Rice yields in Ghana: Macro-level response and some prescriptions

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Accepted 14 October, 2013

With local rice production lagging well behind demand as a result of low productivity of farmers’ fields, this study analyzed the response of rice yields in Ghana using national level data. Yield of rice was found to increase with producer price of rice and labor availability. It however decreased with increases in harvested area and price of urea fertilizer due to fertility issues, producer price of maize due to influences from resource allocation, and with nominal rate of assistance due to secondary distortions on input prices. To increase and sustain rice yields, future rice policy measures should couple area expansion with vital intensification measures to help mitigate the adverse impact from sole expansion of area and should as well ensure appropriate transmission of prices with least distortion. Measures should as well be devised to reduce labor shortages. In improving the fertility of farmers’ fields, the current fertilizer subsidy structure should be improved upon and measures put in place to improve farmers access to credit as this is a vital issue that needs addressing to ensure appropriate response of farmers to future price and non-price incentives.

Key words: Credit access, fertilizer subsidy structure, input prices, intensification

INTRODUCTION

Information about response of rice yields to changes in vital inputs of production allows for the devising and implementation of appropriate rice policy measures. Ghana is a nation whose Agricultural production is characterized by low productivity of farmers’ fields. Like many other West African countries, yield of major staples and agricultural export commodities in Ghana are far below their ecological potential, yet demand for such commodities are ever on the increase domestically and internationally (MoFA 2011; MoFA 2007). Characterized by poor quality and irregular supply resulting from low yields, local rice production in Ghana has failed to catch up with the ever increasing domestic demand, thereby resulting in widening of the gap between demand and production. This gap in demand is bridged annually with huge sums of money through imports. Such imports drain foreign exchange of the country and lead to intense and unbalanced competition on the part of local producers; majority of whom observe negative returns in the process (FAO, 2006).

In pursuit of reviving the local rice industry by induction of increased production through price incentives and restriction measures reflected by imposed ad valorem tariffs and captured by the nominal rate of assistance, the local rice industry is affected in diverse ways; on the positive side through a likely gradual reduction in imports due to increased cost of importation, and on the adverse side through secondary effects on price of imported inputs of production due to the country’s over dependence on imported inputs like fertilizer and pesticides. In the midst of these, several other fixed and variable inputs of production have undergone dramatic changes over the period, influencing local rice production in the process. Failure to capture the influence of such changes may preclude identification of vital prohibitions and boosters of rice production in Ghana.

In bridging the supply gap between demand and domestic production, past research works including that of Olaf and Emmanuel (2009) and Aker et al., (2011) have advised for implementation of policy measures that will help double the area under cultivation and increase yields by at least 50%. Such measures are to be coupled with investment in other vital areas. To help inform future rice
policy decisions, this study assesses the yield response of rice to some selected internal and external factors for the period 1966-2009, and identifies areas worth investing in.

Rice planning of Ghana: Yield gap analysis

Speaking at the launch of a seminar organized by CGIAR Fund Office, Dr Robert Zeigler (Director General of the International Rice Research Institute (IRRI)) placed an advise that "Because of rapid population growth and diminished harvest due to climate change and other weather related stress, such as severe drought and floods, global demand for rice will outstrip supplies unless concerted action is taken now to boost yield growth and improve the management of water, land and other resources on which production depends"

This statement raises an alarm on risk and uncertainty in future supply of rice and the likely impacts that may have on welfare of both producers and consumers globally. Like many other West African countries, rice production in Ghana has been driven mostly by expansion in harvested area (MoFA, 2009) with annual increases in yield more or less stagnating. With anticipated rapid growth in population, urbanization and infrastructural development in the near future (Adu-Gyamfi, 2012), there would be much pressure on available land for alternative uses at the expense of crop production. Such situation if observed could impact adversely on welfare and preclude the achievement of vital food security and poverty reduction goals. Effects of such incidences could however be mitigated by increasing the productivity of farmers' fields today towards meeting demand on the morrow.

