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Fertilizer Response Special Study: Preliminary Results

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Fertilizer Response Special Study: Preliminary Results

Fertilizer subsidies were implemented in Indonesia to encourage the adoption of the green revolution package of inputs by rice farmers. Started in 1971, fertilizer subsidies have been one of the cornerstones of the Government of Indonesia's (GOI's) rice intensification program. The program has been an unequivocal success: fertilizer use is very high in comparison with other Asian rice producers, adoption of high-yielding variety seeds (HYV's) is virtually complete in wetland paddy areas, and rice yields have almost doubled since 1971.

However, the ubiquity of HYV seeds and the high fertilizer use levels give reason to question whether input subsidies still are necessary to maintain rice production levels. If they are not, the current fertilizer subsidy is serving merely as a very expensive income transfer to farmers. The subsidy issue is particularly compelling in light of the GOI's ongoing budgetary difficulties. A resolution of this issue requires an assessment of the effect of a reduction of the subsidy on rice production in Indonesia. Further, because fertilizer application rates have increased on palawija crops, thus widening the incidence of the subsidy, the analysis must include secondary crops as well, particularly corn.

Methodology

A number of researchers have examined the fertilizer issue in Indonesia utilizing different data and analytical approaches.

Analyses range from use of ordinary least squares on annual time-series data (Timmer, 1985) to a simulataneous profit function and input demand estimation of pooled cross-section data (Altemeier et al., 1989) from several years. Econometric estimation results have differed greatly, implying very different policy prescriptions for fertilizer subsidies.

The study at hand will use yet another analytical approach and data set to investigate the fertilizer subsidy issue. An annual time series from 1970-86 consisting of per hectare averages of the Central Bureau of Statistics' (CBS) cost of production farm surveys is utilized as the data base. The econometric analysis is based on the profit function approach. Use of profit maximization as the underlying behavioral assumption means to estimate a system of factor demand functions together with the profit function. The profit function itself is derived as a second order Taylor approximation to the real function. The translog functional form, used because of its flexibility and desirable mathematical properties, implies the following system of equations:

$$
\begin{aligned}
\text{(1a)}\quad \ln\left(\frac{\pi}{p}\right) = {} & a_0 + \ln\left(\frac{q_1}{p^0}\right) + a_2 \ln\left(\frac{q_2}{p^0}\right) + 0.5\, a_3 \left[\ln\left(\frac{q_1}{p^0}\right)\right]^2 \\
& + a_4 \ln\left(\frac{q_1}{p^0}\right) \ln\left(\frac{q_2}{p^0}\right) + 0.5\, a_5 \left[\ln\left(\frac{q_2}{p^0}\right)\right]^2 \\
& + a_6 \ln\left(\frac{q_3 \cdot r_3}{p^0}\right) \ln\left(\frac{q_1}{p^0}\right) + a_7 \ln\left(\frac{q_3 \cdot r_3}{p^0}\right) \ln\left(\frac{q_2}{p^0}\right) \\
& + a_8 \ln\left(\frac{q_3 \cdot r_3}{p^0}\right) + a_9 \left[\ln\left(\frac{q_3 \cdot r_3}{p^0}\right)\right]^2 + e_1
\end{aligned}
$$

$$(1b)\quad \frac{d\left(\frac{\pi}{p}\right)}{dq_1} \Rightarrow -\frac{r_1 \cdot q_1}{\pi} = a_1 + a_4 \ln\left(\frac{q_2}{p^o}\right) + a_5 \ln\left(\frac{q_1}{p^o}\right) + a_6 \ln\left(\frac{q_3 \cdot r_3}{p^o}\right) + \epsilon_2$$

$$(1c)\quad \frac{d\left(\frac{\pi}{p}\right)}{dq_1} \Rightarrow -\frac{r_2 \cdot q_2}{\pi} = a_2 + a_4 \ln\left(\frac{q_1}{p^o}\right) + a_6 \ln\left(\frac{q_2}{p^o}\right) + a_7 \ln\left(\frac{q_3 \cdot r_3}{p^o}\right) + \epsilon_3$$

where:

π = nominal profit (Rp/ha)
p = commodity price (Rp/kg)
p^o = expected commodity price (Rp/kg)
q_1 = fertilizer price (Rp/kg)
q_2 = wage rate (Rp/day)
q_3 = seed price (Rp/kg)
r_1 = fertilizer application rate (kg/ha)
r_2 = labor application rate (days/ha)
r_3 = seed application rate (kg/ha)
ϵ = error terms.

