Estimating the value of knowledge management in the context of agricultural research priority setting: ARPS with ARC Sudan

JEFFREY ALWANG & ABDELAZIZ HASHIM
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OUTLINE OF PRESENTATION

▪ Discuss current year activities
▪ Present methodology
▪ Discuss preliminary findings from analysis of information from ARC Sudan
CURRENT YEAR ACTIVITIES: ARC IN SUDAN

- Design methodology and data collection instruments
- Compile data
  - Crop production: Area planted, quantity harvested, by crop and by year
  - Historical and current data on agricultural research expenditures and full-time equivalent scientists by crop and discipline
- Conduct interviews with scientists and research leaders to determine expected returns from different research programs
THE VALUE OF ALTERNATIVE AGRICULTURAL RESEARCH PROGRAMS

- (Successful) Research leads to reductions in cost of production (cost per unit of output)
  - Examples: Improved wheat varieties that resist diseases; management research to use water more efficiently
  - Cost per unit of output: Either yield increases or cost reduction/avoided input use

- With diffusion of technology, lower cost of production induces a rightward shift in the commodity’s market supply

- Economic benefits emerge: Consumers gain (lower market prices); producers gain (lower cost of production)
Basic Model 1: Closed-Economy Case

Price

\[ P_0 \]
\[ P_1 \]
\[ d \]
\[ I_0 \]
\[ I_1 \]

Quantity

\[ Q_0 \]
\[ Q_1 \]

\[ S_0 \]
\[ S_1 \]
\[ D \]
(EX-ANTE) FACTORS AFFECTING (ECONOMIC) IMPACTS OF ANY RESEARCH PROGRAM

- “Size” of the commodity => P*Q
- Expected size of the shift (S_0 => S_1)
  - Nature of technology (scientist interviews)
  - Diffusion => rate and peak
- Conditions in the market
  - Elasticities of supply and demand
    - Inelastic demand => Consumers benefits more
    - Elastic demand => Producers benefit more
  - These depend on “openness” of market
Suppose the supply and demand take linear forms:

Supply: \[ Q_s = \alpha + \beta(P + k) = (\alpha + \beta k) + \beta P \]
Demand: \[ Q_D = \gamma - \delta P \]

where \( k \) is the downward shift in supply due to a cost saving induced by research, and the supply shift relative to initial equilibrium price is

\[ K = k / P = (P_0 - d) / P_0 \]

In equilibrium, \( P = (\gamma - \alpha - \beta k) / (\beta + \delta) \)

When \( k = 0 \), \( P_0 = (\gamma - \alpha) / (\beta + \delta) \)

When \( k = KP_0 \), \( P_1 = (\gamma - \alpha - \beta KP_0) / (\beta + \delta) \)
Define the relative reduction in price as

\[ Z = -\frac{(P_1 - P_0)}{P_0} \]

where \( P_0 \) and \( Q_0 \) are equilibrium price and quantity before the supply shift; \( \varepsilon \) is the supply elasticity and \( \eta \) is the absolute value of the price elasticity of demand.

Given above, we have \( P_1 - P_0 = -\beta K P_0 / (\beta + \delta) \)

and thus,

\[ Z = -\frac{P_1 - P_0}{P_0} = \frac{\beta K}{\beta + \delta} = \frac{\beta K}{\beta + \delta} \times \frac{P_0 / Q_0}{P_0 / Q_0} = \frac{K \varepsilon}{\varepsilon + \eta} \]
Benefit estimation: Total surplus change due to research-induced supply shift

\[ \Delta TS = \Delta PS + \Delta CS = P_0 abc d = I_0 ab I_1 \]
Basic Model 2: Small Open Economy

The diagram illustrates a small open economy with a demand curve (D) and supply curves ($S_0$, $S_1$). The price ($P_w$) and quantity ($Q_0$, $Q_1$) are shown on the axes. The shaded area represents the change in quantity ($QT_0$ and $QT_1$) due to shifts in the supply curves.
Benefit estimation: Small open economy

- There is no consumer surplus, because price is taken
- Since the country can increase export / reduce imports as much as it needs at the same price, the demand elasticity can be considered as infinite: $\eta \to \infty$
- Thus, an extension of the closed economy model yields:

$$
\Delta PS = \Delta TS = (K - Z)P_0Q_0(1 + 0.5Z\eta)\\
= \lim_{\eta \to \infty}(K - \frac{K\varepsilon}{\varepsilon + \eta})P_0Q_0(1 + 0.5 \frac{K\varepsilon}{\varepsilon + \eta})\\
= P_wQ_0K(1 + 0.5K\varepsilon)
$$
With information on research program outputs and costs, it is straightforward to “optimize” research portfolio=>research allocation that creates most benefits

Provide information to decisionmakers on benefits from different program allocations and how they compare to the optimal

Do decision-makers use this information? What is the “value” of KM?