Although blessed with abundant agricultural and natural resources, yields of most of the crops produced in Ghana by estimates from the Ministry of Food and Agriculture (MoFA 2011: Facts and Figures (2010)) are far below their climatic potential. With achievable yields of 6.0 Mt/ha, 2.0 Mt/ha, 1.0Mt/ha, 49Mt/ha and 72Mt/ha respectively for maize, millet, cocoa, yam and pineapple, 1.7 Mt/ha, 1.3 Mt/ha, 0.4 Mt/ha, 15.3 Mt/ha and 50Mt/ha respectively were observed for these crops. Of a climatic potential of 6.5 Mt/ha for rice, the country observed 2.4Mt/ha in 2009, 2.73 Mt/ha in 2010, and 2.71Mt/ha in 2011 and 2012. This indicates that, Ghana by the 2009 estimate met only 38% of achievable yield, with the years between 2010 and 2012 witnessing observed yields of approximately 42% of the climatic potential.

The yield gap was calculated using the planning gap formula suggested by Licker et al., (2010)
\[
\text{Yield gap} = 1 - \left( \frac{\text{Actual Yield}}{\text{Climatic Potential Yield}} \right)
\]

A value of zero indicates that the decision making unit is on the production frontier, with a value of one indicating no productivity. This is shown in Figure 1. The closer the yield gap (as reflected by the green line in fig. 1) is to zero, the better. By the yield gap line, Ghana as of 2009 (although 42% as of 2012) met only 38% of achievable yield of rice. Measures could therefore be put in place to improve yield in the country through identification and addressing of appropriate influencers as enough room for improvement (62% as of 2009, and 58% as of 2012) still exists.

Literature review

Rice production decision of farmers in economic theory is influenced by both price and non-price factors. The common non-price factors identified in literature include irrigation, investment in research and development, extension services, access to capital and credit, agronomic conditions, rural infrastructure, agricultural labor availability, area of land cultivated and status of rice farmers (Bingxen and Shenggen (2009); Sachcharmarga and Williams (2004); Mythili (2008)). The main price factors identified as having influence on farmer’s production decisions are producer price of rice, producer price of competitive field crops like maize, price of urea.
fertilizer, and world price of rice and maize with important indirect effects to producers (Molua 2010; Mulwanyi et al., 2011). Dercon (1993) suggested that prices are the general conduit through which economic policies are expected to affect agricultural variables such as output, supply, exports and income and that analyzing supply response to changing prices is a crucial element in assessing the effects of increasing openness of the economy.

Whereas the opportunities for developing rice production according to Molua (2008) depend to a large extent on biophysical, socioeconomic and policy factors, Defoer et al., (2004) distinguished three major options for increasing rice production: area expansion, increase in cropping intensity and increase in yield (produce per unit area). Cummings (1975) and Holt (1999) advised that supply response is equivalent to the response of acreage under cultivation to changes in economic and non-economic factors and that estimates from acreage response studies are fair reflections of supply response of a given commodity. In contrast to their suggestion however, Molua (2010) advised that positive signals from acreage response models will reflect positively on output only on the employment of complementary factors of production such as fertilizer, high yielding varieties, farm chemicals, improved cropping techniques and better farm management methods.

In assessing the changing structure, conduct and performance of world rice market, Dawe (2004) advised that, in as much as increased production stability of rice depend on irrigation, improved varieties and access to cheaper fertilizer, ease of entry of the market by major exporters and the role of government in liberalizing rice trade do impact significantly on domestic rice production.

