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PRODUCTION INSTABILITY AND MODERN RICE TECHNOLOGY: A PHILIPPINE CASE STUDY

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A. *Introduction*

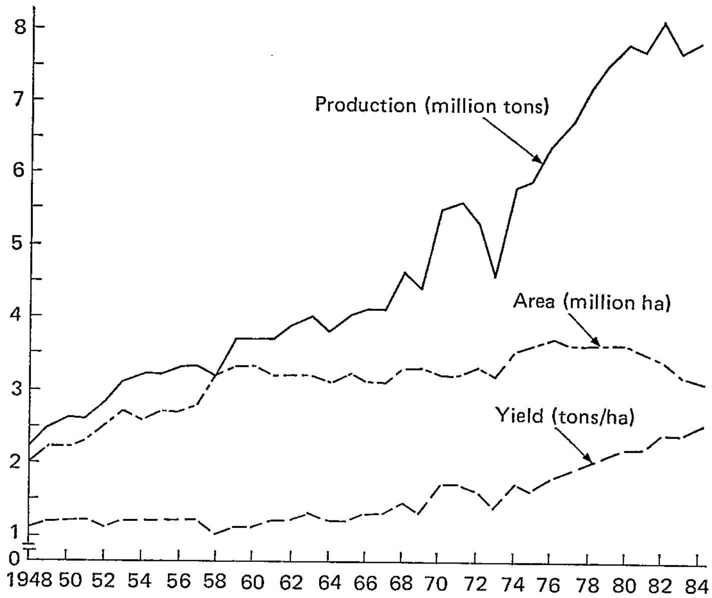
MODERN technology—a combination of modern varieties (MV) increased use of fertilizer, and irrigation development—has contributed substantially to increased rice productivity in South and Southeast Asia. However, there has been less consensus whether this technology has increased or decreased production variability, an issue of central concern to food policy analysts. This debate was rekindled by Barker et al. [1] and by Hazell [10] [11] who observed that production variability in cereals had increased in India and the United States since the mid-1960s, a period corresponding to a rapid expansion in modern agricultural technology.

This paper reports a macro-analysis of changes in rice production stability between the period preceding the advent of modern varieties and the period following their release in the Philippines, and contrasts these results with a comparable analysis of rice production in India [10]. Factors which may contribute to increases or reductions in production stability after the adoption of modern rice technology, are also briefly reviewed. The Philippines was chosen as the case study because: (a) the rate of adoption of MV has been more rapid than in other developing countries [4]; and (b) the existence of regional data allows an examination of changes in production stability, and its sources both nationally and regionally.

B. *Growth in Philippine Rice Production*

Three distinct phases characterize trends in Philippine rice production over the postwar period (Figure 1). Prior to 1965, rice production increased annually at 2.2 per cent, a rate below population growth. Between 1965 and 1984, after the introduction of MV, annual growth rates doubled to 4.5 per cent. Rice production did not increase in 1983 or 1984, leading, inter alia, to rice imports in 1984 and 1985. However, the upward trend in rice production seems to have resumed in 1985–86. David [5] has discussed the price, policy, and weather effects which contributed to reduced production growth rates in rice in the Philippines in this period. However, this "third" phase in Philippine rice production is not included in this analysis because: (a) it is too short to permit realistic time-series analysis, and (b) regional data is not yet available beyond crop year 1983. The acceleration of growth in rice production since 1965 was primarily

Fig. 1. Trends in Production, Area, and Yield for All Types of Rice in the Philippines, 1948–84



Source: [15].

