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

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OUTLINE OF PRESENTATION

- Discuss current year activities
- Present methodology
- Discuss preliminary findings from analysis of information from ARC Sudan

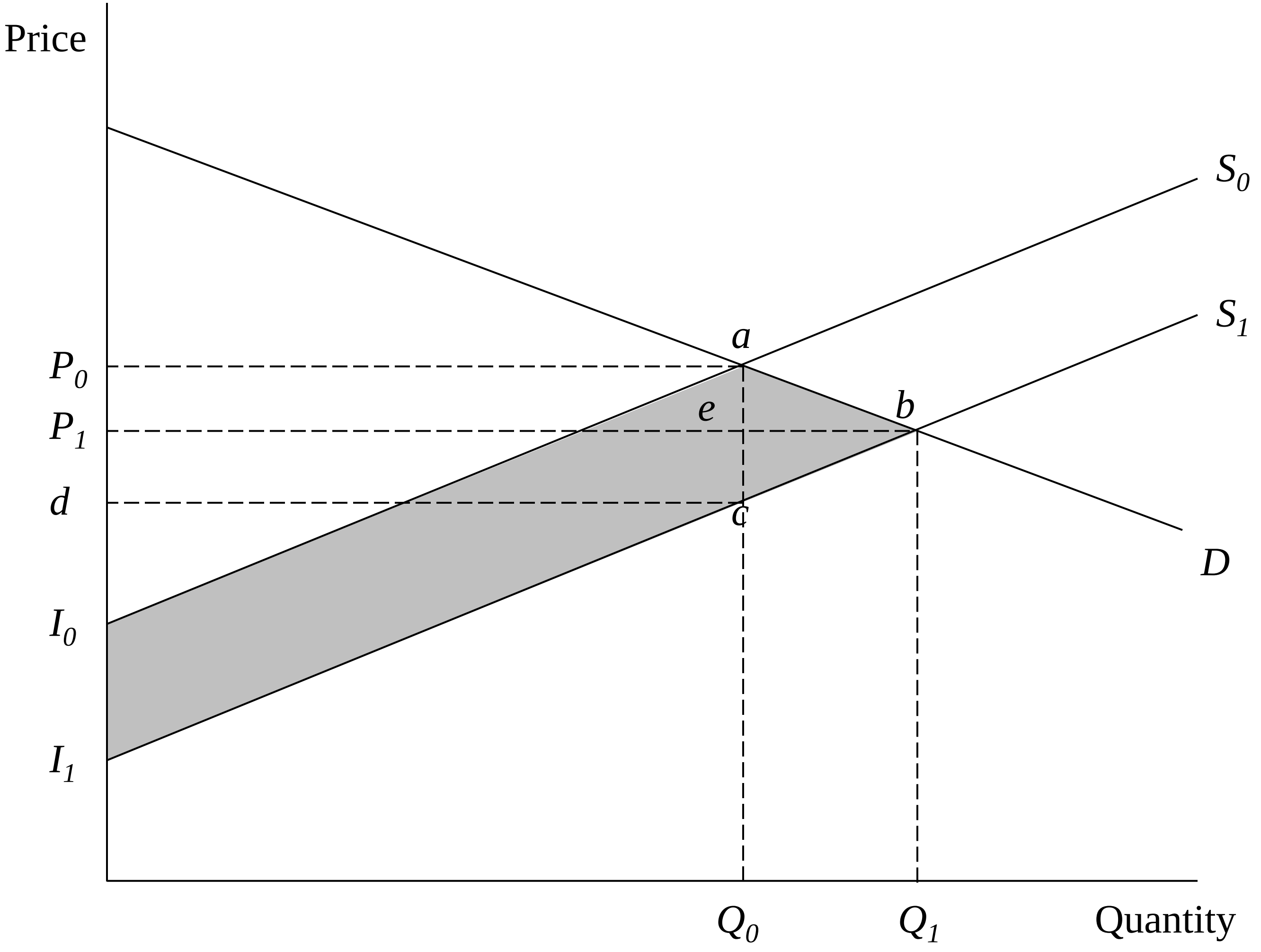
CURRENT YEAR ACTIVITIES: ARC IN SUDAN

- 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



(EX-ANTE) FACTORS AFFECTING (ECONOMIC) IMPACTS OF ANY RESEARCH PROGRAM

- "Size" of the commodity=>P*Q
- Expected size of the shift (S0=>S1)
  - 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

