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Policy Instruments for Reducing Nitrogen Fertilizer Based Emission: Under Policy Conflict of Self Sufficiency of Food versus Sustainable Management of Agriculture

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Abstract

The paper discusses an alternative policy instrument to reduce nitrogen fertilizer based emission in agriculture compared to existing fertilizer subsidy for food self-sufficiency policy. The relative efficiency of fertilizer subsidy policy assessed in terms of budgeting resources and sustainable management of agriculture. It concern of nitrogen leaching and other related atmospheric emission control as climate change adaptation. An analytical framework of ex-post evaluation is developed to access the alternative incentive policies instead of fertilizer subsidy in Bangladesh, which may control emission. It observes the preliminary phase fertilizer subsidy policy efficiently contribute to increase food production. Using partial equilibrium analysis marginal productivity of fertilizer found zero or even negative. Although distributional implication of inputs subsidy is quite high but over dozes of cheap fertilization seriously emit the air as well as hampers water quality and soil. Finally, the implication of results suggests that for any kind of reduction or control in nitrogen fertilizer based emission from agriculture, this policy planner could explore the direct incentives programme instead of subsidized fertilizer any more. The existing subsidy policies contribute to use more than optimum level of fertilizer use especially nitrogen-based fertilizer.

Keywords: Policy instruments, sustainable management, nitrogen emission, ex-post evaluation, subsidy, climate change

Introduction

The pathway of sustainable management of agriculture is to enhance the efficiency and effectiveness of input use in production. Fertilizer use in agriculture undoubtedly increases productivity from technological advances but gains from resulting increments of fertilizer should review under new circumstances. Inefficient or over applications of fertilizer are now a day, a major problem. Some research finding claimed 70 percent of nitrogen fertilizer applied to crops in developing country is lost to runoff or released into the atmosphere that's contributing coastal "dead zones" and global warming, surface water quality degradation [1].

Under the policy goal of food self-sufficiency, most of agriculture inputs like chemical fertilizer were subsidized in Asia. After introduction of HYV rice production technology, chemical fertilizer critically raising the crop yields inevitably. Effort of last three decades all the policy instruments more or less favor for attaining the self-sufficiency in food production. It time to re-thinking or review existing support policy in the context of global climate change and environmental concern. Especially intensive use of chemical fertilizer substantially creates environmental degradation and atmospheric emission. Moreover most of the countries are conscious about environmental quality, service and adopt sustainable environmental policy.

The agricultural sector is the largest source of N_2O and CH_4 emissions. Rice production is 19 percent responsible of anthropogenic methane emissions [2]. Interestingly, N_2O controlled CH_4 emission in rice field under irrigated condition while nitrogen fertilizer used in dry or rain fed rice production increase N_2O emission. There are about 46 percent of anthropogenic emissions occurred from the CH_4 different oxides of nitrogen [3]. N_2O is an important long-lived greenhouse gas that is emitted predominantly by biological sources in soil and water. The N_2O is also primary source in the stratosphere of the oxides of nitrogen, which play a critical role in controlling the abundance and distribution of stratospheric ozone.

Estimates from ice core measurements; the pre-industrial atmospheric concentration of CH_4 was about 275 ppb (with a range of 260 to 285 ppb). By 2005 this had increased by about 15 percent to a level of 1774 ppb [4]. Direct emissions comes from soil nitrogen e.g. applied fertilizers mainly urea (both manures and artificial), the mineralization of organic soils and crop residues.

The soil is getting weaker and weaker over the last 10 to 15 years over the world with fertilization [5]. We need more and more urea to get the same yield. The over use of urea is so degrading to soil that yields on some crops are falling and import levels are raising [1].

Under the sustainable agriculture management policy, environment friendly agricultural practices are to be encouraged. At the same time it should be ensured self-sufficiency in food for poor country. Among the various specific measures, use of natural fertilizers and insecticides is encouraged as opposed to the application of agro-chemicals and artificial materials that are exerting adverse impact on the environment.

But sudden control by sustainable management of agriculture for reducing the chemical fertilizer use will hammer crop production as

well as food self-sufficiency goal. In these circumstances, what is the optimum solution under policy conflict of self-sufficiency of food and emission reduction through urea use controlled? The paper will try to find answer by an ex-entry evaluation of available policy instruments in Bangladesh.