**MATERIALS AND METHODS**

**Model specification and data**

The current study estimates yield response of rice for Ghana based on the following equation:

$$\ln YLD_t = \beta_0 + \beta_1 \ln HARV_{t-1} + \beta_2 \ln PPR_{t-1} + \beta_3 \ln PPM_{t-1} + \beta_4 \ln WPU_{t-2} + \beta_5 \ln AL_{t-1} + B_6 NRA_{t-2} + u_t$$

- $YLD_t$ - yield of rough rice (Mt/ha)
- $HARV_{t-1}$ - lagged harvested rice area (‘000’ ha),
- $PPR_{t-1}$ - lagged nominal producer price of rice (Standard Local Currency Unit),
- $PPM_{t-1}$ - lagged nominal producer price of maize (Standard Local Currency Unit),
- $WPU_{t-2}$ - two-period lag of price of urea fertilizer, world price as proxy for local price (US$/t fob)
- $AL_{t-1}$ - one period lag of labor availability, agricultural labor force as proxy (‘000’ persons)
- $NRA_{t-2}$ - two-period lag of nominal rate of assistance (%)

Supply of rice as suggested by previous researchers including Molua (2010) and Basorun and Fasakin (2012), is influenced by many important variables beside those specified in the model above. Among such variables are use of fertilizer, farmer knowledge and experience, credit access, and weather related parameters like rainfall and temperature. However, with the current study focused on the use of aggregated (national) level data, sourcing and use of farm-level related data like farmers access to credit and expertise of farmers becomes a challenge and to some extent irrelevant (only in this context). Getting access to well documented time series data for the scope of the study (1966-2009) on weather related parameters like precipitation and temperature was quite a challenge, as all efforts put in place to access them proved futile. Aggregated data on fertilizer usage sourced from the World Rice Statistics of IRRI had gaps (less than scope). The current study was therefore directed on estimating yield response at the national level using data for the variables specified in the model as shown in Table 1

Data on all the variables were collected from the IRRI website (World Rice Statistics) and the agricultural production database of the FAO (FAOSTAT) for the period 1966-2009. Nominal local rice and maize prices in Local Currency Units (LCU) were converted to Standard Local Units (SLC) using the FAO conversion Factor of 1GH = 1000 GHC. World price of urea was used as a proxy for local price due to difficulty in getting time series data on local price of urea fertilizer and due to the high dependence of Ghana on imported fertilizer and other inputs for production. Agricultural labor force was used as a proxy for labor availability because it is a fair reflection of labor per unit of agricultural area and gives appropriate signals on the increasing or decreasing availability of labor for cropping and other productive activities (Sachchamarga and Williams 2004).

Prior to estimation of the specified regression (with all variables in the log form except nominal rate of assistance (NRA), the whole set of data was verified to ascertain the order of integration of the individual series, as this is a vital step in the data generation process and choice of estimator.
After estimating the regression equation, diagnostic tests for serial correlation, normality, structural stability and misspecification of the functional form through a Reset test were applied, and the results show that the regression equation passed all the diagnostic tests. The insignificant value for the Reset test reflects appropriate specification of the regression equation. The Jarque-Bera test for ascertaining normality in the distribution of the residuals gave a value below the critical value, thus, implying that the residual series has a normal distribution. Both the Breusch-Godfrey serial correlation LM test and the Q-stat values indicated the absence of first and second order serial correlation in the residuals, with the ARCH test confirming a homoscedastic nature of the residual series.

To affirm the reliability of the estimates (thus checking for spuriousness of the result), the residual series was tested for stationarity through the Augmented Dickey-Fuller test. The result showed that the residual series is stationary, with the ADF statistic being significant at the 1% level. In analyzing the stability of the estimated coefficients, the CUSUM and CUSUM of squares were applied, and the results showed that they remain within the 5% boundary, signaling an appropriately specified regression equation with stable coefficients.

### RESULTS

Table 2 shows the unit root test showed that all the variables are non-stationary at level, but become stationary at first difference. Having observed no \( I(2) \) variable(s) in the data set, the regression equation was estimated using the Ordinary Least Squares (OLS) estimator, followed by series of diagnostic tests to avoid spurious results.