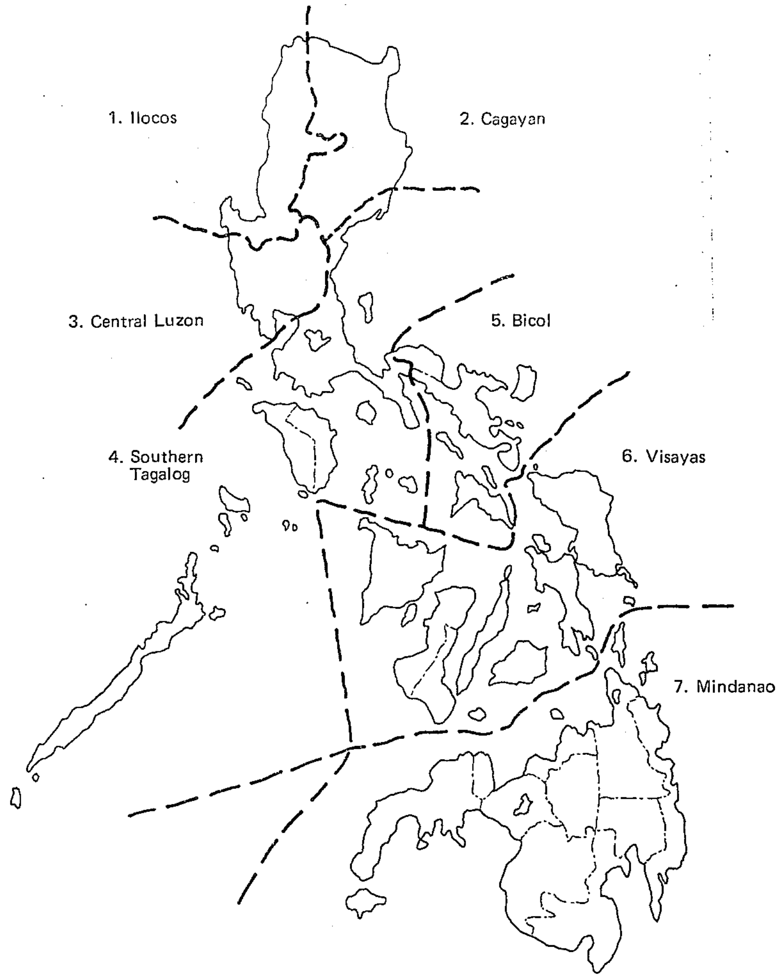
achieved through higher yields rather than through area expansion. Indeed, the area planted to rice has declined in the Philippines since 1977 and is now equal to the rice crop area in the early 1970s when population was only 60 per cent of current levels.

C. *Data Sources and Analysis*

Ideally, tests of the risk-increasing characteristics of new rice technology should be based on individual farm data. However, suitable farm-level time-series data do not exist to permit such an analysis. For this reason, time-series data published by the Philippine Bureau of Agricultural Economics [15] serves as the data base for the analysis which follows.

Hazell's [10] decomposition methodology was employed to identify components and sources of changes in production instability for the Philippines in aggregate, and by seven regions (Figure 2). The regional definitions correspond to broad geographic boundaries and are aggregates of the twelve development regions of the Philippine National Economic Development Authority. Changes in regional definitions prevented analysis by the present twelve development regions. Two intervals, 1948–68 and 1969–83, which roughly corresponds to the periods before

Fig. 2. Development of Regions for Decomposition Analysis of Rice Production Stability in the Philippines



and after the introduction of modern rices, were selected as the time-frames for analysis.

Regional area and yield data published by the Philippine Bureau of Agricultural Economics were detrended for both periods using a quadratic time trend. For more reliable estimates of long-term trends, the regressions were fitted to the full time series in each region. The assumption of a homoscedastic error term is not appropriate when both periods are combined in this way, so a generalized least squares estimation procedure was used. The residuals, centered on the mean area or yield figures became the primary data for analysis. Detrended (total) rice production for each year within each period was estimated as the product of detrended area and detrended yield.

TABLE I

MEAN VALUES AND VARIABILITY IN RICE PRODUCTION, AREA, AND YIELD IN THE PRE–MV (1948–68) AND POST–MV (1969–83) ADOPTION PERIODS

	Mean Values			Coefficient of Variation			F-ratio
	Pre-MV	Post-MV	% Change	Pre-MV	Post-MV	% Change	
Average production (1,000 tons)	3,410	6,566	93	6.7	6.4	−5ns	3.39**
Average area harvested (1,000 tons)	2,826	3,482	23	5.4	4.0	−26ns	0.84ns
Average yield (kg/ha)	1,207	1,885	56	4.4	4.0	−9ns	2.08*

Source: [15].

Notes: 1. F-ratio calculated as the ratio of the variances of the detrended data between the two periods.

2. **, *, and ns imply significance at 5 per cent, 10 per cent, and not significant levels, based on one-tail tests for the F-ratios and two-tail tests for the change in CV.

D. *Changes in Rice Production*

Philippine rice production increased by 3.2 million tons, or by 93 per cent from the first to the second period (Table I). Most of this increase was due to a 56 per cent increase in mean yields (which increased from 1.2 to 1.9 tons/ha) as opposed to an area effect. The coefficients of variation (CV) of national production, area, and yield were less in the second than the first period (CV fell by 5 per cent, 26 per cent, and 9 per cent respectively) although these changes were not significant at the 10 per cent level. While relative variability (i.e., CV) decreased, absolute variability (variances) of average total production and average yields increased, at least at the 10 per cent significance level or better, from the first to the second period. Therefore, while production and yield increased, so did the absolute variability of these parameters, post-MV rices compared to pre-MV rices.

Yields. Changes in mean yields, by region, are listed in Table II. In absolute terms, the greatest increase in yields between periods was in Bicol and Central Luzon where mean yields increased by about 0.8 tons/ha, the remaining regions registered yield gains of about 0.6 tons/ha. The largest increase in mean yield occurred in Bicol (76 per cent), while the smallest was in Cagayan Valley (48 per cent). There were significant increases in yield variances in three regions—in Bicol, Central Luzon, and the Visayas—the former two regions also recorded the greatest absolute yield gains. However, CV decreased in each region from the first to the second period, other than in Central Luzon where it increased by nearly 49 per cent.

