ASIAN DEVELOPMENT BANK

Economics Office Report Series

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DETERMINANTS OF PADDY PRODUCTION IN INDONESIA: 1972-1981 A SIMULTANEOUS EQUATION MODEL APPROACH

by
T. K. Jayaraman*

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Chief Economist
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DETERMINANTS OF PADDY PRODUCTION IN INDONESIA: 1972-1981

A SIMULTANEOUS EQUATION MODEL APPROACH

T. K. Jayaraman

INTRODUCTION

Rice is the major foodcrop in Indonesia. Out of the total harvested area of about 15 million ha in 1981, 9 million ha or about 64 per cent of the area were under rice cultivation. Nearly 7 million ha of the harvested area were receiving irrigation supplies. Production in terms of paddy (unmilled rice) reached a record figure of 32.78 million tons in 1981 from a level of 19.40 million tons in 1972, the rate of increase on an average being 7.6 per cent per annum over the period. Closely examining the growth in production in recent years, we find spectacular jumps in production, in 1973/74 one million tons, in 1977/78 2.42 million tons, and in 1979/80 and 1981/82, 3.37 million tons, 3.13 million tons, respectively. These impressive increases in production have naturally enabled the country to reduce the levels of imports from previous levels of 2 to 3 million tons of rice to about 500,000 tons in 1981 (Table 1).

Increases in paddy production have been attributed to several factors, outstanding among them being improvements in irrigated and wetland production. The average dryland paddy production has remained almost static during the last ten years and the proportion of rice production from the unirrigated land has declined from 10 per cent in 1968/70 to 5 per cent in 1979/81.[1/]

While it is very clear that the paddy production for dryland under rainfed condition has remained the same over the period, there is only a very hazy idea in regard to specific contributions from different factors in the case of irrigated paddy production. It is generally held that irrigation has been a major factor influencing production under irrigated conditions. Besides irrigation, the use of complementary inputs such as fertilizers and pest resistant high yielding seed varieties, and price incentives have also been recognized to have played important parts. Though identification of these factors has fairly been easy, efforts to quantify the respective contributions to local paddy production have been fraught with difficulties. Single equation regression models with production as the dependent variable will serve only limited objectives because of the multicollinearity problems.[2/] In addition to the apparent interdependency between the explanatory variables, these models are also likely to have the simultaneity bias, which could be more effectively dealt with by devising a suitable model of simultaneous equations system. It is proposed to examine in this paper applicability of such an approach in Indonesia during the past ten-year period (1972-1981) for which adequate data, however limited, are available on a consistent basis. The paper is organized into three sections. The first section deals with the model employed in the analysis whereas the second section presents the empirical results. The last section is a summary listing out some policy conclusions.

1.

THE MODEL

Rice production takes place through a process of interaction between different factors: irrigation facilities, availability of fertilizers at attractively low prices fixed by deliberate efforts coupled with appropriate extension advice, incentives in terms of government supported procurement program for each year at certain prices announced well in advanced of the main wet season with a view to stabilize the paddy producers' incomes, and credit facilities to enable farmers to obtain fertilizers and seeds of high yielding varieties. Irrigation facilities are being provided by Government through its massive investment programs supported by international financing agencies both in terms of financial and technical assistance.[3/] Steady increases in irrigated areas have enabled the farmers to resort to double cropping and in turn, the country to reach higher gross harvested area over the period. In addition to irrigation facilities, Government-administered agricultural support services have also helped the paddy production to reach higher levels of technological efficiency. These support services provide a package of credit facilities under the nationally run programs known as BIMAS, INSUS and INMAS.[4/]

