are negligible.

Area planted increases in response to an unexpected increase in yields, starting in the second year and after the shock, and continues to increase for at least 11 years (Figure 4 middle). As with the yield response, the area is consistent with an interpretation of the yield shock as representing a permanent technical improvement. A permanent improvement can cause continuing area expansion as farmers recognize the potential for profitable cultivation of land that was not previously planted to maize, but take time in switching over to the more efficient technique.

The responses over time of area planted to an unexpected increase in area planted are positive and persistent (Figure 3 bottom). The strong positive response at time 0 by definition reflects the exogenous shock. The persistent positive response from time 1 through time 11 shows that the initial, unexpected increase generates additional increases in area planted over the next 11 years.

THE RATE OF RETURN TO INVESTMENTS ON KENYAN MAIZE RESEARCH

The benefits of research are the (annual) increases in social surplus due to the improved technology. Useful formulae for approximating these increases are provided by Akino and Hayami, based on observations of supply and demand elasticities and equilibrium prices and quantitatives, and calculation of the shift in the supply curve. In the Akino and Hayami framework this shift is the percentage increase in yield times the percentage of area planted using the new technique.[5] When the innovation is easily distinguished, such as the introduction of a single hybrid variety, it is often possible to obtain reasonable estimates of yield increases and area planted. However, evaluation of research programs which produce a sequence of innovations is much harder, particularly when it is difficult to tell if or to what degree farmers are implementing the innovations (as might be the case with improved management practices or agronomic recommendations).

The econometric methodology developed in the precursor to the current paper allows for statistical measurement of yield and area responses to research expenditures.

Moreover, it allows for more accurate measurement of research costs, by accounting for any increases in future research expenditures that would result from the current increases. In other words, this procedure models the idea that the intertemporal nature of research and

[5] Yield percentage uses post-innovation yields at the base.

development means that starting a new project or expanding existing projects in one year will result in further commitments in future years in order to bring these new or augmented efforts to fruition. The responses of yield, area planted, and future research expenditures to a hypothetical increase in current research expenditures are all captured by the impulse response weights, the set of D_s.

Impact of Increase Research Expenditure

The projected, 1991-2000 values for variables under the scenario of a hypothetical 10 percent increase in annual expected research expenditure in 1991-1995 appear in Figure 6. The increase in research expenditure brings increases in both yield and area. The impact on area is immediate, but disappears as the research expenditure goes back to expected level. Yield increases slowly from the beginning of the research increase and reaches peak level in the 1994-1997 period, then slowly moves back towards the expected level.

The annual average increase in yield for 1991-2000 was about 14 kg per hectare and was 24 kg per hectare for peak years of 1994-1997.

Impacts on Maize Sector of Alternative Research Funding Scenarios

Historical decompositions of variables from 1979 to 1987 appear in Table 2. The DV79 reflecting the hypothesized structural change in 1979 is found to be significant for the research expenditure projection. The dummy variable representing the structural change has a negative impact on yield and a positive impact on area, but the impacts are statistically insignificant. Statistical insignificance with respect to area and yield is expected, as the dummy variable represents a structural change in the research system, not in the area or yield patterns.

Figure 5 shows actual values and projected values of variables if the structural change didn't occur. The research expenditure would have remained quite stable around 400,000 Kenyan £ and the maize yield would have been increasing steadily. Instead, actual yields have

fluctuated through the period and remained substantially below projected yields except in 1982 and 1986. The reason for the sharp increase in yields for those years are not explainable within the data. 3 year moving averages of actual yields stayed below the project yields for the entire period. Annual average decreases in yield for 1979-86 period caused by the decreased funding were about 181 kg per hectare. Actual maize area also fluctuated and stayed mostly above the projected level. The 3 year moving average of actual area stayed above the projected level for the entire period. The projected maize area remained quite stable around 1.15 million hectares as expected from the stable research expenditure projected. However, it is surprising that the actual maize area stayed above the projected level when the actual research expenditure had fallen. The structural change had positive impacts on maize area which are more prevalant than the negative impact of reduced research expenditure.