Why is “value” important?
  ▪ Prioritize KM & invest in different dimensions of KM
  ▪ Enhance KM according to its functions
    ▪ Provide “good” information
    ▪ Lower cost of obtaining information
Determining Value: A Decision-Theoretic Approach

- Value for KM comes from the value of a decision (DKM) made with KM compared to the value of the decision made without KM.
- This value is determined by the “state of the world” (SOW) and uncertainty about it. Access to knowledge reduces this uncertainty.
- Implications:
  - Prioritize KM investments toward “high value” outcomes.
    - Consequences of making a bad decision are large (important sector/important policy).
    - Uncertainty or misinformation is high.
EXAMPLE: INNOVATION PLATFORMS

- Two states of the world:
  - Innovation platforms aid technology diffusion
  - Innovation platforms do not aid technology diffusion
  - Decision makers do not know which SOW predominates

- Policy question: Do we invest in innovation platforms for the purpose of diffusing a “good” technology?
  - Decision: $D_1=\text{invest in innovation platform}, D_2=\text{invest in traditional extension program}$
  - $V(.)$ is the “value” of the decision given the SOW
VISUALIZING VALUES OF ALTERNATIVE DECISIONS

V(S_1, D) vs. V(S_2, D)

N_1 vs. M_1

N_2 vs. M_2

P_{KM0}
### Valuation

- **Vertical axis** reflects value of decision (under two SOW):
  - If \( D_1 \) is chosen (invest in innovation platforms), outcome is \( M_1 \) if innovation platforms are effective, \( M_2 \) if they are not.
  - If \( D_2 \) is chosen (invest in traditional extension), outcome is \( N_1 \) if innovation platforms are effective, \( N_2 \) if they are not.

- **Horizontal axis** reflects subjective probabilities \( (\pi) \) about \( S_2 \) (increasing from left to right).

- Without KM, “guess” at state of the world \( (\pi=0.5) \) \( \Rightarrow \) expected value of the policy (vertical distance) is \( P_{KM0} \) (choose \( D_1 \)).

- Consider the value of a KM plan to help inform the decision process:
  - The KM innovation will provide information about the effectiveness of innovation platforms (effective/ineffective), but the underlying information may be incorrect.
QUALITY OF INFORMATION IN THE KM PLAN

<table>
<thead>
<tr>
<th>KM message</th>
<th>True “state”</th>
<th>Effective</th>
<th>Ineffective</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁: Effective</td>
<td>.8</td>
<td>.2</td>
<td></td>
</tr>
<tr>
<td>S₂: Ineffective</td>
<td>.4</td>
<td>.6</td>
<td></td>
</tr>
</tbody>
</table>

• If IPs are effective, then there is an 80 % probability that the KM message will convey this information
• It is more difficult to conclude/convey the message that IPs are ineffective so there is a 60% probability that the KM message will convey this ineffectiveness
• Apply Bayes’ theorem to get posterior probabilities of decision makers given the prior and the information content in the KM message
**POSTERIOR PROBABILITIES OF DECISION MAKERS**

<table>
<thead>
<tr>
<th>KM message</th>
<th>True “state”</th>
<th>Effective</th>
<th>Ineffective</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁: Effective</td>
<td>.7</td>
<td>.2</td>
<td></td>
</tr>
<tr>
<td>S₂: Ineffective</td>
<td>.3</td>
<td>.8</td>
<td></td>
</tr>
</tbody>
</table>