Though, of late, the farmers utilizing these credit facilities have decreased in numbers due to their overdues position arising from defaults of non-repayments, it is obvious that they have been increasingly using their own resources to buy fertilizers as reflected in the increases in fertilizer consumption. The incentive for fertilizer application is facilitated by the Government through fixing the price of both urea and TSP at a very low level and by raising the paddy procurement price at appropriate intervals to mainly meet the increasing costs of production in general and partly to compensate the cost of provision of rice to consumers at subsidized prices in the urban sector.[5/] Thus, an attractive output price/input price ratio, in terms of steadily rising paddy procurement price and near-stationary and low fertilizer price, has been the chief feature of Government's incentive programs for paddy production (Table 3). Further, the output/input price ratio can usefully serve as a catch-all variable representing the Government extension efforts for stepping up paddy production, besides the specific efforts relating to irrigation. These efforts have yielded in concrete terms the following impressive results: increase in the use of fertilizers, increase in the area under high yielding varieties, increase in the gross harvested area and finally increase in paddy production.

Besides the above listed factors, we have also to recognize the important role of rainfall. Apart from setting the tone of agricultural operations each year, precipitation is also directly responsible for rice cultivation in both wetlands and drylands. The rainfed systems are composed of about 0.36 million ha of wetland, where drainage and rain water is trapped in low field bunds, and dryland (ladang) of about 1.2 million ha.

In the light of the above, we may construct a model wherein all possible forces can be incorporated. For the purpose of such an analysis, it is postulated that the aggregate paddy production in a given year depends upon the proportion of the total harvested area covered by the high yielding varieties (HYVs) and rainfall received during the year. In turn, the proportion of area under HYVs to total harvested area is hypothesized to depend upon the consumption level of fertilizers since it has been shown that HYVs are highly fertilizer responsive and that fertilizers availability, as a result of promotional efforts, influence the proportion of harvested area under HYV. Further, farmers' decision to allocate the proportion of the cultivable area for HYVs is influenced by the relative attractiveness of rice as a crop to substitute food crops known as palawija crops in terms of their prices as prevalent in the immediate past. The relevant variable to be included in the functional relationship is, therefore, the ratio of price of rice to prices of corn, soybeans and cassava.

This would lead us to hypothesize that the level of fertilizer consumption each year is determined by the paddy and fertilizer price ratio. Apart from standard theoretical justification for including it as a decision making variable, it also symbolizes the orchestrated efforts of the Government in the area of production incentives. In addition, the aggregate fertilizer consumption is also likely to be dependent upon the total harvested area under paddy. The gross harvested area under rice each year is in turn influenced by the availability of irrigation facilities giving rise to possibilities of multiple cropping. Besides irrigation, both rainfall and rice/other food crops' price ratio are included as explanatory variables.

The above formulation of production relationships assumes that the farmers, and consequently the country can adjust to their long-run desired goals of harvested area under HYVs fertilizer consumption and paddy production - rather instantaneously in response to changes in the four exogenous variables - paddy output/fertilizer price ratio, the ratio of rice price to price of substitute food crops, area under irrigation and rainfall. In reality, it takes considerable time for adjustment to changes in these variables, especially in a traditional society of settled agriculture with its characteristic institutional background. Hence, it would be more appropriate to allow for certain adjustment period, and accordingly we may adopt a distributed lag model of response pattern of the Koyck type, which assumes a declining geometric sequence.[6/]

Thus, the above hypothesized relationships can be formalized in the following functional forms:

$$Q_t = f(HYV_t, R_t, Q_{t-1}) \text{ -------------- } 1$$

$$HYV_t = f(F_t, PC_t, HYV_{t-1}) \text{ -------------- } 2$$

$$F_t = f(PF_t, HA_t, F_{t-1}) \text{ -------------- } 3$$

$$HA_t = f(AI_t, PC_t, R_t, HA_{t-1}) \text{ ---------- } 4$$

Where:

Q = production of paddy in million metric tons;

HYV = percentage of total harvested area under high yielding varieties of paddy;

R = rainfall in millimeters;

PF = ratio of paddy support price to fertilizer price;

PC = ratio of rice price to secondary food crops;

F = consumption of fertilizers in million metric tons;

HA = harvested area under paddy in million hectares;

AI = net irrigable area devoted paddy cultivation in million hectares; and

t = the period under consideration.