Methodology

A desk research has been carried out for assessing current nitrogen fertilizer based emission from existing subsidy and self-sufficiency of food policy. Based on published and unpublished data of IPCC, FAO as well as food and agricultural policy documents of Bangladesh were used to analyze the research objectives of the study. The alternative policy options oppose to input subsidy policy evaluated by partial equilibrium analysis is a major focus of the research. Which includes the rationale and systematic analysis of subsidy policy for be validated or refuted in the ground of sustainable use of fertilizer and agro-chemicals.

In economic point of view any policy options could be optimize according to objective function and constraints. If government objective function to optimize production of rice with budgetary constraint, then the least coast combination of inputs that give the highest possible utility is an optimum point. In case of farm level resource use decision optimum use of input could be determine from value product function by using partial derivatives. The resource will be optimum when the marginal value product will be equal to price of the resource. When an intervention of government by subsidizing inputs occurred that the optimum resource use will be optimum at the wasteful use. But if the input price truly reflect in the market than resource use optimum becomes efficient. By the partial equilibrium analysis of the policy option the efficient policy instrument can be chose. The present study aim to evaluate efficient policy instruments for nitrogen fertilizer based emission at Bangladesh case.

The discussion of input subsidy policy consists of a number of sub-sections; these are as follows, discussion of the recent trend of fertilizer subsidy, investigation of rationale for subsidy and deals with the issue of justification of subsidy. In addition to this an ex-ante evaluation of some successful regional and international policy instruments that aiming at control nitrogen based fertilizer use under the perspective of Bangladesh. The following policy instruments have been analyzed qualitatively. Basically, logic behind the fertilized subsidy is intervention to prevent world market price fluctuation of fertilizer and encouraged production by low price input. There is more efficient way of giving incentive through direct compensation payment for volatile price or by assistant card of rationing fertilizer according to area allocation to crop. Introduction of certification system as well as incentive for Fertilizer Best Management Practice (FBMP) of climate change adapted farms. Regulations are imposed for fixing nitrogen vulnerable zone and ceiling of nitrogen per hectare application. Provision of enhancing knowledge based through extension.

Finally the study-analyzed feasibility of proposes policy instruments under the policy goal of self-sufficiency. It also assumes that the policy combination will fully implemented without penetration and adoption measure in the practice.

Discussion

Assessment of existing fertilizer subsidy policy and relevancy to emission

Many developing countries have used inputs subsidies to encourage the use of fertilizer and to offset the effects of low crop prices. It often set by the government or the crop purchasing by the public authority in growing season. A survey of 38 developing countries, by FAO [5] found that 68 percent of the country adapted fertilizer subsidies policy for encourages production. Undoubtedly subsidies can be a useful policy tool during the introduction of fertilizers to the market; the danger is that they become entrenched. After achievement, subsidies are difficult to phase out at a later stage when they are no longer required.

Economic reasoning for providing subsidy for fertilizer is ensuring cheaper agricultural input, for higher production of food grain target. And lower price of staple for higher food security. It helps to closer the food grain production self-sufficiency, less vulnerability to risks of facing high prices of import in the world market [6].

On the contrary, economic reasoning for not providing subsidy for fertilizer is an "inefficient" allocation of resource in the sense that farmers pay for fertilizer a lower price compared to the world price of fertilizer. It is therefore, more incentive to use too much of fertilizer [7]. Continuing with subsidies beyond the introductory phase encourages the wasteful use of fertilizers and it means that the bigger, healthier farmers reap most of the benefits. Experience in Bangladesh showed that a well-managed phasing out of fertilizer subsidies could be achieved without causing a major setback to fertilizer consumption [6].

There is a system loss for target group benefit because some other industrial use of urea likes tobacco industry reaping the benefit of subsidized fertilizer but nothing paid to society. In addition to this illegal border trade of fertilizer with Myanmar and India where urea price is higher easily flow of this and substantially make budgetary pressure to the government of Bangladesh. The key is to synchronize the subsidy removal with the development of a competitive market, which promotes increased efficiency and lower costs.

Yet the counterargument to the second line of argument is with market imperfections such as low access to credit as well as liquidity constraints, farmers already face "*inefficiency*" in allocation of resources, find it difficult to finance fertilizer purchases, and therefore without "*subsidy*" would be using suboptimal amount of fertilizers. Therefore "*subsidy*" is not necessarily introducing "*inefficiency*" in an "*efficient*" world, but may be considered as a "*correcting device*" to address issues of imperfections in the developing country agricultural sector.