Area harvested. The largest increase in average rice area between periods occurred in Mindanao where the mean rice area increased by nearly 296,000 ha (Table III). The smallest increases were recorded in the Visayas (32,000 ha), Ilocos (34,000 ha), and Central Luzon (38,000 ha). Area variances did not

TABLE II

MEAN AN VARIABILITY OF RICE YIELD BY REGION
(PERIOD I: 1948–68, PERIOD II: 1969–83)

Region	Average Yield				Coefficient of Variation (%)			*F*-ratio
	Period I (Kg/Ha)	Period II (Kg/Ha)	Change		Period I	Period II	Change	
			Kg/Ha	%				
1. Ilocos	1,218	1,837	619	50.8	12.5	11.1	-11.2^{ns}	1.81^{ns}
2. Cagayan	1,301	1,921	620	47.6	10.5	4.8	-54.3^{**}	0.46^{ns}
3. Central Luzon	1,550	2,304	754	48.6	8.0	11.9	48.8^{**}	4.83^{**}
4. Southern Tagalog	1,104	1,732	628	56.9	8.3	6.4	-22.9^{ns}	1.48^{ns}
5. Bicol	1,072	1,890	818	76.3	9.0	11.6	-28.9^{ns}	5.12^{**}
6. Visayas	1,039	1,656	617	59.4	7.3	7.1	-2.7^{ns}	2.41^{**}
7. Mindanao	1,200	1,837	637	53.1	18.2	8.7	-52.2^{**}	0.53^{ns}
Philippines total	1,207	1,885	678	56.2	4.4	4.0	-9.1^{ns}	2.08^{ns}

Source: [15].
Note: ** and ns imply significance at 5 per cent and not significant levels, based on one-tail tests for the *F*-ratios and two-tail tests for the change in CV.

TABLE III

MEAN AND VARIABILITY OF RICE AREA HARVESTED BY REGION
(PERIOD I: 1948–68, PERIOD II: 1969–83)

Region	Average Area				Coefficient of Variation (%)			*F*-ratio
	Period I (Ha)	Period II (Ha)	Change		Period I	Period II	Change	
			Ha	%				
1. Ilocos	119,000	153,110	34,110	28.6	10.3	10.9	5.8	1.86
2. Cagayan	262,749	389,550	126,801	48.3	18.6	10.9	−41.4*	0.75
3. Central Luzon	610,812	648,665	37,853	6.2	11.4	8.9	−21.9	0.68
4. Southern Tagalog	365,379	443,593	78,214	21.4	10.1	6.2	−38.6	0.55
5. Bicol	263,803	316,118	52,315	19.8	8.2	7.4	−9.8	1.18
6. Visayas	714,731	746,270	31,539	4.4	15.1	8.2	−45.7*	0.32
7. Mindanao	489,871	785,387	295,516	60.3	17.9	12.4	−30.7	1.23
Philippines total	2,826,339	3,482,681	656,342	23.2	5.4	4.0	−25.9	0.84

Source: [15].
Note: None of the F-ratios implies significance at 10 per cent level, based on one-tail tests and * CV change significance at 10 per cent level.

TABLE IV

MEAN AND VARIABILITY OF RICE PRODUCTION BY REGION
(PERIOD I: 1948–68, PERIOD II: 1969–83)

Region	Average Production				Coefficient of Variation (%)			F-ratio
	Period I (Tons)	Period II (Tons)	Change		Period I	Period II	Change	
			Tons	%				
1. Ilocos	145,501	281,165	135,664	93.2	18.7	14.7	−21.4	2.32**
2. Cagayan	340,814	750,583	309,769	120.2	18.7	13.8	−26.2	2.63**
3. Central Luzon	941,333	1,486,168	554,835	57.9	8.9	10.3	15.7	3.34**
4. Southern Tagalog	402,270	767,347	365,077	90.7	10.1	7.5	−25.7	2.00*
5. Bicol	283,202	596,254	313,052	110.5	13.9	11.6	−16.5	3.04**
6. Visayas	741,804	1,236,945	495,141	66.7	16.1	11.8	−26.7	1.48ns
7. Mindanao	584,195	1,441,389	857,194	46.7	22.2	14.0	−36.9	2.41**
Philippines total	3,410,260	6,566,717	3,156,457	92.5	6.7	6.4	−4.5	3.39**

Source: [15].
Note: None of the CV changes are significant at 10 per cent level. **, *, and ns imply significance at 5 per cent, 10 per cent, and not significant levels, based on one-tail test for the F-ratios.

increase significantly within regions between periods, and other than for Ilocos, there were substantial declines in the CV of rice area harvested.