The data and thus the profit function refer to a single commodity and cropping system rather than a multi-output crop cycle. The data are given in per hectare terms and thus do not allow direct incorporation of land as a fixed factor into the profit function. This complicates inclusion of the effects of technological change on profit and input demands into the

estimation equations. Inclusion of such effects is important because there has been significant technological change in Indonesian food crops agriculture since 1970. The data do include expenditures per hectare for seeds which should perform as a reasonable instrument to trace the impact of the adoption of new technology. Adoption of improved seed varieties, such as HYV's for wetland rice and open-pollinated and hybrid seeds for corn, has been linked historically to the spread of technological change. Since the new seeds tend to be purchased rather than obtained from own production, output-price weighted seed costs are a reasonable representation of the degree of farmers' market orientation as well as the degree of adoption of new technologies. In a practical estimation sense, the weighted seed variable should pick up time trends in fertilizer and labor use resulting from technical change and increased human capital.

Equations (1a), (1b), and (1c) specify a single commodity profit function model. Estimation of such a system with time-series data could be improved by removing autocorrelation from the residuals. Autocorrelation procedures can be applied either to one or more than one of the equations in the system depending on the temporal nature of the disturbances. Similarly, estimation could also be improved by including weather and pest dummy variables in the model equations since agricultural production and profits are closely related to weather and pest conditions.

Farmers may or may not know future commodity prices and per hectare yields. In this regard, it seems more realistic to work

with price expectations. Equations (2a-d) summarize possible specifications incorporating price expectations into the standard profit function model:

(2a) $p^o = p$

(2b) $p^o = p_{t-1}$

(2c) $p^o = p_{fp}$

(2d) $p^o = k_0 + k_1 \cdot p_{t-1} + k_2 \cdot \text{Time}.$

The expectations above are, from (2a-d), the current output price, the output price lagged one period, the floor price (only relevant for rice), and an adaptive process.

The one-period lagged price is not a very realistic representation of farmer expectations for food crops production. Farmers quite simply have better information available upon which to base their behavior. The same criticism can be leveled at the adaptive process although this specification does include partial adjustment of expectations based on new information. For major food crops, such as rice and corn, and particularly on Java, farmers' strong commercial orientation suggests that they have good knowledge of apparent market conditions and thus should have a good sense during the cropping season of what output prices will be at harvest time. This is particularly true of the dry seasons. For rice, the gabah floor price is known at the time the wet season crop is planted. The important issue is whether or not farmers base their behavior on the floor price. Simple correlation analysis indicates that the floor price historically

has not been a good predictor of market conditions.

Estimation Results

The results for wetland rice, corn, and dryland rice are summarized in Tables 1, 2, and 3, respectively. With a few exceptions, the estimated parameters are statistically significant, and of the right sign. Beyond this generalization, results do vary among crops, specification of price expectations, and provinces.

The wetland rice parameters are consistent by province although inconsistent by expectations specification. For all three provinces, the current price estimation yields less elastic parameters than the other estimations. Within specifications, the share parameters and elasticities are very similar for the Java provinces and suggest very little inter-provincial variation in farmer behavior or technology. Fertilizer demand is quite price responsive although the rice yield to fertilizer price elasticities are quite small, generally less than -.1. These results together with a fairly elastic rice yield to output price elasticity suggest that there is scope to raise fertilizer prices without reducing the growth in rice yields and farm incomes too much, if at all. This is particularly true if rice output prices keep pace with inflation. The estimated parameters suggest that the output price has a 5-6 times greater impact on yields than the fertilizer price.

