An Economic Analysis on Water Pollution Impact of Fossil Fuel Power Station on Agriculture: A Case of Onion Cultivation in Sri Lanka

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Introduction

Economic liberalization creates higher demand for electricity through industrial expansion, urbanization and improved life style of people. Increased demand over electricity could not only fulfill by renewable resources (such as water, solar radiation, biomass, wind and waves) based power generation, instead many countries established fossil fuel power plants where generally coal, gasoline, diesel, crude oil, nuclear and natural gases have been highly used to generate power which emit harmful emissions like chemicals, oil to the environment and create various negative impacts on nature, society and economy. According to Shamshad et al. (2012) and Kumar et al. (2013) such power plants have serious negative impact on land, soil, air, water and on human health as well as leads to various social consequences.

Emission of oil and crease wastes into the water sources by fossil fuel power stations is one of the major environmental and economic issue, which leads to water and land pollution that results in loss of biodiversity, increasing human health hazards, decreasing agricultural cultivation and deprivation of livelihood avenues of poor families and also caused to indirect impacts on income, unemployment and poverty. A study by the World Bank (2007) estimated that water pollution caused by power stations leads to loss of 12 percent yield reduction in agriculture. Khai & Yabe (2012) analyzed the impact of industrial water pollution on rice production in Vietnam and identified yield loss in rice production, and which is about 0.67 tons/hectare/crop and the profit loss is about 26 percent. Khait et al. (2014) analyzed quality of surface and ground water around the thermal power plants and found that the people living in surrounding villages have impact on their health and local biota.

With the end of civil war in 2009 in Sri Lanka, resettlement process and rehabilitation of economic activities in the Northern and Eastern provinces induced higher industrial and domestic demand for electricity which leads to expansion of fossil fuel power stations in the region. Over one third of the families living in Jaffna district (about 63,280 families) have been depended on agriculture for their livelihood and income. Hence, establishment of the fossil fuel power plants closer to the agricultural firms in the Jaffna district has been experiencing heavy emissions of oil and crease wastes into the inland water source which create water and land pollution finally have negative impacts on agricultural cultivation, human health and biodiversity Central Environmental Authority (2014).

While there has been many studies such as Effects of thermal power plant on Environmental Pokala (2011), Environmental Impact of Thermal Power Plant for Sustainable Development Kumar et al (2013) and Quality Assessment of Surface and Ground Water around Thermal Power Plants Khati et al (2014) conducted to estimate statistically the impact of power station caused water pollution on agricultural in many countries, such effort is lacking in Sri Lanka and the researchers, government policy makers still pay less attention in this area. Especially, the economic aspects on impact of fossil fuel power station caused water pollution on agricultural cultivation in the Jaffna district is not yet adequately explored.

Objective

This study attempts to conduct an economic analysis on water pollution impact of fossil fuel power station on agricultural cultivation, focusing the onion cultivation in Jaffna district of Sri Lanka. The study evaluate especially the economic impacts of the water pollution considering production, cost and profits structure of the onion cultivation activity by adopting Production, Profit and Cost functions approaches.

Methodology

This study uses primary data collected from two Divisional Secretariat Divisions (DSD) of the Jaffna district: i.e Valikamam South and Valikamam East, both reflect uniform environmental, economic and social characteristics but vary from inland water pollution level caused by fossil fuel power plant. Ground water sources of Valikamam South are identified as contaminated and the Valikamam east as non-contaminated due to emissions from fossil fuel power station based on classification done by Disaster Management Centre in 2015. Eighty agricultural families using ground water for their agricultural activities were selected using stratified random sampling method from above each DSD and primary data were collected from these families by using semi-structured questionnaires, interviews and observations in 2015. The necessary secondary information was collected from reliable official sources.

Theoretical and Functional Models: Kai and Yabe (2012) recommended to estimate economic impacts by using three functions related to the production, cost and profit which is adopted in this study considering most suitable to reach the objective. Hence, the functional forms of the study models have been developed by using neo classical theory which provide basis to modify the Production, Cost and Profit functions of onion cultivation by incorporating water pollution caused by fossil fuel power station as an independent variable that determine the production, cost and profit of the onion cultivations as given below with functional models:

Production Function: $Y = f(L, K, I, E_d, D_W, D_E, D_G)$ (1)

Cost Function: $C = f(W_h, W_f, Ws, E_d, R_c, Y, D_E, D_G, D_w)$ (2)