In this system, there are in all four endogenous variables (Q, HYV, F and HA) and eight predetermined variables. The latter includes four exogenous variables (AI, PF, R and PC) and four lagged endogenous variables. As there is a bias of simultaneity involved in these relationships, the estimation procedure has to be different from the usual ordinary least squares method. The first three equations are overidentified and the last and the fourth equation is in terms of independent exogenous variables. Therefore, the two stage least squares method is resorted to for estimating the parametric coefficients.

However, some of the limitations of the multiple regression analysis in terms of these variables to explain the variations in production level over a time period should be recognized. First, the model does not take into account the weather disturbances within each year such as variations in the distribution of rainfall. It rather assumes the absence of such abnormalities. Secondly, the model trends to ignore the possible repercussions due to non-timely supply or shortages of fertilizers and other inputs on production, which are themselves critical. Thirdly, it also assumes the absence of problems of pests and diseases throughout the period of analysis. These and other limitations can be eliminated to a greater extent if the data were more varied and substantially plentiful and accurate, and consistently available to form a reliable time series. Unfortunately, the data availability is rather limited. Despite these deficiencies, the model constrained by the limited data does seem to represent the pattern of forces at work as verified by the empirical analysis in the next section.

II

RESULTS OF EMPIRICAL ANALYSIS

The model developed in the last section was applied to the time series of data for a period of ten years (1972-1981) presented in Table 4. The variables, except two price ratios and the proportion of harvested area under HYVs are expressed in quantities such as hectares, metric tons and millimeters.

The results of the multiple linear regression adopting the two-stage least squares procedure are summarized in Table 4. All the four estimated linear regression equations have emerged as good fits both in terms of high R^2 and F ratios. In view of the highly aggregative nature of data, the level of significance chosen for testing the significance of parametric coefficient is only 10 per cent by one tailed test. However, the calculated 't' values based on small sample sizes are not reliable in the case of two-stage least squares estimation procedure. But, the large magnitudes of 't' values in respect of the coefficients do indicate their acceptability from the point of view of statistical significance. In regard to serial correlation, Durbin-Watson statistical tests in the case of lagged models are not conclusive and considering the small size of sample, no corrections are made and the results are presented as such.

It will be of interest to note that the signs of the coefficients of the relevant variables included in each of the four equations have turned out to be theoretically correct. In the first equations relating to production (Q) both rainfall (R) and the area under HYVs (HYV) are positively related to production (Q). Similarly, in the second equation with the HYV as dependent variable, both fertilizers (F) and price ratio of rice to substitute food crops have the positive signs. In the third equation with fertilizers (F) as the dependent variable, the paddy fertilizer price ratio (PF) has the appropriate sign. In the last equation, area irrigated (AI), rainfall and price ratio and area harvested (HA) are found to move in the same direction. These results thus confirm the hypotheses formulated in the earlier section.

Utilizing the estimated parametric coefficients of variables employed in the analysis, the endogenous variable paddy production (Q) can be expressed in terms of the eight predetermined variables. The reduced form of the equation is given as follows:

$$Q_t = 5.5571 + 0.1779\ HYV_{t-1} + 1.2348\ F_{t-1} + 0.0361\ HA_{t-1} + 0.1265\ Q_{t-1} + 1.1914\ PS_{t-1} + 0.3407\ AI_t + 1.6535\ PF_t + 0.0022\ R_t.$$

The actual and predicted values of Q, based on the above reduced form of equation for the past ten years are plotted in Figure 2. The percentages of errors (errors as percentages of actual sample values) along with the actual and predicted values are shown in Table 5.

The predictions are observed to be quite close to the actual values. The root-mean-square of percentages of errors is 4 per cent. Considering the limitations imposed by data deficiencies, the error level is quite low, reflecting the model's predictive capability. The model can be updated periodically utilizing more recent data for the variables employed in the analysis. Further, a more comprehensive model can also be developed if the data situation becomes improved in future years.

