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Short Communication

Do Price Subsidies Lead to Over Application of Fertilizers? An Analysis of *Kethata-Aruna* Program of Sri Lanka

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ABSTRACT: *Paddy sector has always been given special treatments by successive governments of Sri Lanka and among the treatments, provision of subsidized fertilizer to small-scale paddy farmers has been recorded as the most expensive program. It has been argued that provision of subsidies had led to the sub-optimum application of fertilizers. This study examined the pattern of chemical fertilizer application by the farmers and paddy yields during the period 2005-2015 where a price subsidy on fertilizer was implemented. During this period, the chemical fertilizer levels recommended by the Department of Agriculture were provided at a rate of Rs. 350 per 50 kg bag to the paddy farmers by the Agrarian Service Centres. A production function was estimated in quadratic form using data extracted from cost of cultivation reports of the Department of Agriculture to determine the effects of application of fertilizer on paddy yields. The results of econometric estimation revealed that the effect of urea application on yield was positive and statistically ($p<0.05$) significant. A simulation exercise was performed to compare potential urea application levels under alternative fertilizer price levels for a profit maximizing farmer. The results indicated a potential over application of fertilizers beyond the recommended levels under the subsidized price levels. However, in practice, farmers could not purchase quantities that would have given them the maximum possible profit as only the recommended levels were provided under the subsidy scheme. The results further indicated that profit maximizing farmers may continue to use urea fertilizers even if the price subsidy is removed.*

Keywords*: Urea fertilizer, input subsidy, paddy farming, Sri Lanka*

INTRODUCTION

Provision of incentives to apply more chemical fertilizers in Sri Lanka was initiated in 1962 with the introduction of High Yielding Variety (HYV). The HYVs are highly responsive for fertilizers and hence it was essential to apply inorganic fertilizers to achieve expected yields. The overall aims of providing a subsidy on fertilizers were to enhance the land productivity and to reduce the cost of production of paddy farming, thereby to increase the profitability of paddy farming (Weerahewa *et al*., 2010).

The subsidy program for fertilizers prevailed from 2005 to 2015 was named as *Kethata Aruna* program. It was initially targeted small paddy farmers who cultivated less than five acres of

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land. The farmers were provided with the recommended quantities of Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MOP) by the Department of Agriculture (DoA) at the rate of Rs.350.00 per 50 kg through the Department of Agrarian Service Centers. In 2006, tea, coconut and rubber smallholders (with less than five acres of holding size) also became eligible for the subsidy. The program was expanded to cover all other crops in 2011 and fertilizers were provided at a rate of Rs. 1,200.00 per 50 kg bag for all other crops. According to the Ministry of Finance and Planning, approximately 91.5% of the total cost of fertilizers subsidized during the program. Even though, the targeted benefits through the *Kethta Aruna* program were to increase rice productivity, to reduce the cost of food imports, to reduce farmers' cost of production and to channel the benefits to consumers (MADAS, 2007). Mixed effects of the program on the paddy economy have been observed. Some claim that the program led to over application of fertilizers which led to pollution of water bodies and some health issues of the country (Wimalawansa, 2014).

A few studies addressed the effects of fertilizer subsidy scheme on fertilizer application rates and paddy yields. Wickramasinghe *et al*. (2009) found that this fertilizer subsidy changed the fertilizer application patterns and increased paddy yields within Sri Lanka. Semsinghe (2014) found that the fertilizers subsidy scheme increased private benefits of paddy cultivation due to reductions in the cost of fertilizers application at farm level. Ekanayake (2009) indicated that fertilizer application rate is mainly determined by the paddy price and the effect of fertilizer price is rather small.

Production function is an appropriate model to determine the nature of the technical relationship between fertilizer and paddy yields though it has not been widely used by the previous authors to address issues with respect to fertilizer subsidy program in Sri Lanka. This approach however has been used to address various other issues in paddy cultivation. Abeysekara (1980) revealed that paddy production in *Maha* season was highly responsive to the application of fertilizers and the availability of labour and it was negatively affected by other agro-chemicals application. Furthermore, coefficient estimates revealed that paddy production technology was characterized by increasing returns to scale. Karunaratne and Herath (1989) found that there are significant differences in yield between *Maha* season and *Yala* season. *Yala* season cultivation was significantly affected by land, fertilizer application, agrochemicals and family labour while the extent of land and fertilizers use affect paddy production in *Maha* season. In both seasons hired labour did not have a significant effect on production. Udayanganie *et al*. (2006) revealed that the extent of cultivation, fertilizers usage and pesticide usage significantly influenced paddy production during the 2003/04 *Maha* season. This paper examines the optimal application rates of fertilizer for a profit-maximizing paddy farmer using coefficients of an econometrically estimated production function.