Profit Function: $\pi = f(W_i, W_s, F_c, E_d, E_x, Y, D_G, D_w)$ (3)

where, Y: yield of onion (Thousand Rs/ Sq Km); C: total cost of a firm (thousand Rs/ Sq km); π: total profit of a firm (thousand Rs/ Sq Km) it indicatestTotal revenue minus variable cost, L: labour (man-day/Sq Km); K: capital (thousand Rs/ Sq Km); I: average cost of inputs (Kg/Sq) [seeds (Kg), fertilizers (Kg), herbicides (ml), pesticides (ml/), fuel (ml), electricity charge (Rs)]; W_h : average price of herbicides & pesticides (Rs/ml); W_f : price of fertilizers (Rs/Kg); W_S : price of seeds (Rs/Kg); R_C : replacement cost of a firm (Rs/ Sq Km); Wi : average price of inputs (Rs/Kg); F_C : fixed cost (thousand Rs/ Sq Km); E_d : education level of the farmer (in years); E_x: experience of the farmer (in years); D_W: location of firm (dummy: if firm is in polluted area = 1, otherwise = 0; D_E : cultivation methods (dummy: if modern technique adopted = 1, otherwise = 0); and D_G : gender (dummy: if men = 1, otherwise = 0)

Econometric Specification: The above three functions are further developed econometrically into Cobb-Douglas production function. These functions are transformed into log-linear form of multiple regression models. This provides econometric basis to identify the water pollution impacts of fossil fuel power station on agricultural cultivation in a linear relation. The Cobb-Douglas models are given as follows:

$$\ln Y_i = \alpha_0 + \alpha_1 \ln L_i + \alpha_2 \ln K_i + \alpha_3 \ln I_i + \alpha_4 \ln Ed_i + \alpha_5 D_{Wi} + \alpha_6 D_{Ei} + \alpha_7 D_{Gi} + \mu_{1i} + U_{1i} \quad (4)$$

$$\ln C_i = \beta_{0+} \beta_1 \ln W_{hi} + \beta_2 \ln W_{fi} + \beta_3 \ln W_{si} + \beta_4 \ln Ed_i + \beta_5 \ln Rc_i + \beta_6 \ln Y_i + \beta_7 D_{Ei} + \beta_8 D_{Gi} + \beta_9 D_{wi} + \mu_{2i} + U_{2i}. \quad (5)$$

$$\ln\pi_i = \delta_0 + \delta_1 \ln W_{ii} + \delta_2 \ln W_{si} + \delta_3 \ln Fc_i + \delta_4 \ln Ed_i + \delta_5 \ln Ex_i + \delta_6 \ln Y_i + \delta_7 D_{Gi} + \delta_8 D_{wi} + \mu_{3i} + U_{3i} \quad (6)$$

Where, α_0, β_0, and δ_0 are intercepts of equation (4), (5) and (6) respectively.
α_1, α_2 ....α_7 are coefficient of explanatory variables of production function.
β_1, β_2............β_9 are the coefficient of explanatory variables of Cost function.
δ_1, δ_2 ....δ_8 are the coefficient of explanatory variables of Profit function.
U_{1i}................U_{3i} are error terms of the equation (4), (5) and (6) respectively.
μ_{1i}.................μ_{3i} are individual specific fixed effect of equation (4), (5) and (6) respectively.

Results and Discussions

The outcome of the Fixed Effect Multiple Linear Regression Model (FEMLRM) (See Annexure I) are given the following three estimated models for production, cost and profit functions respectively.

$$\ln Y = -4.998 + 0.2319 \ln L_i + 0.849 \ln K_i + 0.088 \ln I_i - 0.246 \ln Ed_i - 0.13 D_{Wi} - 0.08 D_{Ei} + 0.037 D_{Gi} + \mu_{1i} + U_{1i} \quad (7)$$

$$\ln C = 4.17 + 0.123 \ln W_{hi} + 0.239 \ln W_{fi} + 0.197 \ln W_{si} - 0.18 \ln Ed_i + 0.129 \ln Rc_i + 0.684 \ln Y_i - 0.32 D_{Ei} + 0.24 D_{Gi} + 1.228 D_{Wi} + \mu_{2i} + U_{2i} \quad (8)$$

$$\ln \pi = 2.96 - 0.675 \ln W_{ii} - 0.264 \ln W_{si} + 0.055 \ln Fc_i - 0.19 \ln Ed_i - 0.012 \ln Ex_i + 1.56 \ln Y_i + 0.255 D_{Gi} - 0.279 D_{Wi} + \mu_{3i} + U_{3i} \quad (9)$$