YEAR	ACREAGE PLANTED (HA)	YIELD (Kg/HA)	RESEARCH EXPENSE (Kenyan Pound)
55	508600	860	79560
56	549300	880	86301
57	640900	890	88832
58	730000	840	99100
59	697400	870	89402
60	702900	1030	91067
61	654800	1090	95050
62	749200	1000	98605
63	777400	1070	94105
64	830182	1100	119316
65	776562	1050	123739
66	900000	1000	136834
67	863309	1390	143253
68	820690	1450	168446

69	855414	1570	194579
70	787333	1500	260816
71	1002029	1470	203815
72	904575	1530	213886
73	836774	1550	204195
74	924667	1500	185368
75	970115	1740	216464
76	1040476	1680	234524
77	1245508	1670	239197
78	1200586	1450	298090
79	1262992	1270	256437
80	1414400	1250	216448
81	1253121	1570	186670
82	1102816	2130	143067
83	1266279	1720	106660
84	987500	1440	92293
85	1388571	1750	108772
86	1486153	1950	74087
87	1437857	1680	172045
88	1469000	2000	

Table 2a. Historical Decomposition of RE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
				Forecast Error Due to					
Time	Actual	Project w/DV79	Project w/o DV79	RE	YD	AP	DV79	S.E. for DV79	
1979	12.45464	12.22120	12.80798	0.23344	0.00000	0.00000	-0.58678	0.15624	*
1980	12.28511	12.07403	12.83726	0.19642	0.03691	0.02225	-0.76323	0.21233	*
1981	12.13710	11.99410	12.87855	0.15316	0.01420	0.02436	-0.88445	0.25077	*
1982	11.87107	11.88789	12.88184	-0.01361	-0.05406	-0.05086	-0.99395	0.30825	*
1983	11.57740	11.87664	12.88896	-0.15799	-0.12464	-0.01661	-1.01232	0.35828	*
1984	11.43272	11.87596	12.90008	-0.32792	-0.07261	-0.04272	-1.02411	0.43024	*
1985	11.59701	11.89743	12.90369	-0.15129	-0.06985	-0.07928	-1.00626	0.48564	*
1986	11.21300	11.93259	12.90434	-0.38883	-0.11180	-0.21896	-0.97175	0.54610	
1987	12.05551	11.97057	12.90045	0.23819	-0.09519	-0.05806	-0.92988	0.60123	

*: Significant at .05 level.

(1) is for actual values for RE. (2) is for base projections and (3) for projections set with DV79=0. Thus, the difference, (2)-(3), produces (7), forecast errors of RE due to DV79. (4), (5), and (6) are forecast errors of Ap due to RE, YD, and AP, respectively. The actual value (1) can be recovered by the sum of projected value and forecast errors, that is (3)+(4)+(5)+(6)+(7). (8) is for the standard errors of forecast error due to DV79.

Table 2b. Historical Decomposition of YD

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
				Forecast Error Due to					
Time	Actual	Project w/DV79	Project w/o DV79	RE	YD	AP	DV79	S.E. for DV79	
1979	7.14677	7.32191	7.39133	0.00000	-0.175414	0.00000	-0.06942	0.09182	
1980	7.13090	7.38128	7.50079	0.00790	-0.24607	-0.01221	-0.11951	0.15685	
1981	7.35883	7.42890	7.54804	0.01798	-0.07564	-0.01241	-0.11914	0.15594	
1982	7.66388	7.43013	7.54310	0.02768	0.18723	0.01883	-0.11297	0.16496	
1983	7.45008	7.43119	7.52251	0.01772	-0.00342	0.00459	-0.09133	0.18243	
1984	7.27240	7.44248	7.51038	-0.00166	-0.14893	-0.01950	-0.06790	0.21021	*
1985	7.46737	7.46250	7.50679	-0.02655	-0.08796	-0.05654	-1.04429	0.23617	*
1986	7.57558	7.48756	7.50665	-0.03682	-0.23680	-0.11196	-0.01908	0.27287	
1987	7.42655	7.51158	7.50558	0.04223	-0.01856	-0.06136	-0.00600	0.30972	

*: Significant at .05 level.