Using the estimated parametric coefficients in the reduced form of equation and the coefficient of adjustment (1-0.1265), both short- and long-run elasticities of production with respect to different variables were calculated and they are shown in Table 6. A ten per cent increase in the short-run either in PF, PS, AI or R would result in 0.7, 0.9, 0.8 or 0.6 per cent increase in paddy production. The corresponding long-run estimates of increases in paddy production are 0.8, 1.0, 0.9 and 0.7, respectively.

III.
SUMMARY AND CONCLUSIONS

In this paper, a simultaneous equation model was developed with a view to find out the determinants of paddy production in Indonesia during the ten year period from 1972 to 1981. The model's predictive ability was tested and it was found that the model could be well utilized with negligible error taking into account minimum available information. The latter is confined to four exogenous variables, two of them determined by Government- irrigation facilities, paddy output price and fertilizer price ratio, the third one being subject to partial control by Government, namely rice and substitute food crops' price ratio and the last one, purely a natural phenomenon, rainfall, which is beyond control. The policy implications, especially in the light of country's recent reported position of being close to self-sufficiency in rice production, are the following:

(i) paddy production being a direct function of area under irrigation, can be maintained if the irrigation facilities are kept up at the current level;

(ii) any desired increase in the production level dictated by demand pressures can be achieved by stepping up irrigation facilities, the paddy/ fertilizer price ratio remaining the same;

(iii) alternately, the Government may, while lowering the paddy/fertilizer price ratio with a view to meet the budgetary gaps arising out of fertilizers' subsidies and other production incentive measures, help to improve the physical irrigation infrastructure and meet the likely deficits in production; and

(iv) rainfall would be playing a less significant role in the light of increased irrigation facilities and consequently, repercussions due to occurence of erratic rainfall would be considerably reduced.

FOOTNOTES

1/ For a detailed discussion, see Leon Mears, The New Rice Economy of Indonesia, Yogyakarta: Gadjah Mada University Press, 1981, pp 15-50.

2/ The usual production function models have to be confined to labor and capital. Inclusion of inputs and their prices will give rise to multicollinearity problems. For greater details, see J. Johnston, Econometrics Methods: New York: McGraw Hill, 1971.

3/ The Asian Development Bank has extended support to the Government's efforts in the irrigation subsector through financial assistance of about $447 million.

4/ Leon Mears, op.cit., pp. 311-350.

5/ C. Peter Timmer, "The Political Economy of Rice in Asia: Indonesia." Food Research Institute Studies, Stanford University, Vol XIV, No. 3, 1975.

6/ L. M. Koyck, Distributed Lags and Investment Analysis, Amsterdam: North Holland Publishing Company, 1954.

Table 1

INDONESIA: PRODUCTION OF PADDY AND IMPORTS OF MILLED RICE: 1972-1981

Year	Production of Paddy (Million Metric Tons)	Imports of Milled Rice ('000 Metric Tons)
1972	19.40	1,229.1
1973	21.49	1,230.0
1974	22.47	1,474.4
1975	22.34	670.2
1976	23.30	1,508.9
1977	23.35	2,308.4
1978	25.77	1,268.0
1979	26.28	2,579.3
1980	29.65	1,213.2
1981	32.78	437.1

Source: Central Bureau of Statistics, Government of Indonesia, Jakarta.

Table 2. VARIABLES USED IN THE REGRESSION ANALYSIS

Year	Harvested Area (In Million Ha)	Area Irrigated (In Million Ha)	Percentage of Harvested Area Under HYVs	Rainfall (In Milli-Meters)	Paddy/ Fertilizer Price Ratio	Rice/Other Foodcrops Price Ratio	Fertilizers (In Million Metric Tons)
1972	7.90	5.06	23.4	110	0.79	1.83	0.251
1973	8.40	5.46	27.1	1,152	0.76	2.15	0.379
1974	8.52	5.71	37.8	850	1.05	1.75	0.394
1975	8.50	5.78	39.8	966	0.98	1.64	0.422
1976	8.27	5.69	45.2	297	0.86	1.82	0.411
1977	8.36	5.85	49.6	669	1.01	2.12	0.558
1978	8.93	6.34	53.9	787	1.07	2.17	0.618
1979	8.80	6.24	59.2	388	1.21	2.03	0.699
1980	9.00	6.48	70.0	415	1.50	2.20	1.013
1981	9.38	6.75	80.0	274	1.90	2.28	1.068

Source: Central Bureau of Statistics, Government of Indonesia, Jakarta and World Bank Issues Paper, 1982.