METHODOLOGY

Specification and estimation of the production function

Among different types of production function specifications, the quadratic form was selected for the estimation in this study as it allows identification of a local maximum or a minimum. With a local maximum, the corresponding marginal product declines as input usage increases, then becomes zero when the output is at its maximum and takes negative values thereafter. The specification adopted is given below (Equation 1) and the description of variables are presented in Table 1.

$$Yiled = \alpha + \beta_1(Season) + \beta_2(Irrgation\,) + \beta_3(Trend) + \beta_4(Machinery) + \beta_5(Seed\,) + \beta_6(Urea) + \beta_7(TSP) + \beta_8(MOP) + \beta_9(Labour) + \beta_{10}(Machinery\; * Machinery\,) + \beta_{11}(Seed * Seed\,) + \beta_{12}(Urea * Urea) + \beta_{13}(TSP * TSP) + \beta_{14}(MOP * MOP) + \beta_{15}(Labour * Labour) \quad \text{…………} (1)$$

where, α and β are parameter esetimates.

Table 1. Description of variables in the production function

Category	Variable name	Description	Units
Dependent Variable	Yield	Average Yield	kg/acre
Independent Variables	Trend	Year	1 for 2005… 11 for 2015
	Irrigation	Irrigation regime	Dummy D=0, Rain-fed D=1, Irrigated
	Season	Cultivating season	Dummy D=0, *Maha* season D=1, *Yala* season
	Machinery	Total machinery cost per season in real monetary value (base year 2002)	Rs. /acre
	Seed	Seed paddy used per season	kg/acre
	Urea	Total Urea application per season	kg/acre
	TSP	Total TSP application per season	kg/acre
	MOP	Total MOP application per season	kg/acre
	Labour	Hired and Family labor per season	Man-days/acre

Optimum level of fertilizer application*:*

The optimum level of Urea application is defined as the application level where the Marginal Value Product (MVP) of Urea is equal to the Marginal Factor Cost of Urea which is the price of Urea.

Marginal product of Urea is given by:

$$MPP_{Urea} = \beta_6 + 2(\,\beta_{12} * Urea) \quad \text{……………} (2)$$

where,

$MPP_{Urea} = Margina\ Physical\ Product\ of\ Urea$

$\beta_6 \quad = Coefficient\ of\ Urea\ in\ the\ Production\ Function$

$\beta_{12} \quad = Coefficinet\ of\ the\ Interaction\ Term\ of\ Urea\ \ in\ Production\ Function$

Marginal value product of Urea is given by:

$$MVP_{Urea} = MPP_{Urea} * P_{Paddy}$$

$$MVP_{Urea} = \{\beta_6 + 2(\,\beta_{12} * Urea)\} * P_{Paddy} \quad \text{………..…………………} (3)$$

where,

$MVP_{Urea} = Marginal\ Value\ Product\ of\ Urea$ and $P_{Paddy} \quad = Output\ Price\ of\ Paddy.$

Optimality condition is given by:

$$MVP_{Urea} = P_{Urea}$$
$$\{\beta_6 + 2(\beta_{12} * Urea)\} * P_{Paddy} = P_{Urea}$$

Optimum level of Urea is given by:

$$Urea = \frac{P_{Urea}}{2(P_{Paddy}* \beta_{12})} - \frac{\beta_6}{2\beta_{12}} \ldots\ldots\ldots\ldots\ldots (4)$$

Price of Urea (P_{Urea}) depends on the scenario under consideration. With the fertilizers subsidy scheme, price of Urea is subsidized price. If fertilizers subsidy is completely removed, then the price of Urea is the market price of Urea. At maximum yield level price of Urea should be zero, according to production theory. The price of Urea that gives rise to a particular Urea application is given by:

$$P_{Urea} = \{\beta_6 + 2(\beta_{12} * Urea)\} * P_{Paddy} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Sources of data

Secondary data gathered from Cost of Cultivation reports of the Department of Agriculture, Sri Lanka published during 20015-2015 was used. Data on seed paddy, labor, machinery, fertilizers and paddy production at district level data for main cropping seasons (*Yala* season and *Maha* season) at different irrigation management (rainfed and irrigated) were employed. The main type of fertilizers considered were Urea, MOP and TSP while the fertilizers recommendation (2001 and 2013) for paddy by the Department of Agriculture was fixed as crop requirement of fertilizer. Fertilizers' price data were obtained from the annual reports of the Ministry of Finance and Planning. The farming locations covered were *Ampara*, *Anuradhapura, Hambantota, Kurunegala*, *Mannar, Polonnaruwa, Mahaweli (B, C, H), Trincomalee, Gampaha, Kalurata* and *Kandy*. Altogether 234 observations were used in the study for different years with uneven distribution over the years.