There is some political reasoning for providing subsidy for fertilizer; these are requirement of a democratically elected government to meet election pledges for "cheap rice". Since Bangladeshi households are, on average, net buyers of rice, it may be politically costly for the government not to be able to keep rice prices low.

Therefore, the subsidy related literature has two strands of arguments. One is that subsidy for fertilizer keeps prices of fertilizers artificially low as compared to the world price of fertilizers, thus creating an incentive for farmers to use more-than-optimal amount of fertilizers. These would bring inefficiency in the allocation of

resources. One can bolster this argument by further adding that farmers actually receive fertilizer subsidy in two stages; one is at the stage of production of fertilizer itself, since the natural gas used to manufacture urea is sold to the five fertilizer factories at a subsidized rate, and the other is the ex-factory price of urea fertilizer dealers need to pay is lower than the cost of production of one unit of urea. The other argument is that, as it is mentioned earlier, *subsidy* is a form of correcting device for existing market imperfections in the food grain production sector.

Finally, current subsidies on urea have a harmful effect by encouraging relatively more nitrogenous fertilizer to be used. Additions of nitrogen fertilizer alone can give a short-term boost to yields, but only at the cost of further depleting other nutrients and emits the atmosphere and ground or surface water. Under the changing climate condition the net effect of nitrogen fertilizer is unpredictable. The urea application is 32 percent higher from balance dozes that are concentration of rice production [5]. On farm GHG emissions for rice production is excessive nitrogen fertilizer that fall into CH_4 and N_2O emissions [8].

Environmental Consequences	Causative Mechanism
Ground water Contamination	Nitrate leaching from soil
Acid rain and ammonia re-deposition	Ammonia volatilization
Global warming	Nitrous oxide emission from soil

Table 1: Consequences of Excessive Nitrogen Fertilizer use (Source Pathak [9])

All kind of market failure or inefficiencies is possible to remove through combination of some policy instruments and commitments of the community. Optimum solution of balance between environmental sustainability and food self-sufficiency could be found with cautious gradual implementation of policy mix described in the next section. Another consideration is to phase the policy change at the beginning of a general downturn in the international fertilizer prices.

Policy instruments for reducing nitrogen fertilizer based emission

Environmentally sound agricultural practices are to be encouraged and ensured for attainment of self-sufficiency in food are two conflicting policy goal in most of the developing country like Bangladesh. Among the various specific measures, use of natural fertilizers and insecticides is encouraged as opposed to the application of agro-chemicals and artificial materials exerting adverse impact on the environment. Considering the sensitivity of existing food policy, agriculture policy and environmental policy are a combination of management options. These policy instrument options might help substantial reduction of emission without hampering the production. These are summaries in following two Tables 1,2.

Management options as adaptation

Crop management option is the lowering or optimizing of fertilizer application rate to crop grown. On the nutrient management side, nitrogen management emphasizes the synchronization of N supply and crop nitrogen demand. The nitrogen fertilizer applications can be split to match crop requirements at different growth stages, based on the total fertilizer N rate required at the specific sites; to minimize N losses from the soil-plant system. These are managing with irrigation and soil P^H management. It should be maintained by the fertilizer efficiency management practice, which is described below.

Name of Options	Management options
Crop management	Change in fertilizer application rates Irrigation management Soil pH management
Fertilizer efficiency management	Controlled release rate (coating to limit or retard water solubility) Fertilizer placement and timing (e.g Granules form in the middle of row

Table 2: Fertilizer Best Management Practice (FBMP) options influencing emission reduction.

Under the option of fertilizer efficiency management, controlling release rate by deep-placed N is in a chemically available form (NH_4^+-N) in the proximity of the placement site. The uptake of deep-placed N can be elongated by placing the USG (Urea Supper Granule) at lower depths and away from the plant. With USG, recovery of deep placed N in wetland rice is greater than the N recovery from surface applied and/or incorporated ordinary urea.

Fertilizer recovery in the wetland rice plant tops is found significantly higher for deep placed as USG/UMG/15N (50-60%) than for split – applied Urea 15N (25-34%). About 40% nitrogen can be saved by using USG or UMG (Urea Supper Granule) in rice and 20% in vegetable and fruit crops (viz. cabbage, cauliflower, tomato, potato and papaya) [1].

