Does Late Delivery of Subsidized Fertilizer Affect Smallholder Maize Productivity and Production?

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Farm input subsidy programs are commonly used by governments in Sub-Saharan Africa as a means to improve agricultural productivity.

Zambia introduced the fertilizer support program (FSP) in 2002 and since then input distribution has increased drastically.

A number of changes were made to the subsidy program in 2009:

- Name changed from FSP to Farmer Input Support Program (FISP)
- Input pack cut in half; 200kg fertilizer and 10kg of hybrid maize seed
- Local leaders involved in selection of beneficiaries
Objectives of Farmer Input Support Program (FISP)

- Improve access to agricultural inputs by smallholder farmers
- Ensure timely, effective and adequate supply of agricultural inputs to targeted smallholder farmers
- Raise incomes & improve household food security
- Expand markets for private input suppliers and increase their involvement in the distribution of agricultural inputs in rural areas
38.4% Households (HH) acquired fertilizer from commercial only

48.7% HH acquired fertilizer from government’s FISP only

12.9% HH acquired from both FISP and commercial traders

22% FISP recipients reported to have received fertilizer late

Source: 2012 RALS
What is late??

Farming in Zambia is rain-fed (November to March)

Based on field officers' recommendations to the farmers

- Planting is said to be late when done in 3rd week of December and beyond
- Fertilizer application
  1. At planting or at seedling emergence
  2. When plant is at knee high (3-6 weeks after planting)

Maximum uptake of nutrients is between germination and flowering period of 30 days: vegetative phase (Scharf and Lory 2006)
Late application of fertilizer is widely understood to depress the efficiency with which farmers use fertilizer, and thus leads to sub-optimal growth of maize plants.

Despite persistent calls by farmers and other stakeholders, timely delivery of subsidized fertilizer is still a challenge in Zambia.

However, to my knowledge, these issues have never been quantified in Zambia.
Only one study by Xu et al., (2009) addressed the issue of timely availability of fertilizer to smallholder farmers in Zambia.

Results from this study showed that timely availability of fertilizer increased maize yield by 11%.

For the study by Xu et al., (2009) timely receipt of fertilizer is not specific to a particular fertilizer source (government or private traders).

Governments are largely unaware of how chronically late delivery of inputs affects national maize output or the effectiveness of their subsidy programs in achieving their objectives.
Distribution Channel for FISP Fertilizer

- Government contracts private suppliers through tender process
- Suppliers deliver fertilizer to the main depots in districts
- Local transporters deliver fertilizer to farmer organizations within the district
- Fertilizer distributed to the farmers through farmer organizations
Research Questions

1. Why does timeliness of receipt of FISP fertilizer vary across beneficiaries in Zambia? Are there specific household and individual factors that affect timely receipt of fertilizer?

2. To what extent does late delivery of FISP fertilizer contribute to technical inefficiency among smallholder farmers?

3. How much national maize output is foregone due to late delivery of fertilizer to the farmers?
Late delivery is detrimental to governments’ objective of improving productivity among smallholder farmers – but magnitude unknown.

A potentially sizeable reduction in maize yield is likely to result from late application of fertilizer.

Potential negative effect on stated goals of FISP of enhancing the capacity of private companies to supply agricultural inputs to smallholder farmers in a timely manner.
Data

- Rural Agricultural Livelihood Survey data (RALS)
  - 2010/11 agricultural season
  - 8,839 households randomly sampled and interviewed
  - Nationally representative households (HH) cultivating less than 20ha
- Focus on sub-sample of HH that acquired fertilizer from FISP and had at least one maize field
- Focus on sub-sample of HH that acquired fertilizer from commercial traders
- Non-fertilizer users are not included in the analysis
RQ#1: Factors affecting timely receipt of FISP fertilizer

- **Dep. Var:** Fertilizer from FISP received on time (=1)

- **\( H_0 \):** Household and individual characteristics have no effect on timely receipt of fertilizer

- Binary response model: **Probit Model**

\[ Y_i = \alpha_i + X_i \beta + \varepsilon_i \]

- Linear Probability Model (**LPM**) & include community fixed effects

- Unit of observation: Households that acquired fertilizer from FISP

- **Expl. Var:** Household and individual specific characteristics (**\( X_i \)**)
## Descriptive Statistics: RQ#1