RESULTS AND DISCUSSION

Descriptive statistics

Table 2 presents the descriptive statistics of the data used for the estimation. Inputs include seed paddy, machinery, labour and fertilizers application. Urea, TSP and MOP were the types of fertilizer considered for the study. Both family labour and hired labour were included in variable "labour". Cost of machinery use was included as a monetary value.

Table 2. Descriptive statistics of the variable.

Variable Name	Units	Mean	SD	Minimum	Maximum
Yield	kg/acre	1,897.14	431.82	706.00	2,826.00
Machinery	Rs. /acre	5,097.61	1,166.49	809.80	7,885.35
Seed	kg/acre	49.81	12.93	36.23	99.30
Urea	kg/acre	92.48	23.11	36.00	146.00
TSP	kg/acre	31.86	7.20	13.00	59.00
MOP	kg/acre	32.72	32.72	15.00	60.00
Labour	Man-days/acre	25.02	7.56	13.00	48.00

Results of the estimation of production function

The results of the estimation are presented in Table 3. The goodness of fit of the quadratic functional form was 77.48%. The estimates indicate that irrigated cultivation systems are more productive than rain-fed and the yield differences between the two seasons are statistically significant. Among conventional input used for paddy cultivation, machinery, labour and Urea application significantly affect the paddy yields. Machinery usage negatively affects while application of Urea positively affects the productivity of paddy.

Table 3. Results of estimation of paddy production function in Sri Lanka 2005-2015.

Variable	Coefficient value	S.E.	t value	P value
Season	53.17*	28.03	1.90	0.059
Irrigation	548.12**	54.44	10.07	0.000
Trend	17.55*	9.03	1.94	0.053
Machinery	-0.22**	0. 08	-2.55	0.011
Seed	8.01	11.41	0.70	0.480
Urea	10.61 *	4.69	2.26	0.024
TSP	-4.79	16.52	-0.29	0.772
MOP	20.74	15.12	1.37	0.172
Labour	27.29*	14.03	1.94	0.053
Machinery* Machinery	2.49×10^{-5}**	8.28×10^{-6}	3.00	0.003
Seed*seed	0.01	0.09	0.09	0.927
Urea*Urea	-0.04	0.03	-1.42	0.158
TSP*TSP	-0.02	0.24	-0.08	0.937
MOP*MOP	-0.28	0.21	-1.37	0.172
Labour*Labour	-0.46*	0.24	-1.94	0.053
Constant	205.07	533.39	0.38	0.701

** significant at 5% level * significant at 10%   Source: Authors' estimations

Optimum level fertilizer application in paddy production

Among the three fertilizers, only Urea has a statistically significant effect on the paddy yield and hence optimum levels of Urea under various scenarios were simulated in this study. The following section summarizes the results obtained from the pooled sample.

It is important to note that the average application of Urea in the pooled sample was 92.48 kg/acre and it corresponds to 1,898.40 kg/acre of paddy production. The DOA recommendation of Urea application for the pooled sample is 87.42 kg/acre indicating a slight over-application of Urea by farmers compared to the recommendation. The simulation results indicated that profit-maximizing paddy farmers would maintain the recommended level of application of Urea when Urea is sold at Rs.122.00 per kg at the market. The recommended rate of application will be resulted about 1,844.68 kg/acre of paddy. Table 4 shows the key findings of the simulation exercise.

The results of the production function estimates revealed that the maximum potential yield of 2,476.03 kg/acre of paddy will be achieved when 146.90 kg/acre of Urea is applied. It was found that if an unlimited quantity of Urea fertilizer is sold at Rs. 7.00 per kg, farmers would apply 143.20 kg/acre of Urea and obtain a paddy yield of 2,436.61 kg/acre. This implies that if subsidized Urea is provided without any limits on the quantity, the application corresponds to the application associated with maximum yield. If the government does not intervene to fertilizer market, Urea would be sold at Rs. 60.78 per kilogram. The simulation results revealed that optimal application of Urea at this price would be 116.61kg/acre which will give rise to a yield of 2,154.42 kg/acre.

These results indicate that the actual application is far below the simulated application levels. This under-application is partly due to the quota level associated with the distribution of fertilizers, i.e., subsidized fertilizers were given only up to the recommended rates. It is also since farmers might not be maximizing profits as anticipated.