Production. Mindanao (857,000 tons) recorded the greatest increase in total rice production (Table IV), where area increased by over 60 per cent and yields by over 50 per cent. The second largest increase in regional production was in Central Luzon (555,000 tons), the "rice bowl" of the Philippines, where there was a substantial increase in mean yields associated with a small increase in mean area. The smallest absolute gain in total rice production (136,000 tons) occurred in the Ilocos region.

An interesting result of the region-wise analysis of increases in rice production are for Central Luzon and for Bicol where yield and production variances increased significantly from the first to the second period. Disease monitoring records of IRRI's Pathology Department show that these two regions are "hot spots" for rice diseases as rice *tungro* virus and bacterial leaf blight. Therefore, they may represent higher stress rice environment than is generally the case in the Philippines.

Central Luzon has the highest rate of MV adoption and irrigated area (both in absolute and relative terms) in the Philippines. It is also one of the most typhoon-prone regions of the country, and dry season irrigation in recent years (e.g., in 1982 and 1983) was substantially reduced due to inadequate water supplies. Thus, while MV yields increased with improved agronomic practices (e.g., with irrigation and increased fertilizer use), losses are larger, in comparison to local varieties

TABLE V

COMPONENTS OF CHANGE IN AVERAGE PHILIPPINE RICE PRODUCTION
(PERIOD I: 1948–68, PERIOD II: 1969–83)

(%)

Region	Change in Mean Yield	Change in Mean area	Change in Area-Yield Covariances	Change in Interaction Term	Contribution to Change in Average Production of Total Rice
Ilocos	54.4	30.6	−0.6	15.6	4.35
Cagayan	37.0	40.2	0.9	19.2	13.14
Central Luzon	84.6	10.8	−0.6	5.2	17.45
Southern Tagalog	62.8	23.6	0.1	13.4	11.70
Bicol	69.0	17.9	−0.6	13.7	10.03
Visayas	89.1	6.6	0.3	3.9	15.87
Mindanao	36.4	41.4	0.3	22.0	27.47
Philippine total	60.7	25.5	0.1	13.7	100.0

(LV), if typhoons occur or if there is a failure in the input delivery system (e.g., in irrigation water or fertilizer supplies).

E. *Sources of Production Changes*

The changes in average production $E(Q)$ between periods reported in Table IV, may be decomposed into four sources [10, p. 181].

$$E(Q)=\bar{A}_1\Delta\bar{Y}+\bar{Y}_1\Delta\bar{A}+\Delta\bar{A}\Delta\bar{Y}+\Delta\text{Cov}(A, Y), \quad (1)$$

where $\bar{A}_1$ is the mean area in the first period, and $\Delta\bar{A}$ is the change in mean area from the first to the second period; $\bar{Y}_1$ is the mean yield in the first period, and $\Delta\bar{Y}_1$ is the change in mean yield from the first to the second period; and $\Delta\text{Cov}(A, Y)$ is the change in area-yield covariances between periods. The first two sources of change in average production identified in equation (1) arise from changes in mean yield and mean area. The third, $\Delta\bar{A}\Delta\bar{Y}$, is an interaction effect, while the last term results from changes in the variances of areas and yields and from changes in the correlation between areas and yields.

These components of change in average Philippine rice production are listed in Table V. Nationally, production changes were dominated by changes in mean yield which accounted for 61 per cent of total change. The impact of the area effect, 26 per cent, was the second most important cause of change. This contrasts with the Indian experience over a comparable period, where increases in area (48 per cent) were as important as increases in mean yields (47 per cent) as the major components of increased rice production in India [11]. That is, expanded irrigation coverage and resultant increases in multiple cropping of rice contributed more importantly to growth in Indian rice production than has been the case in the Philippines.

Changes in the interaction effect in the Philippines—which occurred because of simultaneous changes in mean yield and mean area—accounted for about 14 per cent of total change in rice production between periods. Changes in area-yield covariances between periods in the Philippines, as in India, were small and accounted for less than 1 per cent of the total change in average rice production between the two periods.

As previously discussed, the area effect identified in Table V was mainly due to intensification as opposed to area expansion. Changes in harvested areas varied considerably between regions, from a high of about 40 per cent in Cagayan Valley and Mindanao, to a low of about 10 per cent or less in Central Luzon and in the Visayas. The increase in cropping intensity was facilitated through irrigation expansion (allowing increased dry-season rice production), and through shorter duration MV, coupled with techniques of early crop establishment, which allowed two rice crops to be grown in rainfed areas in the one wet season where previously only one was possible.

The region which contributed most to the national increase in rice production from the first to the second period was Mindanao (27 per cent), followed by Central Luzon (17 per cent) and the Visayas (16 per cent).