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Means</th>
<th>Difference in Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fertilizer received late</td>
<td>Fertilizer received on time</td>
</tr>
<tr>
<td>Female head (=1)</td>
<td>0.141</td>
<td>0.157</td>
</tr>
<tr>
<td>Education of the hh head</td>
<td>7.27</td>
<td>6.82</td>
</tr>
<tr>
<td>Age of the hh head</td>
<td>47.26</td>
<td>46.65</td>
</tr>
<tr>
<td>Distance to the district town center</td>
<td>32.34</td>
<td>36.65</td>
</tr>
<tr>
<td>Distance to FISP collection point</td>
<td>5.29</td>
<td>4.99</td>
</tr>
<tr>
<td>Value of productive assets (ZMW)</td>
<td>22,138</td>
<td>31,265</td>
</tr>
<tr>
<td>Total landholding size (Ha)</td>
<td>4.161</td>
<td>4.886</td>
</tr>
<tr>
<td>HH head related to headman (=1)</td>
<td>0.336</td>
<td>0.437</td>
</tr>
<tr>
<td>Spouse related to the headman (=1)</td>
<td>0.244</td>
<td>0.294</td>
</tr>
</tbody>
</table>
Econometric Results: RQ#1

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Probit Model</th>
<th>LPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female hh head (=1)</td>
<td>0.0165</td>
<td>0.0182</td>
</tr>
<tr>
<td>Education of hh head (years)</td>
<td>-0.0047**</td>
<td>-0.0046**</td>
</tr>
<tr>
<td>Age of hh head (years)</td>
<td>-0.0011**</td>
<td>-0.0011**</td>
</tr>
<tr>
<td>Value of productive assets (ZMW)</td>
<td>0.0131***</td>
<td>0.0122***</td>
</tr>
<tr>
<td>Total landholding size (ha)</td>
<td>0.0020**</td>
<td>0.0037**</td>
</tr>
<tr>
<td>Distance to FISP collection point (Km)</td>
<td>-0.0003</td>
<td>-0.0003</td>
</tr>
<tr>
<td>Distance to the district town center (Km)</td>
<td>0.00065**</td>
<td>0.00066**</td>
</tr>
<tr>
<td>Extension service (=1)</td>
<td>0.0212</td>
<td>0.0206</td>
</tr>
<tr>
<td>hh head related headman(=1)</td>
<td>0.0439***</td>
<td>0.0429***</td>
</tr>
<tr>
<td>hh head is headman/woman(=1)</td>
<td>0.0504</td>
<td>0.0530*</td>
</tr>
<tr>
<td>Spouse related to the headman/woman (=1)</td>
<td>0.0078</td>
<td>0.0083</td>
</tr>
<tr>
<td>Member of cooperative (=1)</td>
<td>-0.0257</td>
<td>-0.0260</td>
</tr>
</tbody>
</table>

***p<0.01, ** p<0.05, * p<0.1
The general form for yield functions is given by

\[ Y = f\{ X, Z \} \]
Method

1. Stochastic Frontier Approach (SFA) is used as outlined by Battese and Coelli, (1995)

2. Stochastic frontier model is given as; 
   \[ Y_i = X'_i \beta + V_i - U_i \]
   
   - \( Y_i \) observed frontier output
   - \( X_i \) vector of explanatory variables (inputs)
   - \( \beta \) unknown parameters to be estimated
   - \( V_i \) symmetric error term (accounting for statistical noise)
   - \( U_i \) one sided error term which captures the technical inefficiency

3. \( U_i = \delta Z_i + W_i \)
   
   - \( Z_i \) is a vector of explanatory variables that affect the deviation of output from the frontier
RQ2: Descriptive statistics of variables in the inefficiency term

<table>
<thead>
<tr>
<th>Variables (Z_i)</th>
<th>Mean</th>
<th>5th</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer received late (=1)</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of HH head (years)</td>
<td>46.7</td>
<td>27</td>
<td>36</td>
<td>44</td>
<td>56</td>
<td>73</td>
</tr>
<tr>
<td>Education of HH head (years)</td>
<td>7.1</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Female head (=1)</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to FISP collection point</td>
<td>5.25</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Distance to District town center</td>
<td>36.23</td>
<td>2</td>
<td>15</td>
<td>29</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Value of productive assets (ZMW)</td>
<td>29,700</td>
<td>500</td>
<td>1,910</td>
<td>6,410</td>
<td>21,000</td>
<td>92,800</td>
</tr>
<tr>
<td>Access to extension service (=1)</td>
<td>0.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household size (member)</td>
<td>6.6</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>
Partial effects on inefficiency/yield