Table 4. Optimum level of Urea under different conditions: Pooled sample.

Scenario	Level of Urea (kg/acre)	Price of Urea (Rs. /kg)	Paddy yield (kg/acre)
DOA recommendation of application	87.42	122.00	1,844.68
Maximum yield level	146.90		2,476.03
Urea is sold with subsidy: No quota on sales	143.20	7.00	2,436.61
Urea is sold at market prices	116.61	60.78	2,154.42
Actual fertilizer application by farmers	92.48		1,898.40

The above results mask the variability within and across geographical locations, seasons and years. The following sections provide optimum levels of Urea for main paddy producing areas for *Yala* season and *Maha* season. *Ampara, Anuradhapura, Hambanthota, Polonnaruwa* and *Kurunegala* were selected as dry zone districts and *Gampaha, Kandy and Kaluthra* were chosen as the wet zone for the analysis. The year 2014 was used as the reference year.

Tables 5 and 6 present the key results for dry zone districts. The application of Urea in *Ampara* and *Kurunegala* (irrigated) slightly deviated from the recommended level. In *Maha* season actual yields in different locations were varied between 2,062.70 kg/acre to 2,346.00 kg/acre. Even though profit-maximizing paddy farmer is expected to apply 144.00kg/acre of Urea, the actual application was around 50kg/acre less than this amount. Under free market price, the Urea application level for a profit-maximizing farmer range from 122.00 kg/acre to 128.00kg/acre and if farmers in dry zone aim maximize yield 147.00kg/ha of Urea should be applied. The level is far more of the DOA recommendation level of Urea.

Table 5. Expected yield level, Urea level and price of Urea under different policy perspectives for *Maha* season in dry zone areas

Variable	Location	WS[2]	WOS	DOAR	MY	AFA[3]
Paddy yield (kg/acre)	*Ampara East*	2,802.13	2,599.63	2,224.00	2,828.03	2,234.61
	Ampara West	2,750.40	2,563.44	2,170.28	2,774.32	2,117.22
	Anuradhapura	2,787.73	2,576.67	2,210.69	2,814.73	2,210.69
	Hambanthota	2,927.30	2,744.59	2,346.64	2,950.67	2,346.64
	Kurunegala (RF)	2,635.84	2,398.86	2,062.70	2,666.74	2,062.70
	Kurunegala (IR)	2,621.11	2,410.22	2,044.05	2,648.09	2,097.12
	Pollonnaruwa	2,660.01	2,434.60	2,085.36	2,689.40	2,085.36
Price of Urea (Rs. /kg)	*Ampara East*	7.00	61.72	163.22		
	Ampara West	7.00	61.72	176.79		
	Anuradhapura	7.00	61.72	156.61		
	Hambanthota	7.00	61.72	180.9		
	Kurunegala (RF)	7.00	60.70	136.87		
	Kurunegala (IR)	7.00	61.72	156.73		
	Polonnaruwa	7.00	60.70	143.90		
Level of Urea (kg/acre)	*Ampara East*	144.47	125.39	90.00	146.91	91.00
	Ampara West	144.66	127.05	90.00	146.91	85.00
	Anuradhapura	144.37	124.48	90.00	146.91	90.00
	Hambanthota	144.71	127.5	90.00	146.91	90.00
	Kurunegala (RF)	144.00	121.67	90.00	146.91	90.00
	Kurunegala (IR)	144.37	124.50	90.00	146.91	95.00
	Polonnaruwa	144.15	122.91	90.00	146.91	90.00

Note: WS: With Fertilizer Subsidy, WOS: Without Fertilizer Subsidy, DOAR: Department of Agriculture Fertilizer Recommendation, MY: Maximum Yield Level, AFA: Actual fertilizer Application by Farmers, RF: Rainfed, IR: Irrigated

[2] WS indicate the simulations with subsidy and without quota of fertilizer.

[3] AFA indicate the actual fertilizer application and paddy yield obtained by paddy farmers with subsidy under quota of fertilizer issues.