F. *Sources of Changes in Production Variability*

The variance of national rice production may be partitioned into two broad components: (a) the sum of production variances within regions, and (b) the sum of interregional production covariances. Notationally, following Hazell [10, p. 21],

$$V(Q)=\sum_{i} V(A_i Y_i)+\sum_{i\neq j}\sum \mathrm{Cov}(A_i Y_i,\ A_j V_j), \tag{2}$$

where $V(Q)$ is total production variance; A_i, A_j denote area harvested in region i and region j; and Y_i, Y_j denote yield in region i and region j, respectively.

Hazell [11] further shows that changes in each of the two terms in equation (2) can be attributed to eleven sources. In the case of changes in production variance there are changes in mean yield, mean area, yield variance, area variance, and area yield covariances; interactions between changes in mean yield and mean area, in mean area and yield variances, in mean yield and area variances, and mean area and yield and changes in area yield covariances; and a residual component. Analogous components are statistically defined for changes in the production covariances [10, p. 47].

The decomposition of changes in the variance of Philippine rice production between 1948–68 and 1969–83 are listed in Table VI. All entries in the table are expressed as a per cent of the change in the variance of total rice production, hence the rows and columns both sum to 100 per cent. Nationally, the increase in production variance was equally attributed to increases in production variances within regions, and to increased production covariances between regions. Two regions, Mindanao (20 per cent) and Central Luzon (14 per cent) accounted for two-thirds of the within-region increases in variance.

Increases in production covariances account for 50.3 per cent of the increase in the variance of Philippine rice production. This contrasts sharply with Hazell's

TABLE VI

DISAGGREGATION OF THE COMPONENTS OF CHANGE IN THE VARIANCE OF RICE PRODUCTION (PERIOD I: 1948–68, PERIOD II: 1969–83)

	Change in Mean Yields	Change in Mean Areas	Change in Yield Variances & Covariances	Change in Area Variances & Covariances	Change in Area-Yield Covariances	Change in Interaction Terms	Change in Residual	Row Sums
Regional variances								
Ilocos	0.31	0.22	0.22	0.16	−0.20	0.19	−0.09	0.81
Cagayan	3.68	0.95	−0.58	−0.83	2.10	0.68	−0.45	5.55
Central Luzon	7.44	0.07	18.59	−3.05	−5.33	−4.63	0.59	13.68
Southern Tagalog	1.54	0.26	0.45	−0.62	0.27	−0.54	0.03	1.39
Bicol	1.12	0.28	2.26	0.08	−0.88	0.23	−0.42	2.67
Visayas	15.83	0.19	3.47	−7.14	2.09	−9.34	0.62	5.72
Mindanao	10.46	12.79	−4.52	2.11	2.21	−2.30	−0.82	19.93
Sum regional variances	40.41	14.78	19.89	−9.30	0.25	−15.77	−0.53	49.74
Interregional covariances	−1.43	9.30	1.41	1.39	23.99	19.47	−3.88	50.25
Column sums	38.98	24.08	21.30	−7.91	24.25	3.71	−4.41	100.00

Note: The five interaction terms identified in the text are aggregated in this table.

[10, Table 19] analysis of the increase in the variability of India's rice production between 1954–64 and 1967–77, where changes in interregional covariances accounted for 80.6 per cent of the total variance change. Part of the difference is due to the greater number of regions included in the Indian analysis (fifteen rather than seven) because there are n^2-n covariances for every n variances. A more interesting difference, though, is that changes in interregional yield covariances in the Philippines are tiny (1.4 per cent), whereas they accounted for 46 per cent of the variance increase in rice production in India. Separate analysis of the interregional yield correlations also shows little change in the number of statistically significant and positive correlations in the Philippines, whereas Hazell [11] reports these increased sharply in India.

The Philippine results, contrary to that found in India, suggest that a shift towards greater varietal homogeneity and more input-intensive rice production does not necessarily lead to more synchronized patterns of yield variation nationally. Perhaps one reason for the difference is the geographical difference between the Philippines as an archipelago and India as a continental land mass. For example, catastrophic weather effects, as typhoons, are localized in the damage they cause in the Philippines; and indeed, they often benefit fringe areas. By contrast, floods and droughts are often widespread in India. Similarly, diseases and pests are less likely to reach epidemic proportions in the Philippines, given the dispersed nature of rice production, and the sea barriers to constrain their spread. Another reason may be the extremely rapid adoption of pest-resistant modern rice varieties which are widely adopted to the favorable rice growing conditions of the Philippines.

Table VI also shows that increases in mean areas and mean yields were important components of the production variance increase, as were increases in area-yield covariances. Hazell found that the latter were also an important factor in India. Why the area harvested should now be more positively correlated with yield, both within and across regions, is not readily transparent. It may be related to increased irrigation infrastructure and farmers' enhanced ability to sustain both area and yield in low rainfall years given short-duration modern varieties, and innovations as wet seeding, than was previously the case.