Table 3

SUPPORT PRICE OF PADDY AND FERTILIZER SALE PRICE

Year	Rp per Kg Paddy	Rp per Kg Fertilizer	Paddy/Fertilizer Price Ratio
1972	20.9	26.4	0.79
1973	30.4	40.4	0.76
1974	41.8	40.0	1.05
1975	58.5	60.0	0.98
1976	68.5	80.0	0.86
1977	71.0	70.0	1.01
1978	75.0	70.0	1.07
1979	85.0	70.0	1.21
1980	105.0	70.0	1.50
1981	135.0	70.0	1.90

Source: Statistics, Pertanian, 1968-1981 Department of Agriculture, Bureau of Planning, Government of Indonesia, Jakarta, 1982.

Table 4. Results of Two-Stage Least Squares Multiple Linear Regression

Endogenous Variables	Intercept	Endogenous Variables: HA_t	Endogenous Variables: HYV_t	Endogenous Variables: F_t	Predetermined Variables – Exogenous: AI_t	Exogenous: PF_t	Exogenous: R_t	Lagged: PS_{t-1}	Lagged: Q_{t-1}	Lagged: HYV_{t-1}	Lagged: F_{t-1}	Lagged: HA_{t-1}	R^2	F Ratio	Degrees of Freedom	Durbin Watson Statistic
Q	9.0288		0.2313*				0.0021		0.1265				0.9475	30.10	5	1.5529
	(0.9449)		(1.9480)				(1.0290)		(0.2031)							
HYV	-3.2572			17.3723*				4.6852		0.7692*			0.9838	101.12	5	2.7566
	(-0.3164)			(1.7003)				(0.8361)		(4.5914)						
F	-0.9419	0.1066				0.4115*					0.3073		0.8949	14.19	5	2.1153
	(-0.4234)	(0.3248)				(1.9472)					(0.4218)					
HA	2.4896				0.7959*		0.0003	0.2520				0.0842	0.9472	17.96	4	1.2780
	(1.2403)				(4.0732)		(1.1235)	(0.8259)				(0.3188)				

(Figures in parentheses denote "t" values)

* Indicates significance at 10 per cent level by one tailed test.

Table 5

ACTUAL AND PREDICTED VALUES OF PADDY PRODUCTION: 1973-1981

Year	Actual (In Million Metric Tons)	Predicted (In Million Metric Tons)	Error	Error as Percentage of Actual
1973	21.49	20.60	+0.89	+ 4.14
1974	22.47	21.98	+0.49	+ 2.18
1975	22.34	23.71	-1.37	- 6.13
1976	23.30	22.26	+1.04	+ 4.46
1977	23.35	24.65	-1.30	- 5.57
1978	25.77	26.51	-0.74	- 2.87
1979	26.28	27.05	-0.77	- 2.93
1980	29.65	28.61	+1.04	+ 3.51
1981	32.78	31.99	+0.79	+ 2.41

Root Mean Square of Percentage Error: 4.00

Table 6

SHORT AND LONG-RUN PADDY PRODUCTION ELASTICITY ESTIMATES

	Elasticity of Paddy Production With Respect to:			
	PF	PS	AI	R
Short-run	0.07	0.09	0.08	0.06
Long-run	0.08	0.10	0.09	0.07

Figure 1.