Benefit Estimation

Suppose the supply and demand take linear forms:

$$\text{Supply:} \quad Q_S = \alpha + \beta(P + k) = (\alpha + \beta k) + \beta P$$

$$\text{Demand:} \quad Q_D = \gamma - \delta P$$

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 $k = KP_0,\ P_1 = (\gamma - \alpha - \beta KP_0) / (\beta + \delta)$

Benefit Estimation

Define the relative reduction in price as

$$Z = -(P_1 - P_0) / P_0$$

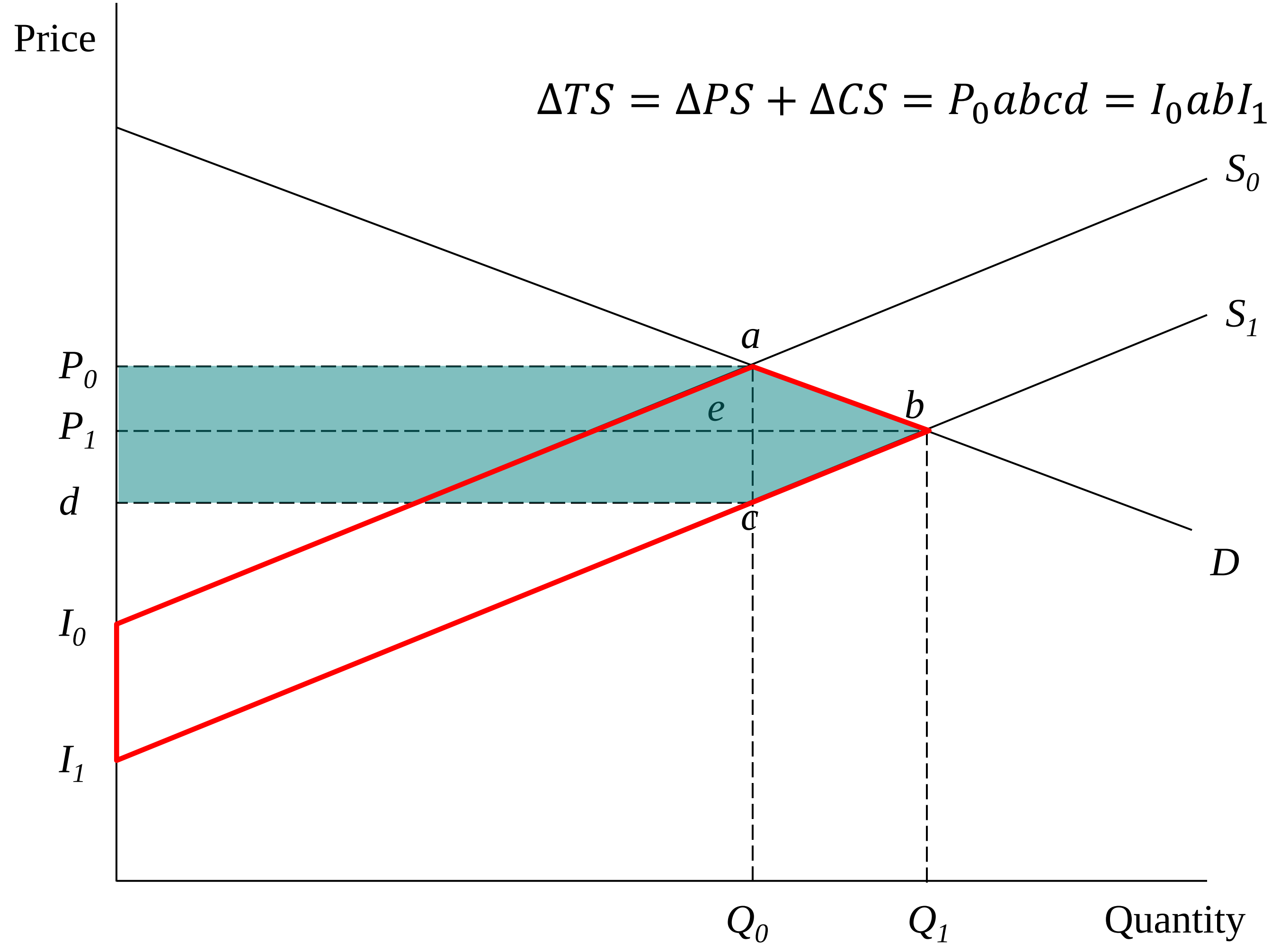
where P_0 and Q_0 are equilibrium price and quantity before the supply shift; ε is the supply elasticity and η is the absolute value of the price elasticity of demand