G. *Modern Technology and Production Variability*

The previous sections provided quantitative evidence of changes in mean values and variability of Philippine rice production, area, and yield. However, it provided no insights into the causes of, for example, changes in mean yields or yield variability over time. A series of models designed to quantify the relationship between these variables, and factors hypothesized to be their determinants (as percentage area under MV, irrigation rate, fertilizer use, and a set of weather variables) were therefore estimated following the approaches adopted by Ray [16] and Walker [19] for analysis of the same class of issue using Indian data.

This analysis was singularly unsuccessful due to extreme problems of collinearity between MV, irrigation, and fertilizer use, and in general, due to an extremely noisy data set. In essence, the complementary inputs of modern rice technology moved together, so it was not possible to ascribe changes in yields or yield variability to individual inputs. Carlson [2] was able to avoid this problem by using a cross-country data set, where the level of MV adoption and irrigation varied somewhat between countries. Similarly, the variability in these factors across India and over time permitted both Ray [16] and Walker [19] to incorporate them as independent variables in their analysis.

As a fall-back position, the impact of a number of the components of modern rice technology on yield variability are examined in a disaggregated manner. The factors examined are: (a) irrigation expansion, (b) double cropping of rain-fed rice, (c) fertilizer use, and (d) the impact of price variability, on yield variability of rice. The analysis which follows differs from that previously discussed in the sense that it relates production and production variability between modern systems of rice production within the same (i.e., post-MV) time period.

Irrigation. Irrigation may increase or reduce rice yield variability, depending largely on the dependability of irrigation water supplies [1]. Production, area, and yield variability of irrigated and lowland rain-fed rice within the period 1974–83 (the period when disaggregated data is available) are compared in Table VIIA. The mean yields of irrigated rice (2.6 tons/ha) were significantly higher than for lowland rain-fed rice (1.6 tons/ha). The yield variance was higher (but not significantly so) for irrigated rice, but the CV was substantially higher for rain-fed rice. The CV of area and total production were less for irrigated rice. Thus, in aggregate, a change from rain-fed to irrigated rice land has not resulted in greater instability in rice yields or production in the Philippines.

A between-season comparison of production, area, and yield variability of wet and dry season irrigated rice are shown in Table VIIB for the period 1974 to 1980. Mean irrigated rice yields in the dry season (2.7 tons/ha) were significantly higher than in the wet season (2.3 tons/ha). But dry season yields also had significantly higher variances and higher CV than the wet season irrigated rice. However, when area effects are considered, absolute and relative variability of total irrigated rice production was higher in the wet season; that is, total production was more stable in the dry season.

Wetland rain-fed. The short-duration, second-generation MV rices, coupled with early establishment techniques as direct seeding, has allowed an increase in cropping intensity, i.e., growing two rain-fed rice crops in the one wet season where previously only one longer-duration crop was possible. Production, area, and yield stability coefficients for the first and second rain-fed rice crops are compared in Table VIII for the period 1974 to 1980. Mean yields of lowland rain-fed rice were higher for the first (1.6 tons/ha) than the second (1.4 tons/ha) crop, but not significantly so; yield variances did not differ significantly, although the CV was higher for the lower-yielding second crop. Area variance was significantly higher for the late crop, and as a result, production variability was higher for the second rain-fed rice crop.

Fertilizer. Estimates of fertilizer use on rice are not available by region or by culture type in the Philippines. Figures which are available are assessed as a proportion (in the range of 40–50 per cent) of the total nutrient offtake for the

TABLE VII

MEAN VALUES, VARIANCES, AND COEFFICIENTS OF VARIATION OF RICE PRODUCTION, AREA, AND YIELD BY WATER REGIME AND SEASON IN THE POST-MV ADOPTION PERIOD

A. Irrigated versus rain-fed rice (1974–83)

	Mean Values			Variances			Coefficient of Variation		
	Irrigated	Rain-fed	Difference (%)	Irrigated	Rain-fed	Difference (%)	Irrigated	Rain-fed	Difference (%)
Average production (1,000 tons)	4,134	2,623	−37**	15,484	16,928	9ns	3.01	4.96	65**
Average area harvested (1,000 ha)	1,579	1,602	2ns	1,109	3,003	171ns	2.11	3.42	62**
Average yield (kg/ha)	2,606	1,645	−37**	4,987	3,785	24ns	2.71	3.74	38ns

B. Irrigated wet seasons versus irrigated dry season rice (1974–80)

	Mean Values			Variances			Coefficient of Variation		
	Wet	Dry	Difference (%)	Wet	Dry	Difference (%)	Wet	Dry	Difference (%)
Average production (1,000 tons)	2,095	1,703	−19**	15,545	1,303	−92**	5.95	2.12	−64*
Average area harvested (1,000 ha)	892	637	−29**	1,149	712	−38ns	3.80	4.19	10ns
Average yield (kg/ha)	2,346	2,670	14**	6,065	23,822	293**	3.32	5.78	74**

Source: [15].
Notes: 1. Variances computed from residuals about second-order time trend.
2. Wet and dry season data disaggregated only available to 1980.
3. **, *, and ns imply significance at the 5 per cent, 10 per cent, and not significant levels.