According to result of FEMLRA, the goodness of fit (R^2) and F-tests of all three models: the Production, Cost and Profit Functions show that all models are statistically significant at 5 % level. The estimation of the Production function (equation 7) explain that explanatory variables of the model; Labour (L) and Capital (K) statistically have positive impact while Education of the farmer (Ed) have negative impact on onion production at 5 % significant level. However, Location of farms (D_W) has statistically negative impact on at 10 % significant level. The estimated values of Cost function (equation 8) shows that independent variables such as Price of fertilizers (W_f), Price of seeds (Ws), Replacement cost of a farmer (R_C), Onion yield of a firm (Y) and Location of farms ($D_{W)}$ have a statistically positive impacts while Cultivation methods (D_E) has statistically negative significant impact on the onion production at 5% significant level. The estimated values of Profit function (equation 9) indicates that the independent variables such as Average price of inputs (Wi), Average price of seeds (Ws) and Location of farms (D_W) have a statistically negative impact on onion profit at 5% significant level but Onion yield of a firm (Y) has a statistically positive impact on the onion profit at only 5% significant level.

Location of firms (D_W) is an important variable of these models have statistically significant negative impacts on production and profit while has statistically significant positive impact on cost. This reflects that the water pollution caused by fossil fuel power station in Jaffna district has negative impacts on onion cultivation which confirms that fossil fuel power plant caused water pollution reduce the agricultural cultivation. The results further shows that the impacts of water pollution caused by emissions from fossil fuel power station contributes negatively to the onion cultivation by 0.13 %, and 0.279 % in the aspect of change in production, and profit respectively but it contributes by 1.228 % positively to the cost structure of onion cultivation, which identify as the negative economic impact on onion cultivation.

Conclusion

The study concludes that the inland water pollution caused by fossil fuel power plants have negative economic impact on agricultural cultivation. In a war recovery situation while larger number of population depend on agriculture for their livelihood and income, the government should give more attention considering it is a more sensitive issue in livelihood building process. The government should implement the necessary action to clean the inland water sources which are already polluted and necessarily be avoided in establishing the fossil fuel power plants closer to the fertile agricultural lands and the land which are highly sensitive to agricultural activities.

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Table 1: Estimated results of production function

Lny	**Coef.**	**Std. Err.**	**t**	**P>|t|**
Lnl	0.231937	0.0874588	2.65	0.01*
Lnk	0.8489009	0.0783896	10.83	0*
Lni	0.0882551	0.0711407	1.24	0.219
lned	-0.246456	0.1017271	-2.42	0.018*
Dw	**-0.1300236**	0.0704315	-1.85	**0.069****
De	-0.0834744	0.0770042	-1.08	0.282
Dg	0.0375158	0.1962465	0.19	0.849
Cons	-4.998053	0.6637364	-7.53	0*

No of observation - 80 R^2= 0.9321 *, ** denotes Significant at 5%, 10% level

Table 2: Estimated result of cost function

	Coef.	**Std. Err.**	**t**	**P>|t|**
lnwh	0.1231434	0.0668833	1.84	0.07**
lnwf	0.2390269	0.0473263	5.05	0*
lnws	0.1971626	0.0922806	2.14	0.036*
Lned	-0.1805051	0.1365697	-1.32	0.191
Lnrc	0.1286792	0.0606608	2.12	0.037*
Lny	0.6839626	0.0593693	11.52	0*
De	-0.3221171	0.0885122	-3.64	0.001*
Dg	0.2432715	0.1870911	1.3	0.198
Dw	**1.228016**	0.5759974	2.13	**0.037***
Cons.	4.167776	0.6166746	6.76	0*

No of observation - 80 R^2= 0.8469 *, ** denotes Significant at 5%,10% level

Table 3: Estimated result of profit function

ln π	Coef.	Std. Err.	t	P>|t|
Lnwi	-0.67498	0.099247	-6.8	0*
Lnws	-0.26388	0.153406	-1.72	0.09**
Lnfc	0.054677	0.045772	1.19	0.236
Lned	-0.19152	0.188853	-1.01	0.314
Lnex	-0.01245	0.09215	-0.14	0.893
Lny	1.559489	0.081323	19.18	0*
Dw	**-0.27885**	0.102621	-2.72	**0.008***
Dg	0.254911	0.339502	0.75	0.455
Cons.	2.958787	0.819682	3.61	0.001*

No of observation - 80 R^2= 0.8871 *, ** denotes Significant at 5% ,10% level