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

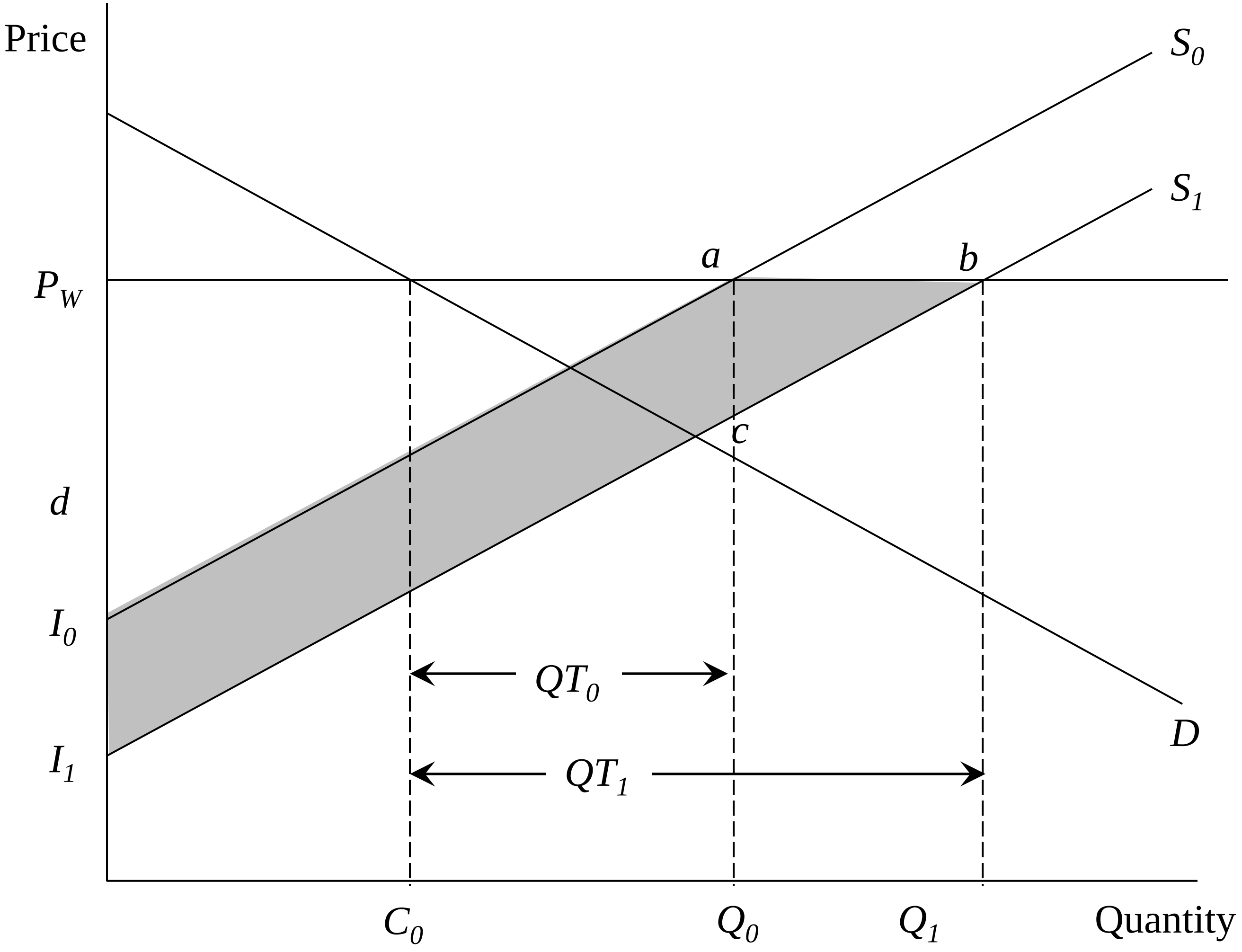
and thus,

$$Z = -\frac{P_1 - P_0}{P_0} = \frac{\beta K}{\beta + \delta} = \frac{\beta K}{\beta + \delta} \times \frac{P_0 / Q_0}{P_0 / Q_0} = \frac{K\varepsilon}{\varepsilon + \eta}$$