In interpreting the output from the estimation process, in Table 3 it was observed that the individual effects of the

### Table 3. Estimates of yield response of rice for Ghana

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>t-statistic</th>
<th>F-statistic</th>
<th>Source: Author’s computation (output of EViews)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-5.791076</td>
<td>-2.054231**</td>
<td>34.97766</td>
<td></td>
</tr>
<tr>
<td>ln HARV</td>
<td>-0.336208</td>
<td>-3.049347***</td>
<td>0.000000</td>
<td></td>
</tr>
<tr>
<td>ln PPR</td>
<td>0.358095</td>
<td>3.869307***</td>
<td>20.78501</td>
<td></td>
</tr>
<tr>
<td>ln PPM</td>
<td>-0.335959</td>
<td>-3.577129***</td>
<td>0.656429</td>
<td></td>
</tr>
<tr>
<td>ln WPU</td>
<td>-0.157525</td>
<td>-2.533458**</td>
<td>-0.366818</td>
<td></td>
</tr>
<tr>
<td>ln AL</td>
<td>1.006282</td>
<td>2.762924***</td>
<td>0.550275</td>
<td></td>
</tr>
<tr>
<td>NRA</td>
<td>-0.101455</td>
<td>-1.806152*</td>
<td>0.309781</td>
<td></td>
</tr>
<tr>
<td>Adj. Rs2</td>
<td>0.832561</td>
<td></td>
<td>0.394913</td>
<td>0.309781</td>
</tr>
<tr>
<td>Durbin-Wat stat</td>
<td>2.026165</td>
<td></td>
<td>0.309781</td>
<td>0.309781</td>
</tr>
<tr>
<td>Jarque-Bera</td>
<td>1.066789 (0.586610)</td>
<td></td>
<td>0.309781</td>
<td>0.309781</td>
</tr>
<tr>
<td>B-G LM F-stat (1):</td>
<td>0.475670 (0.4951)</td>
<td></td>
<td>0.309781</td>
<td>0.309781</td>
</tr>
<tr>
<td>F-stat (2):</td>
<td>2.415297 (0.1050)</td>
<td></td>
<td>0.309781</td>
<td>0.309781</td>
</tr>
<tr>
<td>Q-stat (1):</td>
<td>0.5584 (0.455)</td>
<td></td>
<td>0.309781</td>
<td>0.309781</td>
</tr>
<tr>
<td>Q-stat (2):</td>
<td>3.2364 (0.190)</td>
<td></td>
<td>0.309781</td>
<td>0.309781</td>
</tr>
<tr>
<td>ARCH Test, F-stat:</td>
<td>2.204524 (0.1456)</td>
<td></td>
<td>0.394913</td>
<td>0.309781</td>
</tr>
<tr>
<td>Reset Test</td>
<td>1.507632 (0.2279)</td>
<td></td>
<td>0.161595</td>
<td>0.309781</td>
</tr>
<tr>
<td>ADF of residual</td>
<td>-7.532843***</td>
<td></td>
<td>0.913959</td>
<td>0.309781</td>
</tr>
</tbody>
</table>

***1%, ***5%, *10%

### Table 2. Unit root test of variables (Augmented Dickey-Fuller and Phillips-Perron tests)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level ADF</th>
<th>Level PP</th>
<th>First Difference ADF</th>
<th>First Difference PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln YLD</td>
<td>-3.447409</td>
<td>-3.309861</td>
<td>-10.35932***</td>
<td>-11.39051***</td>
</tr>
<tr>
<td>ln HARV</td>
<td>-3.453404</td>
<td>-3.416014</td>
<td>-8.517481***</td>
<td>-8.991357***</td>
</tr>
<tr>
<td>ln PPR</td>
<td>-0.772423</td>
<td>-0.713302</td>
<td>-6.237591***</td>
<td>-6.232334***</td>
</tr>
<tr>
<td>ln PPM</td>
<td>-2.589135</td>
<td>-2.623278</td>
<td>-8.462565***</td>
<td>-8.588702***</td>
</tr>
<tr>
<td>ln WPU</td>
<td>-2.520567</td>
<td>-2.630823</td>
<td>-5.314694***</td>
<td>-5.631326***</td>
</tr>
<tr>
<td>ln AL</td>
<td>-1.662729</td>
<td>-1.697834</td>
<td>-6.245319***</td>
<td>-6.244984***</td>
</tr>
<tr>
<td>NRA</td>
<td>-3.403103</td>
<td>-3.389663</td>
<td>-6.746493***</td>
<td>-9.662176***</td>
</tr>
</tbody>
</table>

Critical value: -3.518090

NB: 95 percent confidence level for critical value, ***1%, ***5%, *10%

Source: Author’s computation (output of EViews)
variables on yield of rice were all found to be significant. Of the total variations in yield of rice observed in the country, a total of about 83.26% are explained by variables in the specified equation for the current study. 