A SCHEMATIC MODEL OF PADDY PRODUCTION IN INDONESIA

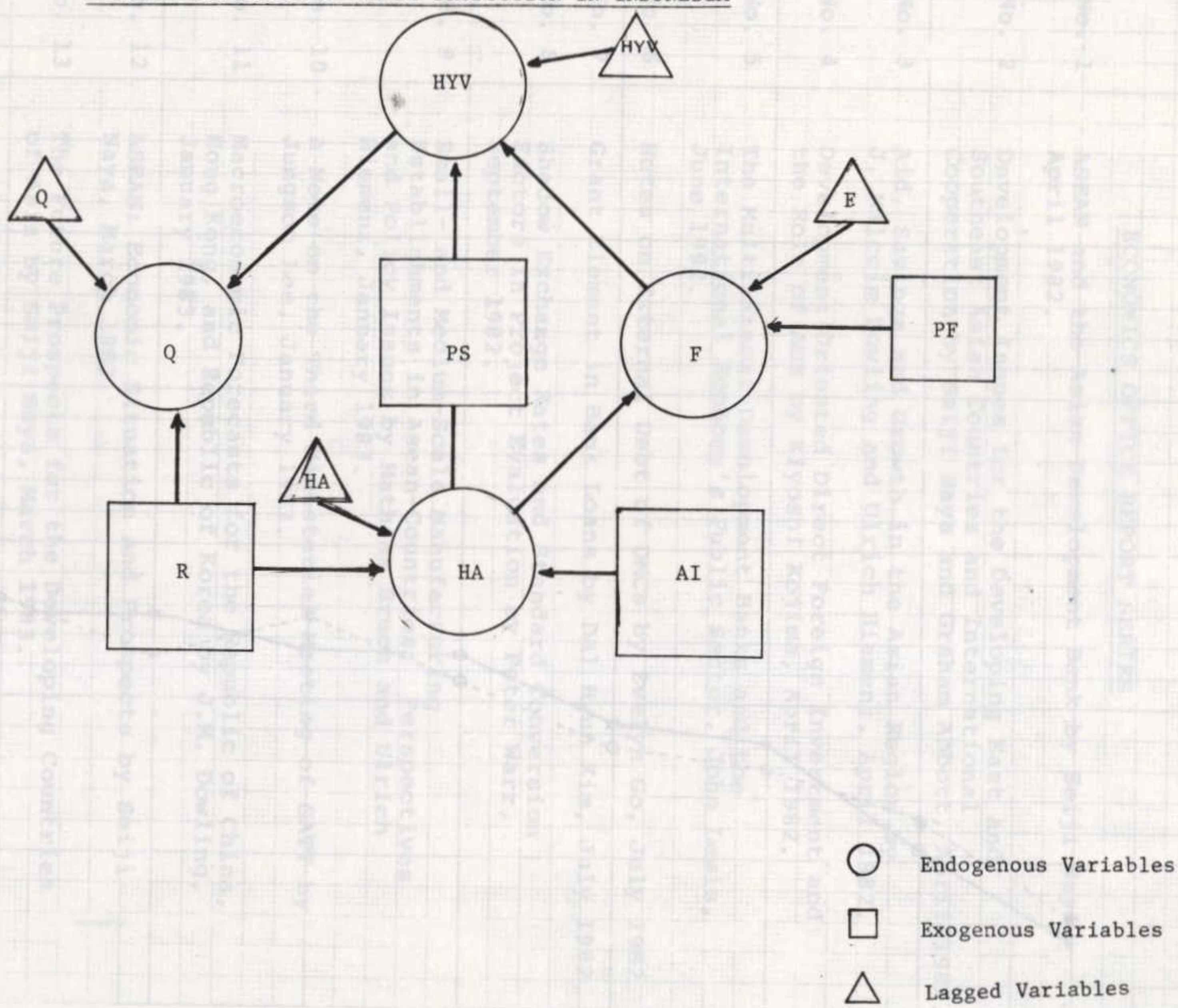
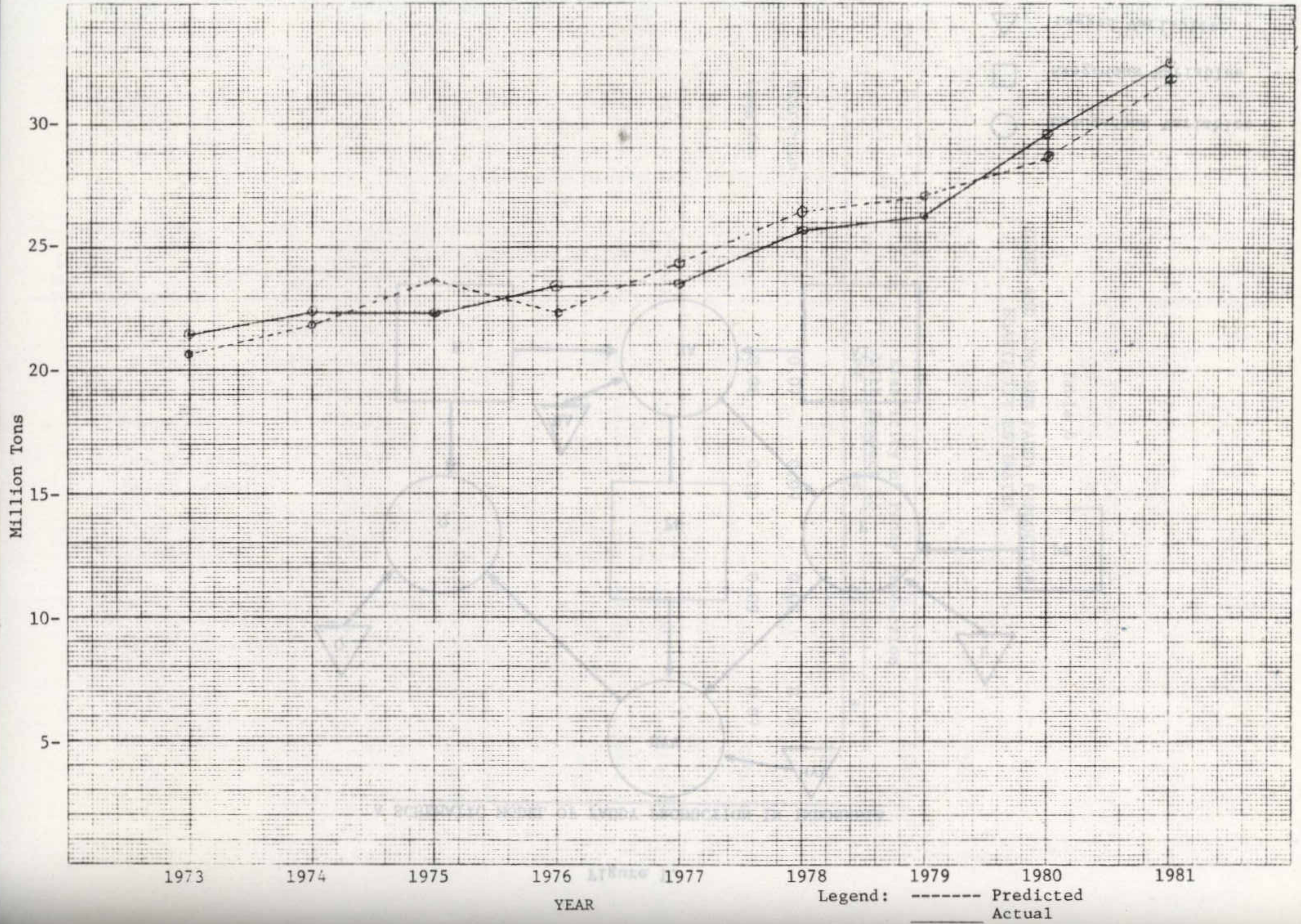


Figure 2

ACTUAL AND PREDICTED VALUES OF PADDY PRODUCTION (1973-1981)



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