- If KM conveys message that IPs are effective, then $\pi=0.3$ and $D_1$ will be chosen with expected benefits at $A$ (no change in decision compared to prior).
- If KM system conveys the message that IPs are ineffective, then $\pi=0.8$ and $D_2$ will be chosen $B$ (switch from IPs to extension-based programming).
- Ex ante value of KM: If both outcomes are equally likely, the expected value of $V(.)$ is the mid-point between $A$ and $B$, and the value of the KM program is the vertical difference between the value without KM ($P_{KM0}$) and the (expected) value with KM (Distance $D$).
VISUALIZING VALUES OF ALTERNATIVE DECISIONS

V(S₁, D) vs. M₁

V(S₂, D) vs. M₂

M₁  0.0  0.3  0.5  0.8  1.0  N₁

M₂

N₂

D

Pₘ₀

A

B

C

0.3

0.5

0.8

1.0
THREE ELEMENTS DETERMINE THE VALUE OF KM

1. The value of acting on the knowledge if the knowledge is correct (\(M_1-N_1\) or \(N_2-M_2\))
2. Amount and accuracy of prior knowledge (knowledge without KM)—0.5 in our example
3. Quality of knowledge in the KM system (puts us as point A or B)

These factors alone determine the value=>
   a. If SOW is known with certainty, there is no value to KM
   b. If KM does nothing to reduce this uncertainty, there is no value to KM
   c. If decision is the same under all SOW, no value to KM
QUANTITY PRODUCED BY YEAR, MOROCCO

Harvest quantity (MT), major crops by year
QUANTITY PRODUCED BY YEAR, SUDAN

Quantity harvested (MT), by major crop by year

- Cereals
- Citrus
- Fruit
- Oilcrops
- Pulses
- Roots & tubers
- Vegetables
INFORMATION NEEDED TO ESTIMATE BENEFITS OF ALTERNATIVE RESEARCH PORTFOLIOS

• Prices of specific commodities/crops (to calibrate model)
• Conditions in markets (elasticities)
• Current research allocations by research theme and crop (obtained for Sudan in 2021)
• Expected gains from research (obtained for Sudan in 2021)
• Likelihood of adoption (obtained for Sudan in 2021)
## SHARE OF TOTAL VALUE OF AGRICULTURAL PRODUCTION, KEY CROPS, MULTIPLE YEARS

<table>
<thead>
<tr>
<th>Year</th>
<th>Groundnut</th>
<th>Millet</th>
<th>Seed cotton</th>
<th>Sesame</th>
<th>Sorghum</th>
<th>Sugarcane</th>
<th>Sunflower</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>34.5%</td>
<td>8.8%</td>
<td>2.0%</td>
<td>17.2%</td>
<td>26.5%</td>
<td>8.2%</td>
<td>1.1%</td>
<td>1.7%</td>
</tr>
<tr>
<td>2014</td>
<td>30.7%</td>
<td>8.5%</td>
<td>2.3%</td>
<td>18.5%</td>
<td>31.0%</td>
<td>5.9%</td>
<td>0.6%</td>
<td>2.5%</td>
</tr>
<tr>
<td>2015</td>
<td>30.5%</td>
<td>5.9%</td>
<td>4.8%</td>
<td>15.1%</td>
<td>24.1%</td>
<td>10.7%</td>
<td>1.4%</td>
<td>7.5%</td>
</tr>
<tr>
<td>2016</td>
<td>30.8%</td>
<td>10.1%</td>
<td>2.3%</td>
<td>13.9%</td>
<td>32.8%</td>
<td>6.3%</td>
<td>1.0%</td>
<td>2.9%</td>
</tr>
<tr>
<td>2017</td>
<td>31.1%</td>
<td>6.9%</td>
<td>2.4%</td>
<td>23.1%</td>
<td>24.1%</td>
<td>7.6%</td>
<td>1.9%</td>
<td>2.9%</td>
</tr>
<tr>
<td>2018</td>
<td>36.1%</td>
<td>13.7%</td>
<td>2.5%</td>
<td>18.8%</td>
<td>20.4%</td>
<td>4.7%</td>
<td>0.9%</td>
<td>2.9%</td>
</tr>
<tr>
<td>2019</td>
<td>39.4%</td>
<td>6.5%</td>
<td>3.2%</td>
<td>26.4%</td>
<td>15.5%</td>
<td>4.7%</td>
<td>1.0%</td>
<td>3.3%</td>
</tr>
<tr>
<td><strong>Average share</strong></td>
<td><strong>33.8%</strong></td>
<td><strong>9.0%</strong></td>
<td><strong>2.7%</strong></td>
<td><strong>19.4%</strong></td>
<td><strong>24.4%</strong></td>
<td><strong>6.4%</strong></td>
<td><strong>1.1%</strong></td>
<td><strong>3.1%</strong></td>
</tr>
</tbody>
</table>
### Summary of Scientists/Technicians by Commodity and Area of Research