(1) is for actual values for RE. (2) is for base projections and (3) for projections set with DV79=0. Thus, the difference, (2)-(3), produces (7), forecast errors of RE due to DV79. (4), (5), and (6) are forecast errors of Ap due to RE, YD, and AP, respectively. The actual value (1) can be recovered by the sum of projected value and forecast errors, that is (3)+(4)+(5)+(6)+(7). (8) is for the standard errors of forecast error due to DV79.

Table 2c. Historical Decomposition of AP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Forecast Error Due to				
Time	Actual	Project w/DV79	Project w/o DV79	RE	YD	AP	DV79	S.E. for DV79
1979	14.04899	14.12217	13.99218	0.00000	0.00000	-0.07317	0.12999	0.08835
1980	14.16222	14.02101	13.94239	0.04209	0.00192	0.09719	0.07862	0.12670
1981	14.04115	14.05767	13.91286	0.00796	-0.03193	0.00746	0.14481	0.12861
1982	13.91338	14.08257	13.91953	0.00234	-0.07565	-0.09588	0.16303	0.16032
1983	14.05159	14.10689	13.92118	-0.02544	-0.06955	0.03969	0.18571	0.17464
1984	13.80293	14.13993	13.92272	-0.02951	-0.00910	-0.29839	0.21720	0.19499
1985	14.14379	14.16001	13.91948	0.04122	-0.00436	-0.02936	0.24053	0.21520
1986	14.21170	14.18060	13.91405	0.01328	-0.03882	0.05665	0.26655	0.23357
1987	14.17866	14.19939	13.90980	-0.04884	-0.00503	0.03314	0.28958	0.25730

*: Significant at .05 level.

(1) is for actual values for RE. (2) is for base projections and (3) for projections set with DV79=0. Thus, the difference, (2)-(3), produces (7), forecast errors of RE due to DV79. (4), (5), and (6) are forecast errors of Ap due to RE, YD, and AP, respectively. The actual value (1) can be recovered by the sum of projected value and forecast errors, that is (3)+(4)+(5)+(6)+(7). (8) is for the standard errors of forecast error due to DV79.

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Table 2. Estimates and Evaluation Statistics for the Reduced Form Model

Dep. Var.	Const.	DV	RE_{t-1}	RE_{t-2}	YD_{t-1}	YD_{t-2}	AP_{t-1}	AP_{t-2}	Statistics		
									R^2	Q_{20}	ARCH
RE_t	-8.599	-.587	.393	.189	-.211	.301	.304	.653	.841	22.813	13.996
	(-2.26)	(-3.80)	(1.67)	(.71)	(-.69)	(1.03)	(.96)	(1.80)		{.29}	{.83}
YD_t	-2.712	-.069	.034	-.682	.748	-.218	.167	.256	.795	15.188	9.168
	(-1.02)	(-.64)	(.20)	(-.04)	(3.50)	(-1.05)	(.75)	(1.01)		{.77}	{.98}
AP_t	4.144	.130	.180	-.192	-.011	.240	.413	.176	.846	25.265	8.771
	(1.78)	(1.37)	(1.25)	(-1.18)	(-.06)	(1.33)	(2.13)	(.79)		{.19}	{.99}

( ) indicates t values.
{ } indicates significance level.

Table 3. Results of F-tests on Set of Lagged Variables

Dependent Variables	Lagged Variables		
	RE	YD	AP
RE	11.860	.526	3.027
	(.003)	(.598)	(.068)
YD	.066	7.918	1.185
	(.936)	(.002)	(.324)
AP	.795	1.614	3.574
	(.464)	(.221)	(.044)

( ) indicates significance level.

Table z. Estimates of the Shift in Supply Curve

Year After	Additional Research Fund	Changes in Yield	Changes in Area	Supply Shift
		----------(%)----------		
0	100.00	0.00	0.00	0.00
1	39.30	3.38	18.03	3.99
2	39.09	6.19	-4.68	5.90
3	32.84	8.78	1.50	8.91
4	17.70	5.12	-.39	5.10
5	15.58	2.61	-.95	2.59
6	9.91	.99	0.16	.99
Total	254.42			27.48

Supply shift = (the percentage increase in yield) x (1 + percentage increase in area planted).

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