TABLE VIII

MEAN VALUES, VARIANCES, AND COEFFICIENTS OF VARIATION OF RICE PRODUCTION, AREA, AND YIELD FOR FIRST-CROP COMPARED TO SECOND-CROP LOWLAND RAIN-FED RICE IN THE PRE-MV TO POST-MV ADOPTION PERIOD

	Mean Values			Variances			Coefficient of Variation		
	First Crop	Second Crop	Difference (%)	First Crop	Second Crop	Difference (%)	First Crop	Second Crop	Difference (%)
Average production (1,000 tons)	1,864	717	−62**	7,969	12,850	61^{ns}	4.79	15.82	230**
Average area harvested (1,000 ha)	1,146	514	−55**	706	3,136	344**	2.32	10.90	370**
Average yield (kg/ha)	1,628	1,392	14^{ns}	8,279	7,497	-9^{ns}	5.59	6.22	11^{ns}

Source: [15].

Notes:
1. First and second crop data disaggregated only available to 1980.
2. Variances computed from residuals about second order time trend.
3. ** and ^{ns} imply significance at the 5 per cent and not significant levels. Mean difference based on *t*-test and variance difference on *F*-test.

TABLE IX

VARIABILITY OF WORLD AND PHILIPPINE FERTILIZER PRICES, 1958–67 TO 1974–83

	Mean Values		Variances			Coefficient of Variation		
	First Crop	Second Crop	First Crop	Second Crop	Difference (%)	First Crop	Second Crop	Difference (%)
Price of fertilizer, *N* as urea (/tons):								
Philippines	47.93	213.59	3	462	large**	3.87	10.06	160**
World	33.41	167.34	39	1,938	large**	18.71	26.31	40ns
Real price of fertilizer:								
Philippines	3.32	3.64	0.03	0.15	422**	5.18	10.79	108**
World	1.38	1.10	0.04	0.01	65**	14.16	10.48	26ns

Source: International Rice Research Institute, *World Rice Statistics, 1985* (Manila, 1986).

Notes: 1. Variances and coefficients of variations calculated from standard errors of second-order polynomial time trends.

2. Urea price is f.o.b. Europe and rice f.o.b. Bangkok. Rice price for milled rice.

3. ** and ns imply significance at 5 per cent and not significant levels.

country. Therefore, analysis of the relationship between fertilizer use, rice production, and production variability by rice culture type was not possible. As a fall-back position, yield variability-fertilizer relationships were examined in an empirical, heuristic manner.

Fertilizer price variability increased both internationally and domestically in the Philippines from the 1960s to the 1970s and beyond (Table IX). The oil shocks of 1973/74 and 1980 contributed substantially to this increase, although fertilizer price variability remained less in the Philippines than in international markets. Fertilizer prices in the Philippines were higher than border prices for most of this time [4]. Nonetheless, the variability in the real price of fertilizer (i.e., fertilizer price divided by rice price) increased in absolute and relative terms from the first to the second period (Table IX).

The elasticity of rice supply with respect to fertilizer (at optimal *N*-rates) is larger for MV than LV because of the higher fertilizer responsiveness of MV (Table X). This, together with higher yields of MV for a given *N*-rate, results in a small change in the real fertilizer price having a larger impact on MV than LV yields. By inference, a shift in the real price of fertilizer has a greater impact on rice yields in the period since MV have been adopted compared to the pre-MV era. As also illustrated in Table X, the yield difference induced by a change in the real price of fertilizer has a greater impact in irrigated compared to rain-fed environments.

Fertilizer use rates on rice have increased in the Philippines from less than 10 kg/ha in the early 1960s to over 40 kg/ha by the early 1980. This, of itself, leads to increased yield variability as rice yield variability increases as *N*-fertilizer rates increase. This variability is induced through strong interaction between applied nitrogen and the levels of uncontrolled factors such as solar radiation,

TABLE X

OUTPUT ELASTICITIES AND OUTPUT RESPONSE OF SMALL CHANGES IN REAL FERTILIZER PRICES FOR LV AND MV RICES

Environment	Response Function	Optimal[a] (Kg/Ha)		Output Elasticity[b]	Output Response Y^c
		N-Rate	Yield (Y)		
Irrigated (modern)	$2000+19N-0.09N^2$	86	2,969	0.10	19
Irrigated (traditional)	$1600+11N-0.13N^2$	29	1,809	0.06	11
Rain-fed (modern)	$1200+16N-0.11N^2$	57	1,754	0.11	16
Rain-fed (traditional)	$1200+9N-0.16N^2$	17	1,307	0.05	9

Source: For response function, R. W. Herdt and C. Capule, *Adoption, Spread and Production Impact of Modern Rice Varieties in Asia* (Los Baños: International Rice Research Institute, 1983).