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Genetic resource enhancement</th>
<th>Agronomy &amp; crop management</th>
<th>Policies</th>
<th>Post-harvest management</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>12/15</td>
<td>5/5</td>
<td>-</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>Sorghum</td>
<td>12</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Groundnut</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sesame</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Sunflower</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Legumes (Faba)</td>
<td>3</td>
<td>-</td>
<td>=</td>
<td>=</td>
<td>-</td>
</tr>
<tr>
<td>Legumes (Chickpeas)</td>
<td>-</td>
<td>1 part time</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Legumes (Lentils)</td>
<td>1 part time</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Legumes (Dry beans)</td>
<td>1</td>
<td>2 part time</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gum Arabic</td>
<td>3/2</td>
<td>6/2</td>
<td>-</td>
<td>2/1</td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hort crops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Total FTE</th>
<th>Share of total</th>
<th>Share of value of production</th>
<th>Value-consistent FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>20</td>
<td>0.312</td>
<td>.034</td>
<td>2</td>
</tr>
<tr>
<td>Sorghum</td>
<td>15</td>
<td>0.234</td>
<td>.296</td>
<td>19</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>11</td>
<td>0.172</td>
<td>.099</td>
<td>6</td>
</tr>
<tr>
<td>Groundnut</td>
<td>8</td>
<td>0.125</td>
<td>.327</td>
<td>21</td>
</tr>
<tr>
<td>Sesame</td>
<td>7</td>
<td>0.109</td>
<td>.214</td>
<td>14</td>
</tr>
<tr>
<td>Sunflower</td>
<td>3</td>
<td>0.047</td>
<td>.012</td>
<td>1</td>
</tr>
</tbody>
</table>
# RESULTS: BENEFITS UNDER DIFFERENT SCENARIOS

<table>
<thead>
<tr>
<th>Commodity</th>
<th>% increase in research allocation</th>
<th>Discounted producer surplus gain</th>
<th>Discounted producer surplus gains excluding cost increases</th>
<th>Discounted producer surplus gains, identical adoption patterns</th>
<th>Years to release</th>
<th>Maximum adoption (%)</th>
<th>Years to maximum adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>50%</td>
<td>$66,803</td>
<td>$66,803</td>
<td>$64,616</td>
<td>6</td>
<td>80</td>
<td>12</td>
</tr>
<tr>
<td>Sorghum</td>
<td>67%</td>
<td>607,324</td>
<td>746,052</td>
<td>1,220,805</td>
<td>7</td>
<td>50</td>
<td>16</td>
</tr>
<tr>
<td>Pearl Millet</td>
<td>91%</td>
<td>1,553,982</td>
<td>1,709,907</td>
<td>698,308</td>
<td>3</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>Groundnut</td>
<td>125%</td>
<td>11,386,964</td>
<td>14,009,967</td>
<td>4,215,142</td>
<td>3</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Sesame</td>
<td>143%</td>
<td>11,361,948</td>
<td>12,095,996</td>
<td>4,854,569</td>
<td>3</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>Sunflower</td>
<td>333%</td>
<td>53,360</td>
<td>61,419</td>
<td>47,224</td>
<td>3</td>
<td>60</td>
<td>8</td>
</tr>
</tbody>
</table>
Research resources spent by ARC produce substantial benefits to Sudanese farmers.

Discounted (at 3 percent) benefits over 14 years to additional research FTEs by commodity vary from a low of $53,000 (if resources are allocated to sunflower) to more than $11,000,000 (allocated to groundnuts or sesame).

Additional research resources have the largest benefit streams allocated to groundnut and sesame. Additional wheat researchers should be a low priority.
NEXT STEPS

- Present findings to policymakers
- Use Bayesian framework to understand impacts of “knowledge” on decision making