Lagged harvested area of rice had a coefficient of -0.336, and this was significant at the 1% level. This indicates that a unit increase in area harvested of rice leads to a 0.336% decrease in yield. Rice farmers in Ghana are reported to be mostly financially constrained and majority of the fields are reported to be low in fertility. With current output of rice in the country reported to be driven by increases in harvested area rather than by yield (MoFA, 2009), an increase in area harvested leads to intense competition for the limited nutrients available in the soil, as most farmers either do not patronize fertilizer in their production or use inadequate amounts due to financial problems, resulting from lack of access to credit (with high interest rates on those available) and to inadequate returns due to the poor transmission of price increments. Although increasing area harvested may pave room for mechanizing rice production, as well as making efficient use of available labor and exploiting economies of scale, inability of farmers to complement area expansion with vital inputs of production could result in the adverse effect observed for the current study.

A unit increase in the farm gate price of rice leads to a 0.358% increase in yield, and this increase is significant at the 1% level. An increase in the farm gate price of rice increases the financial base of local rice farmers and offers them an opportunity to meet vital short and long-run production costs as well as acquiring other fixed assets vital for improving yield. Contrary to this however, a unit increase in the farm gate price of maize leads to a decrease of 0.336% in yield, significant at the 1% level. This decrease is attributed to resource allocation decisions of farmers in times of price increment in competitive field crops like maize. Increase in the price of competitive field crop like maize leads to withdrawal of vital resources from the production of rice into the production of maize in pursuit of making higher profits. As rationale beings, farmers mostly allocate resources in favor of the most enticing area of production in order to sustain their families and ensure continuous investment in and sustenance of their cropping activities and outputs.

A unit increase in the price of urea fertilizer leads to a decrease of 0.158% in yield and this decrease is significant at the 5% level. Fertilizer is regarded one of the very essential inputs in rice production for enhancing productivity. With most of the local rice farmers being financially constrained, an increase in the price of fertilizer would reduce their purchasing power on the amount they are able to access and purchase for their cropping. Inability to meet the nutritional needs of the rice plants through application of adequate amounts of fertilizer, may result in the obvious adverse effect observed for the current study. It is reported by Fintrac Inc (2012) in a USAID funded project 'Enabling Agriculture Trade' that the government of Ghana currently covers 33% of the price of fertilizer through subsidy on purchases, yet the remaining 67% is still regarded a high amount for the financially challenged farmers in the country.

A unit increase in labor availability leads to a 1.006% increase in yield of rice, and this increase is significant at the 1% level. This elastic response of yield to increasing availability of labor confirms the labor-intensive nature of rice production in Ghana. Increasing labor available in the country by economic theory leads to lower cost of accessing/employing a hand to work on a farm. The ready availability of hands to work on the farm could induce an increase in area cultivated of rice and at the same time ensure timely undertaking of vital cultural practices like weed control, pesticide application, fertilizer application and timely harvesting. Increasing availability of labor (capturing a greater part of the youth) could as well catalyze the adoption of modern techniques of production to help improve and sustain yields in the country.