USG and UMG are used to increase nitrogen use efficiency. Urea Super Granules (USG) are small (0.9 g) and Urea Mega Granules (UMG) are large sized (1.8 or 2.7 g) pellets made of ordinary granular urea by compressing. The amount of USG or UMG should be adjusted to the recommended dose of N for different crops and soils. The granules (USG/UMG) need to be placed after 5-7 days of transplanting of rice at 8-10 cm soil depth at the center of every four hills between rows 1 and 2, between rows 3 and 4, and so on. Recommended numbers of USG ball for each vegetable plant should be applied at 6-10 cm apart from base of plant and into 6-8 cm deep as ring method at 10-15 days after transplanting [1].

The main benefit of USG/UMG placement is that N losses through NH3 volatilization, nitrification, de-nitrification and runoff are significantly minimized. Deep-placed N as USG/UMG is less subject to algal immobilization and uptake by aquatic needs than broadcast and/or incorporated urea. These two factors contribute to the improved nitrogen use efficiency (NUE=60%) of USG/UMG in the wetland rice [1].

Policy instruments

The following policy instruments in the Table 2 could govern the better implementation of nitrogen emission reduction from fertilizer application practice. Use of chemical fertilizers in the Asian region has increased considerably in recent years. Application of fertilizers per unit area is the maximum in Korea followed by China and the minimum in Myanmar. During the past few years, total fertilizer use in Bangladesh has increased significantly. A further increase in fertilizer use needs to occur in those countries where more production

has to be realized from the limited areas of land. The increasing trend of fertilizer use, particularly urea-N, still continues and it is 80 percent higher of other organic fertilizer. Because of N fertilizer found comparatively cheap for agricultural production. The scientist claim that use of urea per hectare per year is over the optimum.

For nitrogen fertilizer based emission control usually EU country and U.S. used tax on fertilizer but in Bangladesh, the country has a very sensitive to food security issue to handle by the government. Therefore most feasible way of fertilizer emission controlled through economic or market based instrument is abolishment of existing subsidy policy of fertilizer. These instruments at least ensure optimum allocation of fertilizer and reduce nitrogen release in technical point of view. In farmer's point of view the subsidy withdrawal policy instruments helps to reduce nitrogen fertilizer use keeping the maximum attainable output by assumption of following mathematical formulation of two factor least cost combination.

Assume, Cob Douglas production function

$Y= AH^{\alpha} F^{\beta}$ (1)

Where Y= output, A= constant, H= labor F = fertilizer α=elasticity of production in response to labor β= elasticity of production in response to fertilizer.

Given the iso-cost line

$C = wH+P_mF$ (2)

W= wage rate P_m= market price

Therefore maximizing $Y= A.H^{\alpha}. F^{\beta}$ Subject to $C = wH+P_mF$ by using Lagranzian as:

$L= AH^{\alpha}F^{\beta} + \lambda(C- wH-P_mF)$

Now FOC (First Order Condition)

$$\frac{\partial L}{\partial H} = A\alpha H^{\alpha-1}F^{\beta} - \lambda w = 0$$

$$\frac{\partial L}{\partial F} = A\beta H^{\alpha}F^{\beta-1} - \lambda P_m = 0$$

From equation 3 and 4 optimum level of labor (H) and fertilizer (F) found

$H = (\alpha PmF)/w$

$F = (\beta wH)/Pm$

When we consider subsidy constraint function would be

$C = wH + (Pm-S)F$ (5)

S= per unit of fertilizer subsidy.

Therefore with the subsidy, maximizing $Y= AH\alpha F\beta$ Subject to $C = wH + (Pm-S) F$

First order Condition (FOC)

$$\frac{\partial L}{\partial H} = A\alpha H^{\alpha-1}F^{\beta} - \lambda w = 0 \quad (6)$$

Same as before.

$$\frac{\partial L}{\partial F} = A\beta H^{\alpha}F^{\beta-1} - \lambda(P_m - S) = 0$$

From equation (3)

$$\lambda = (A\alpha H^{\alpha-1}F^{\beta}) / W \; or \; \lambda = \alpha Y / wH \quad (8)$$

From equation (7)

$$\lambda = (A\beta H^{\alpha}F^{\beta-1}) / (P_m + S) or \; \lambda = \beta Y / F(P_m - S) \quad (9)$$

From equation (8) and (9) optimum allocation of fertilizer could be found when it is subsidized derived as:

$F= (\beta_wH)/(P_m-S)$ (10)

Therefore if we compare two case with subsidy and abolishment of subsidy

Optimum fertilizer allocation is

$(\beta_wH)/ ((P_m-S)$ (with subsidy)$> (\beta_wH)/ P_{m\ (withdrawal\ of\ subsidy)}$ (11)

The abolishment of subsidy is a significant policy instrument of nitrogen use control without hampering the threshold output.