Although slightly less statistically significant, the corn and dryland rice estimations yield the same general conclusions

Wetland Rice

Estimated Parameter (T-stat)	West Java				Central Java				East Java			
	Current Price	Lagged Price	Floor Price	Adaptive	Current Price	Lagged Price	Floor Price	Adaptive	Current Price	Lagged Price	Floor Price	Adaptive
Share Labor	-0.433	-0.396	-0.387	-0.41	-0.385	-0.296	-0.337	-0.355	-0.345	-0.332	-0.322	-0.336
	(23.69)	(15.43)	(17.56)	(14.30)	(14.84)	(7.23)	(9.35)	(9.09)	(12.80)	(8.95)	(9.57)	(10.90)
Share Fertilizer	-0.078	-0.065	-0.073	-0.075	-0.08	-0.053	-0.072	-0.079	-0.08	-0.065	-0.087	-0.099
	(16.12)	(9.61)	(12.11)	(9.91)	(14.47)	(4.94)	(8.03)	(8.00)	(14.81)	(6.30)	(7.73)	(7.91)
Yield/Wage	-0.351	-0.46	-0.467	-0.391	-0.176	-0.373	-0.29	-0.229	-0.148	-0.307	-0.268	-0.234
	(10.00)	(7.24)	(7.41)	(5.47)	(5.06)	(4.62)	(3.59)	(3.43)	(4.56)	(5.36)	(6.06)	(5.85)
Yield/Fertilizer Price	-0.04	-0.083	-0.087	-0.078	-0.031	-0.106	-0.087	-0.082	-0.003	-0.145	-0.13	-0.136
	(3.94)	(4.44)	(5.23)	(3.91)	(2.77)	(4.15)	(3.79)	(4.30)	(.22)	(5.31)	(6.55)	(7.13)
Yield/Output Price	0.391	0.543	0.554	0.469	0.207	0.479	0.378	0.311	0.152	0.453	0.398	0.375
	(9.22)	(6.77)	(7.14)	(5.25)	(5.10)	(4.68)	(3.77)	(3.76)	(3.59)	(5.62)	(6.64)	(6.61)
Labor Use/Wage	-1.16	-1.498	-1.6	-1.313	-0.64	-1.375	-1.073	-0.884	-0.649	-0.994	-1.024	-0.929
	(10.36)	(7.06)	(7.65)	(5.55)	(5.56)	(3.68)	(3.37)	(3.54)	(6.48)	(5.25)	(6.08)	(6.69)
Labor Use/Fertilizer Price	-0.065	-0.199	-0.161	-0.105	-0.029	-0.324	-0.142	-0.042	0.036	-0.301	-0.15	-0.091
	(1.78)	(3.13)	(2.85)	(1.59)	(.73)	(2.55)	(1.56)	(.59)	(.94)	(3.12)	(2.33)	(1.62)
Labor Use/Output Price	1.224	1.697	1.763	1.418	0.669	1.699	1.215	0.926	0.613	1.294	1.174	1.02
	(9.61)	(6.56)	(7.08)	(4.86)	(5.30)	(3.54)	(3.12)	(3.04)	(5.01)	(4.77)	(5.42)	(5.58)
Fertilizer/Fertilizer Price	-0.413	-0.652	-0.886	-0.964	-0.429	-0.893	-1.052	-1.3	-0.214	-1.586	-1.55	-1.665
	(2.84)	(4.10)	(6.26)	(5.97)	(2.52)	(3.67)	(6.27)	(7.72)	(1.38)	(5.13)	(8.74)	(10.54)
Fertilizer/Wage	-0.356	-1.205	-0.859	-0.576	-0.141	-1.83	-0.664	-0.186	0.157	-1.53	-0.551	-0.309
	(1.66)	(2.71)	(2.60)	(1.50)	(.702)	(2.05)	(1.45)	(.58)	(.97)	(2.54)	(2.14)	(1.56)
Fertilizer/Output Price	0.77	1.857	1.745	1.54	0.57	2.73	1.717	1.486	0.057	3.115	2.1	1.974
	(3.83)	(3.85)	(4.97)	(3.39)	(2.72)	(2.65)	(3.08)	(3.50)	(.22)	(3.56)	(5.24)	(6.02)