According to Wang (2002) ; \[ \frac{\partial E(\ln Y)}{\partial Z} = - \frac{\partial E(U)}{\partial Z} \]

<table>
<thead>
<tr>
<th>Variables (Z)</th>
<th>Average Partial effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer received late</td>
<td>0.042**</td>
</tr>
<tr>
<td>Age of hh</td>
<td>0.0015***</td>
</tr>
<tr>
<td>Education of hh</td>
<td>-0.0005</td>
</tr>
<tr>
<td>Female head</td>
<td>0.0379**</td>
</tr>
<tr>
<td>Distance to FISP collection point</td>
<td>0.0009**</td>
</tr>
<tr>
<td>Access extension</td>
<td>-0.0561**</td>
</tr>
<tr>
<td>Distance to district town center</td>
<td>0.0005</td>
</tr>
<tr>
<td>Log of productive assets</td>
<td>-0.0164*</td>
</tr>
</tbody>
</table>
Mean technical efficiency level of the smallholder maize farms is estimated to be 68.2%.

By moving to the frontier, maize yield can increase by 31.8%.
Potential Yield

Potential Yield = \( \frac{Actual \ yield}{Technical \ Efficiency} \)

- Actual mean Yield = 2.86 ton/ha; TE = 68.2%; Potential Yield = 3.95 ton/ha
RQ3: Foregone national maize output due to late delivery

\[
\text{Foregone Mz} = 0.042 \left( \sum_{i=1}^{n} W_i Q_{\text{FISP}} \right) + 0.032 \left( \sum_{j=1}^{n} W_i Q_{\text{Comm}} \right) + 0.042 \left( \sum_{h=1}^{n} W_i Q_{\text{BOTH}} \right)
\]

\[
= 84,924 \text{ MT}.
\]

<table>
<thead>
<tr>
<th>Term</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_i )</td>
<td>Sampling weights</td>
</tr>
<tr>
<td>( Q_{\text{FISP}} )</td>
<td>Maize output fertilizer from FISP only</td>
</tr>
<tr>
<td>0.042</td>
<td>Effect of late delivery of FISP on maize output</td>
</tr>
<tr>
<td>0.032</td>
<td>Effect of late delivery of commercial fertilizer on maize output</td>
</tr>
<tr>
<td>( Q_{\text{comm}} )</td>
<td>Maize output fertilizer from commercial traders only</td>
</tr>
<tr>
<td>( Q_{\text{BOTH}} )</td>
<td>Maize fertilizer from both FISP and commercial traders</td>
</tr>
</tbody>
</table>
Summary

- **RQ # 1**
  - hh and individual characteristics influence timely receipt of fertilizer
  - Landholding size; Value assets and Kinship relations

- **RQ # 2**
  - Late delivery of FISP fertilizer increases technical inefficiency of smallholder farmers by 4.2%
RQ #3

- Holding other factors constant, total national maize output would increase by ~85,000 MT if all fertilizer was received on time.
- If valued at the government’s maize purchase price (250 USD/MT), the foregone maize production = USD 21.2 million.
- Considerable loss in income for farm hh (78% of rural hh fall below the US$1.25/day poverty line).
- FISP cost in 2010 = USD 99.8 million (Jayne and Rashid 2013).
- Approximately 21.2% of the total cost of the FISP program.
Recommendations

- Use of e-vouchers to ensure farmers get inputs on time and also reduce on costs (Sitko et al. 2012)

- Eliminate cost of selecting the private suppliers through a tendering process

- Reduction in local transportation costs

- Eliminate storage costs

- Extension services must be enhanced through assigning more staff to the smallholder farmers
Proposed Distribution Channel for FISP

Agriculture Camp officers distribute vouchers to farmer organizations

Farmer organizations distribute vouchers to FISP beneficiaries

Farmers obtain inputs from local agro-dealers using the vouchers
How does it link with employment strategies in the developing world??
Agriculture accounts for 71.3% to total labor force in Zambia (CSO 2012)
Can improving agriculture productivity contribute to job creation?
Conclusion

- Production linkage
  1. Forward linkages – From agriculture to nonfarm processors of agricultural raw materials
  2. Backward linkages- Input suppliers of farm equipment, fertilizer & repair services
- Consumption linkage
  1. Spending by farm families on locally produced consumer goods and services
- Loss in farm income due to late delivery of inputs greatly affects other services
THANK YOU!!!