Different study argued that willingness to pay for urea price is higher than the existing subsidized price if they get the supply timely. So there will be a possible risk of timely availability of urea at fair price because of world market price of fertilizer is volatile in nature. The agricultural support is always necessary for subsistence farming but not in the input subsidy form. The farer facing liquidity problem in production season, if the market price of fertilizer raises abnormally their inputs use will be sub optimal. That will hamper the production as a whole and aggravate the food security problem.

To overcome the problem compensation payment system will work as effective policy instruments. The government provides compensation payment for unanticipated price hike of inputs according to their area allocation to crop and balance amount of fertilizer they use. This is the payment over the government pre-declared administrative price to the existing market price.

The best fertilizer management practice is a labor-intensive technique, which required extra human resources and motivation about the side effect of agro-chemicals. For popularizing the technique of nitrogen emission reduction from agriculture there should be incentive and certification of environmental friendly practice. If they economizing the nitrogen use for crop growing his compensation payment will be high in this regard. For extensive user or wasteful user will disqualify for having compensation payment.

Some regulative measures will be helpful for system operation like identification nitrogen vulnerable area where incidence of sea or normal flooding is high. The urea application restriction in flooding season could be good administrative policy.

It is proved that urea application in Bangladesh is over optimal or some time it cross the technical efficiency limit. With the guild line of fertilizer balance dozes a regulation of ceiling per hectare per year urea application should be fixed according to agro-ecological zone.

Finally, all suggested instruments well work effectively and efficiently when a comprehensive extension service work whole over the nitrogen vulnerable zone. The continued research and extension funding will significantly reduce the nitrogen emission from agriculture.

Type of policy options	Instrument
Economic or Market based instrument.	Removing existing fertilizer subsidy Intervention to prevent world market price fluctuation of fertilizer through direct compensation payment for volatile price by assistant card according to area allocation to crop. Certification as well as incentive for FBMP.
Regulation (restrictions on nitrogen and crop management).	Fixing nitrate vulnerable zones. Ceiling on nitrogen /ha applications. According to recommended dozes in AEZ Restriction on broadcast application encourage granular form application
Enhancing the knowledge base	Funding on Scientific research Extension service (dissemination, codes of good practice etc. Awareness building.

Table 3: The feasible policy instruments for nitrogen emission reduction by implement of FBMP.

Conclusion

The nitrogen fertilizer based emission from agriculture through volatilization of NH_3 and N_2O to atmosphere and leaching of NO_3 to surface and ground water are related to the amount of N within the system and to N surplus. In efficient management of fertilization are in soil have substantially complicated effect on earth system. The subsidized fertilizer leads this inefficiency in nutrient management in soil. From 1960 Bangladesh implemented food self-sufficiency policy at the cost of revenue pressure and other policy conflict. But still it is going on for economic and political background. After 1992 when an environmental policy significantly appeared, the instrument of fertilizer subsidy went through a critical evaluation. Considering the climate change and global warming sustainable management is now national as well international priority. Anyhow the country should reduce CH_4 and N_2O emission from rice farming by nitrogen fertilizer use controlled. The policy instruments must be an integrated approached by combining market based and crop and soil management practice implementation through extension. Because of developing countries have food sufficiency policy goal.

The first and foremost steps to do this are withdrawal of urea subsidy and ensure best fertilizer management practice. The subsidy withdrawal policy will helps to reduce wasteful use of resources as the raw material of the urea are natural gas and improve environmental quality of agricultural land, surface emission by CH_4 and underground water from nitrogen leaching problem. When price of an inputs are competitive the use of the inputs should at least optimum or economize. The abolishment of the fertilizer subsidy will create some problem of food security goal but in long run the benefit of good soil health helps to sustain production. The policy mix of economic, regulatory and knowledge base development will help to target oriented incentive to food policy and environmental policy for poverty reduction. The most of policy study relating to fertilizer subsidy withdrawal is always starting with good economics rationality of efficiency ground. But at the end they are try to have conclusion on the favor of subsidy that mentioning the distributional aspect of humanitarian ground of subsistence farming survival issue. Sometime inconclusive to the decision of sustain environment and food security or some sort of compromise with nitrogen fertilizer based emission. The well co-ordinate combination of policy instruments mention in the paper should carefully implement.

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