Intervention of the state, captured by the nominal rate of assistance is observed to have an adverse effect on yield of rice through secondary distortion in prices of intermediate inputs of production. Although the primary purpose of such assistance is to create a wedge between international and domestic prices of the commodity, unlike the effective rate of assistance, the nominal rate of assistance mostly fail to capture distortion in the prices of intermediate inputs of production, resulting in increases in the price of such inputs (most of which are vital for rice production). Distortions in prices of both output and inputs have several effects on production. Increases in the price of rice through tariffs imposed on imports are poorly transmitted based on the market structure and the subsequent increase in the price of inputs worsens the burden of farmers due to increased cost of production, thereby affecting farmer incentives. This effect could however be mitigated to a greater extent through devising and implementation of offsetting measures for majority of the imported inputs for production. This as well would come at a cost. A unit increase in the nominal rate of assistance lead to a 0.101% decrease in yield and this was significant at the 10% level.

The intercept term had a coefficient of -5.791 significant at the 5% level. This implies that, should the current state of all the other variables/parameters be maintained, yield will decrease significantly with time. This signals significant withdrawal of nutrients from the soil with time and the need for re-nourishment/fertilization of the soil to help enhance sustainable yield.

The overall effect of all the variables as captured by the F-statistic was found to be highly significant.

**CONCLUSIONS AND RECOMMENDATIONS**

Yield of rice in Ghana is observed to vary significantly with
changes in area harvested of rice, producer price of rice, producer price of maize, price of urea fertilizer, availability of labor, and nominal rate of assistance. These variables explain about 83.26% of the total variation observed in yields of rice. Yield increases with producer price of rice, and labor availability. It decreases with increases in harvested area and price of urea (due to fertility issues), producer price of maize (due to influences from resource allocation in favor of maize production) and with nominal rate of assistance (due to secondary distortion on input prices, which consequently lead to increased cost of production).

To increase and sustain yields, future rice policy should couple area expansion with vital intensification measures to help mitigate the adverse impact from sole expansion of area harvested. Measures should as well be put in place to ensure appropriate transmission of prices with least distortion as such distorytion measures usually lead to increases in input prices through secondary effects. Emphasis should as well be placed on reducing labor shortages and drudgery by improved mechanization. The current fertilizer subsidy structure should be improved upon and measures put in place to improve farmers access to credit as this is a vital issue that needs addressing to ensure appropriate response of farmers to future price and non-price incentives.

In spite of fertilizer subsidy programs implemented in Ghana and other West African countries, fertilizer usage by farmers in the sub-region is quoted by Norman and Kebe (2006) to be quite low, resulting in low productivity of farmers' fields. Pegging the fertilizer subsidy at 33% with a purpose of boosting local rice production, efforts by the government to help improve fertilizer usage on farms have proved quite futile as its usage is still reported to be low (Moro et al., 2008; Fintrac Inc 2012). Among the factors reported to preclude farmers from accessing and/or using adequate amounts of fertilizer for their cropping are insufficient credit support for farmers and high lending rates by Commercial Banks (FAO 2005). In addition to this, most farmers in the major rice producing districts (Upper East, Upper West, Northern Region and Volta Region) are poor and are unable to meet the cost of fertilizing their fields in spite of the 33% subsidy (Fintrac Inc 2012). Marketing of fertilizer is also concentrated in the southern parts of the country (relatively low rice producing regions), thereby increasing the challenge in accessing the input and cost of fertilizing rice farms in the major producing districts. This to a greater extent precludes the appropriate delivery and achievement of the goals for the fertilizer subsidy program.

To ensure appropriate response of rice farmers to incentives by the government and enhance appropriate delivery of the subsidy program, retail and wholesale outlets for fertilizer distribution should be set up in several locations in the major rice producing regions (to improve accessibility and reduce cost). Lending rates should be reduced to help farmers access loans to meet vital production costs, and regular evaluation of the subsidy program should be undertaken to check on its effectiveness and for meting out of corrective measures. Rice farmer’s organizations in the country should be strengthened to help improve negotiations on access of farmers to credit. Contrastingly, should efforts to reduce lending rates prove futile, the percentage of subsidy on fertilizer could be increased with a purpose of increasing fertilizer usage on rice farms in the country to help meet the 2018 rice sub-sector goals (doubling rice production and reducing imports by 50%) stated in the National Rice Development Strategy 2009.

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