Corn

Estimated Parameter (T-stat)	West Java			Central Java			East Java		
	Current Price	Lagged Price	Adaptive	Current Price	Lagged Price	Adaptive	Current Price	Lagged Price	Adaptive
Share Labor	-0.382	-0.368	-0.316	-0.183	-0.18	-0.162	-0.274	-0.22	-0.266
	(6.94)	(7.56)	(8.27)	(12.67)	(11.37)	(8.82)	(12.18)	(10.82)	(9.89)
Share Fertilizer	-0.089	-0.092	-0.089	-0.057	-0.061	-0.062	-0.107	-0.088	-0.1
	(5.60)	(6.87)	(7.97)	(11.10)	(10.23)	(10.49)	(12.89)	(12.39)	(10.24)
Yield/Wage	-0.312	-0.44	-0.4	-0.258	-0.24	-0.304	-0.184	-0.246	-0.194
	(1.56)	(3.25)	(4.02)	(4.80)	(2.58)	(5.05)	(6.30)	(5.59)	(5.61)
Yield/Fertilizer Price	-0.052	-0.101	-0.093	-0.055	-0.074	-0.077	-0.074	-0.109	-0.085
	(1.04)	(3.04)	(4.07)	(2.93)	(2.28)	(3.81)	(3.85)	(5.26)	(4.16)
Yield/Output Price	0.364	0.541	0.493	0.313	0.314	0.381	0.258	0.355	0.279
	(1.55)	(3.44)	(4.38)	(4.53)	(2.63)	(4.96)	(5.91)	(5.78)	(5.50)
Labor Use/Wage	-1.217	-1.628	-1.747	-1.635	-1.543	-2.16	-0.951	-1.317	-0.978
	(2.08)	(4.21)	(4.75)	(4.97)	(2.87)	(4.52)	(9.54)	(5.50)	(7.30)
Labor Use/Fertilizer Price	0.015	-0.118	-0.032	-0.11	-0.112	-0.139	0.025	-0.147	-0.017
	(.10)	(1.09)	(.32)	(1.16)	(.72)	(1.14)	(.54)	(1.68)	(.29)
Labor Use/Output Price	1.202	1.745	1.779	1.745	1.655	2.299	0.926	1.464	0.996
	(1.79)	(4.18)	(4.53)	(4.31)	(2.52)	(4.04)	(6.79)	(4.61)	(5.41)
Fertilizer/Fertilizer Price	-0.921	-1.139	-1.345	-0.844	-1.174	-1.151	-1.015	-1.258	-1.12
	(3.39)	(5.94)	(7.84)	(5.18)	(5.76)	(8.14)	(6.07)	(8.71)	(6.21)
Fertilizer/Wage	0.062	-0.473	-0.114	-0.353	-0.333	-0.362	0.064	-0.369	-0.046
	(.19)	(1.05)	(.31)	(1.14)	(.71)	(1.14)	(.54)	(1.67)	(.29)
Fertilizer/Output Price	0.858	1.612	1.459	1.197	1.507	1.513	0.951	1.627	1.165
	(1.18)	(3.81)	(4.53)	(2.93)	(2.38)	(3.56)	(3.80)	(4.80)	(3.79)