[a] Assuming a price ratio 3.5 : 1.

[b] $Ey = \frac{dy}{dn} \cdot \frac{n}{y}$ at N optimal.

[c] Marginal change in yield at optimal N for small change in N-rate.

water regimes, and pest incidence [7]. Several authors have estimated the relationship between mean yield, yield variability, and N-rates [9] [17]. In general, they observe that yield variance increases with N-rate, more rapidly in the wet than the dry season (Figure 3). Therefore, the so-called modern "seed-fertilizer" technology is likely to result in increased yield variability for at least two reasons: (a) MV are more fertilizer responsive than LV, so are more sensitive to changes in input use brought about by changes in relative prices, which will also have contributed to increased interregional covariances; and (b) yield variability increases as fertilizer use rates increase.

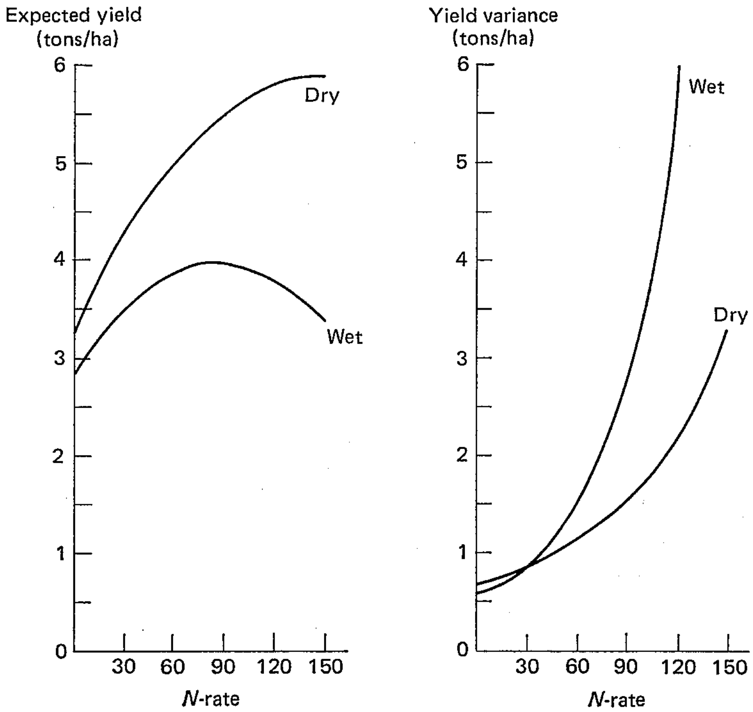
Price variability. Hazell [12] speculates that the greater price variability observed in international trade for cereals in recent years may contribute to increased production instability. He also observed that (detrended) farm-gate rice price variability in the Philippines fell from the 1960s (CV=13 per cent) to the 1970s and beyond (CV=4 per cent). That is, Philippine farmers (and consumers) were insulated from international rice price variability. However, Philippine rice prices were also generally below border prices though most of the 1970s and early 1980s, providing a disincentive to increase production [18].

Small changes in rice prices are anticipated to bring about larger changes in rice supplies now than historically was the case because the assumption that other factors remain the same, is not true. For example, MV are more responsive to modern agronomic practices than are LV. Therefore, a small change in rice price is likely to induce a larger response in rice supply when MV technology has been adopted. Mangahas et al. [14] estimated that the own price elasticity of supply for irrigated rice in the Philippines was less than 0.6 for LV, this figure may well exceeds 0.9 for modern irrigated rice technology [8]. Rice farmers also appear to be more commercially oriented now than traditionally [2]. This, of itself, would induce greater farmer responsiveness to price changes.

Fig. 3. Relationship between *N*-rate, Yield, and Variance of Yield for IR36 by Season, Laguna

a. Relationship between *N*-rate and yield

b. Relationship between *N*-rate and yield variance



Source: [9].

H. *Conclusions*

Growth in rice production in the Philippines since the mid-1960s has been dominated by a yield as opposed to an area effect. In aggregate, relative production variability (CV) has changed little, while absolute production variability (variance) has increased significantly with the introduction of modern rice technology in the Philippines. Changes in rice production variability which has occurred were equally due to changes in production variances within, and increases in positive covariances between regions. Increases in area-yield covariances between regions also contributed to increased variability in total rice production from the pre-MV to the post-MV era. Irrigation has probably not led to increased production instability, although increasing variability in the real price of fertilizer may have. An increase in the irrigated dry season rice crop has helped to reduce production variability, whereas increases in the rain-fed second rice crop has worked in the opposite direction.

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