Table 6. Expected yield level, Urea level and price of Urea under different policy perspectives for *Yala* season in dry zone areas

Variable	Location	WS	WOS	DOAR	MY	AFA
Paddy yield (kg/acre)	*Ampara East*	2,784.52	2,527.37	2,214.01	2,818.04	2,192.78
	Ampara West	2,603.73	2,369.63	2,030.21	2,634.25	2,030.21
	Anuradhapura	2,679.90	2,430.79	2,108.34	2,712.37	2,044.66
	Hambanthota	2,856.33	2,601.83	2,285.47	2,889.5	2,285.47
	Kurunegala (RF)	2,080.42	1,829.88	1,296.78	2,113.07	1,286.17
	Kurunegala (IR)	2,198.81	1,971.71	1,411.56	2,227.86	1,369.11
	Polonnaruwa	2,705.28	2,496.03	2,128.01	2,732.05	2,011.27
Price of Urea (Rs./ kg)	*Ampara East*	7.00	60.70	126.14		
	Ampara West	7.00	60.70	138.56		
	Anuradhapura	7.00	60.70	130.21		
	Hambanthota	7.00	60.70	127.46		
	Kurunegala (RF)	7.00	60.70	174.97		
	Kurunegala (IR)	7.00	61.72	196.69		
	Polonnaruwa	7.00	61.72	157.96		
Level of Urea (kg/acre)	*Ampara East*	143.76	119.53	90.00	146.91	88.00
	Ampara West	144.04	121.98	90.00	146.91	90.00
	Anuradhapura	143.86	120.38	90.00	146.91	84.00
	Hambanthota	143.79	119.81	90.00	146.91	90.00
	Kurunegala (RF)	143.84	120.23	70.00	146.91	69.00
	Kurunegala (IR)	144.18	122.78	70.00	146.91	66.00
	Polonnaruwa	144.39	124.68	90.00	146.91	79.00

Note: WS: With Fertilizer Subsidy, WOS: Without Fertilizer Subsidy, DOAR: Department of Agriculture Fertilizer Recommendation, MY: Maximum Yield Level, AFA: Actual fertilizer Application by Farmers, RF: Rainfed, IR: Irrigated

As depicted in Tables 7 and 8, recommended levels of Urea are lesser for the wet zone compared to those for the dry zone. With the subsidy Urea application rate is more uniform across the locations in wet zone. If subsidy is eliminated, Urea would be sold around 60.00 Rs. /kg and profit-maximizing paddy farmers in the wet zone would apply 118.00 – 125.00 kg/acre of Urea.

Table 7. Expected yield level, Urea level and price of Urea under different policy perspectives for *Maha* season in wet zone areas

Variable	Location	WS	WOS	DOAR	MY	AFA
Paddy yield (kg/acre)	*Gampaha*	2,274.56	2,034.25	1,171.21	2,305.89	1,277.34
	Kaluthara	2,343.35	2,080.37	1,242.94	2,377.63	1,242.94
	Kandy	2,352.12	2,089.15	1,251.72	2,386.40	1,251.72
Price of Urea (Rs./ kg)	*Gampaha*	7.00	60.70	253.56		
	Kaluthara	7.00	60.70	231.7		
	Kandy	7.00	60.70	231.7		
Level of Urea (kg/acre)	*Gampaha*	143.96	121.32	40.00	146.91	50.00
	Kaluthara	143.68	118.91	40.00	146.91	40.00
	Kandy	143.68	118.91	40.00	146.91	40.00

Note: WS: With Fertilizer Subsidy, WOS: Without Fertilizer Subsidy, DOAR: Department of Agriculture Fertilizer Recommendation, MY: Maximum Yield Level, AFA: Actual fertilizer Application by Farmers,

Table 8. Expected yield level, Urea level and price of Urea under different policy perspectives for *Yala* season in wet zone areas

Variable	Location	WS	WOS	DOAR	MY	AFA
Paddy yield (kg/acre)	*Gampaha*	2,310.20	2,062.84	1,207.16	2,341.85	1,313.29
	Kaluthara	2,621.11	2,410.22	2,044.05	2,648.09	2,097.12
	Kandy	2,377.85	2,109.88	1,277.45	2,412.13	1,457.87
Price of Urea (Rs./ kg)	*Gampaha*	7.00	61.72	251.01		
	Kaluthara	7.00	61.72	156.73		
	Kandy	7.00	61.72	231.70		
Level of Urea (kg/acre)	*Gampaha*	143.93	120.63	40.00	146.91	50.00
	Kaluthara	144.37	124.50	90.00	146.91	95.00
	Kandy	143.68	118.44	40.00	146.91	57.00

Note: WS: With Fertilizer Subsidy, WOS: Without Fertilizer Subsidy, DOAR: Department of Agriculture Fertilizer Recommendation, MY: Maximum Yield Level, AFA: Actual fertilizer Application by Farmers,

CONCLUSIONS

Since the price subsidy for fertilizers prevailed in Sri Lanka was associated with a quota system, farmers could not purchase quantities of urea fertilizer that would have given them the maximum possible profits. The results further indicate that profit-maximizing paddy farmers may continue to use Urea fertilizers even if the price subsidy is removed and with the removal of the quota associated with the price subsidy.

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