Dryland Rice

Estimated Parameter (T-stat)	West Java				Central Java				East Java			
	Current Price	Lagged Price	Floor Price	Adaptive	Current Price	Lagged Price	Floor Price	Adaptive	Current Price	Lagged Price	Floor Price	Adaptive
Share Labor	-0.488	-0.419	-0.445	-0.472	-0.481	-0.508	-0.518	-0.537	-0.615	-0.496	-0.531	-0.48
	(10.99)	(6.96)	(8.78)	(6.77)	(9.20)	(7.74)	(10.39)	(10.62)	(6.47)	(6.03)	(4.89)	(5.29)
Share Fertilizer	-0.111	-0.098	-0.099	-0.106	-0.085	-0.061	-0.094	-0.101	-0.25	-0.134	-0.194	-0.182
	(8.87)	(7.66)	(8.29)	(7.64)	(7.22)	(3.53)	(6.86)	(7.01)	(8.00)	(5.99)	(6.66)	(6.82)
Yield/Wage	-0.241	-0.299	-0.292	-0.193	-0.207	-0.367	-0.297	-0.199	-0.05	-0.235	-0.067	-0.082
	(3.37)	(2.45)	(2.69)	(1.71)	(3.81)	(5.79)	(3.67)	(3.04)	(.66)	(2.17)	(.82)	(1.02)
Yield/Fertilizer Price	-0.054	-0.05	-0.054	-0.043	-0.015	-0.093	-0.137	-0.001	-0.132	-0.145	-0.177	-0.129
	(3.14)	(2.46)	(2.77)	(2.13)	(.54)	(3.23)	(3.41)	(.04)	(4.20)	(3.74)	(5.48)	(4.20)
Yield/Output Price	0.295	0.349	0.346	0.236	0.222	0.46	0.434	0.2	0.182	0.38	0.244	0.21
	(4.04)	(2.67)	(2.94)	(1.97)	(3.13)	(5.61)	(3.82)	(2.29)	(1.82)	(2.70)	(2.34)	(2.06)
Labor Use/Wage	-1.007	-1.263	-1.16	-0.862	-0.637	-0.918	-0.74	-0.629	-0.328	-0.627	-0.266	-0.383
	(4.20)	(2.77)	(3.19)	(2.22)	(5.51)	(7.18)	(4.05)	(4.65)	(1.85)	(2.15)	(1.16)	(1.61)
Labor Use/Fertilizer Price	0.218	0.181	0.147	0.216	-0.039	-0.216	-0.137	0.022	0.178	-0.145	-0.048	0.1
	(3.13)	(1.88)	(1.80)	(2.59)	(.77)	(3.32)	(2.20)	(.32)	(2.29)	(1.44)	(.71)	(1.54)
Labor Use/Output Price	0.789	1.083	1.014	0.646	0.676	1.133	0.925	0.607	0.15	0.772	0.218	0.283
	(3.56)	(2.39)	(2.73)	(1.68)	(4.64)	(6.99)	(3.72)	(3.25)	(.69)	(2.06)	(.84)	(1.04)
Fertilizer/Fertilizer Price	-1.727	-1.54	-1.502	-1.603	-0.052	-0.586	-1.329	-0.137	-1.424	-1.232	-1.703	-1.435
	(12.25)	(13.22)	(12.88)	(11.79)	(.14)	(1.51)	(4.45)	(.42)	(17.79)	(6.55)	(10.45)	(10.64)
Fertilizer/Wage	0.953	0.765	0.659	0.964	-0.219	-1.793	-1.017	0.117	0.438	-0.537	0.131	0.263
	(3.54)	(2.30)	(2.09)	(3.24)	(.73)	(2.07)	(1.95)	(.33)	(2.61)	(1.40)	(.74)	(1.61)
Fertilizer/Output Price	0.774	0.775	0.843	0.639	0.271	2.379	2.347	0.021	0.987	1.769	1.573	1.173
	(3.51)	(2.45)	(2.82)	(2.18)	(.55)	(2.30)	(3.09)	(.04)	(5.00)	(3.32)	(5.55)	(4.70)

as wetland rice and the estimated parameters are of the same order of magnitude. Both the corn and dryrice results indicate that fertilizer demand is considerably more responsive to changes in fertilizer prices than yields. The yield/output price elasticities are also quite elastic.

The estimation results, then, indicate that there is scope for phasing out fertilizer subsidies without substantially reducing growth in food crops production and farmer incomes. Yield/fertilizer price elasticities are low and fertilizer input costs are generally less than 10 percent of profits from crop production. Although quite low, the estimated yield/fertilizer price elasticities do suggest that ceteris paribus yields will fall if fertilizer prices increase substantially. For example, an elasticity of -.1 implies a 3 percent reduction in yields with a 30 percent rise in fertilizer prices. However, a yield reduction of this magnitude probably only applies to nitrogen (urea) and perhaps sulfur (ZA). There is strong agronomic evidence (Manwan and Fagi and Adiningsih et al., 1989) in Indonesia that TSP and KCl applications could be reduced substantially with no impact on crop yields (but with considerable savings to the government budget). Therefore, price differentials should widen in the future for fertilizers; TSP and KCl prices should be much higher than those for urea and ZA and the economic subsidy (i.e. that measured relative to world prices) should be phased out more quickly for TSP and KCl.

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