Benefit estimation: Total surplus change due to research-induced supply shift



Basic Model 2: Small Open Economy



Benefit estimation: Small open economy

- There is no consumer surplus, because price is taken

- Since the country can increase export / reduce importss 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:

$$\Delta PS = \Delta TS = (K - Z)P_0 Q_0 (1 + 0.5 Z\eta)$$

$$= \lim_{\eta \to \infty} (K - \frac{K\varepsilon}{\varepsilon + \eta}) P_0 Q_0 (1 + 0.5 \frac{K\varepsilon}{\varepsilon + \eta} \eta)$$

$$= P_W Q_0 K (1 + 0.5 K\varepsilon)$$

KNOWLEDGE MANAGEMENT

- 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

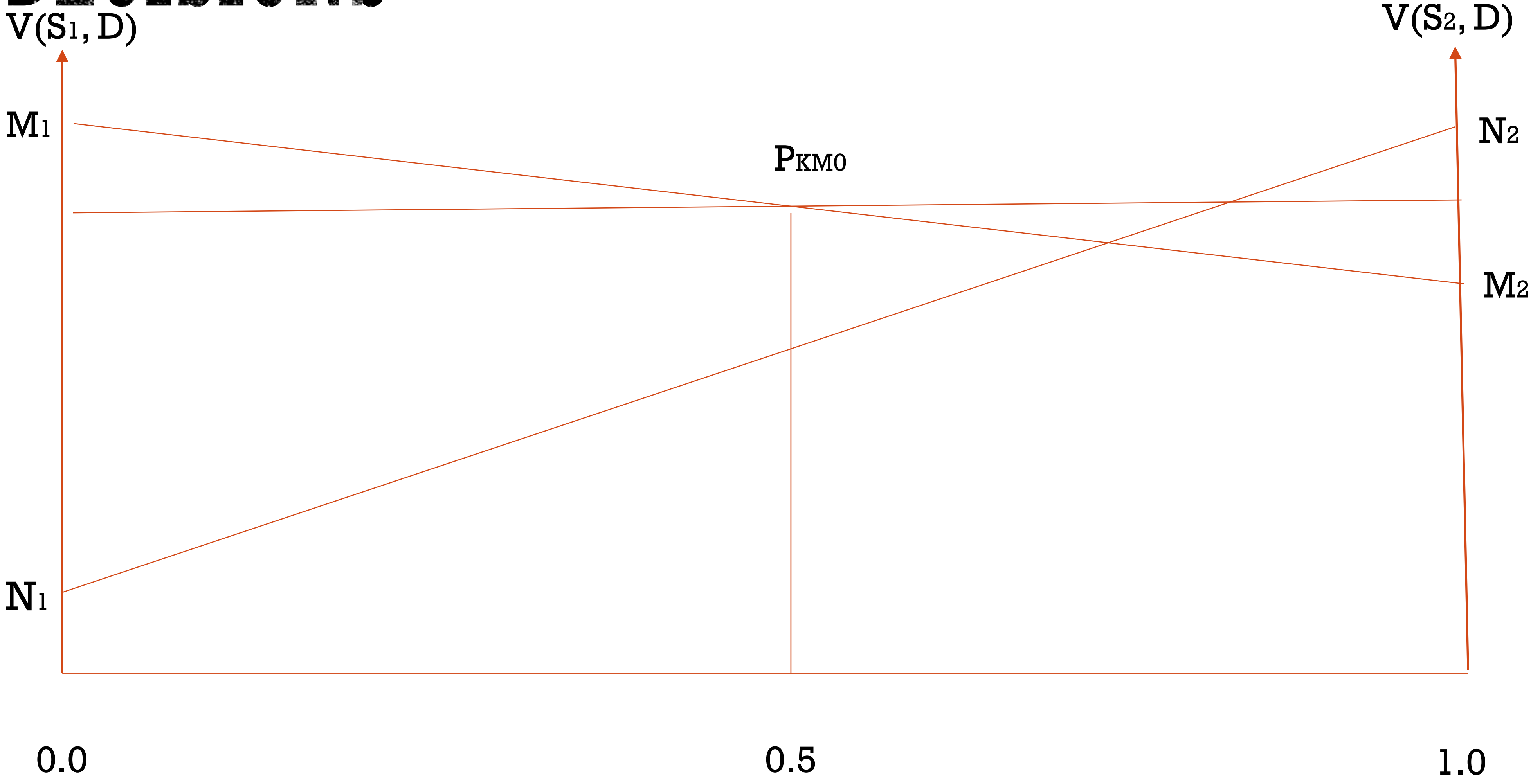
DETERMINING VALUE: A DECISION-THEORETIC APPROACH

- 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: D1=invest in innovation platform, D2=invest in traditional extension program
  - V(.) is the "value" of the decision given the SOW

VISUALIZING VALUES OF ALTERNATIVE DECISIONS



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 (π) about S_2 (increasing from left to right)
- Without KM, "guess" at state of the world (π=0.5)=>expected value of the policy (vertical distance) is P_{KM0} (choose D1)
- 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

	KM message	
True "state"	Effective	Ineffective
S_1: Effective	.8	.2
S_2: Ineffective	.4	.6

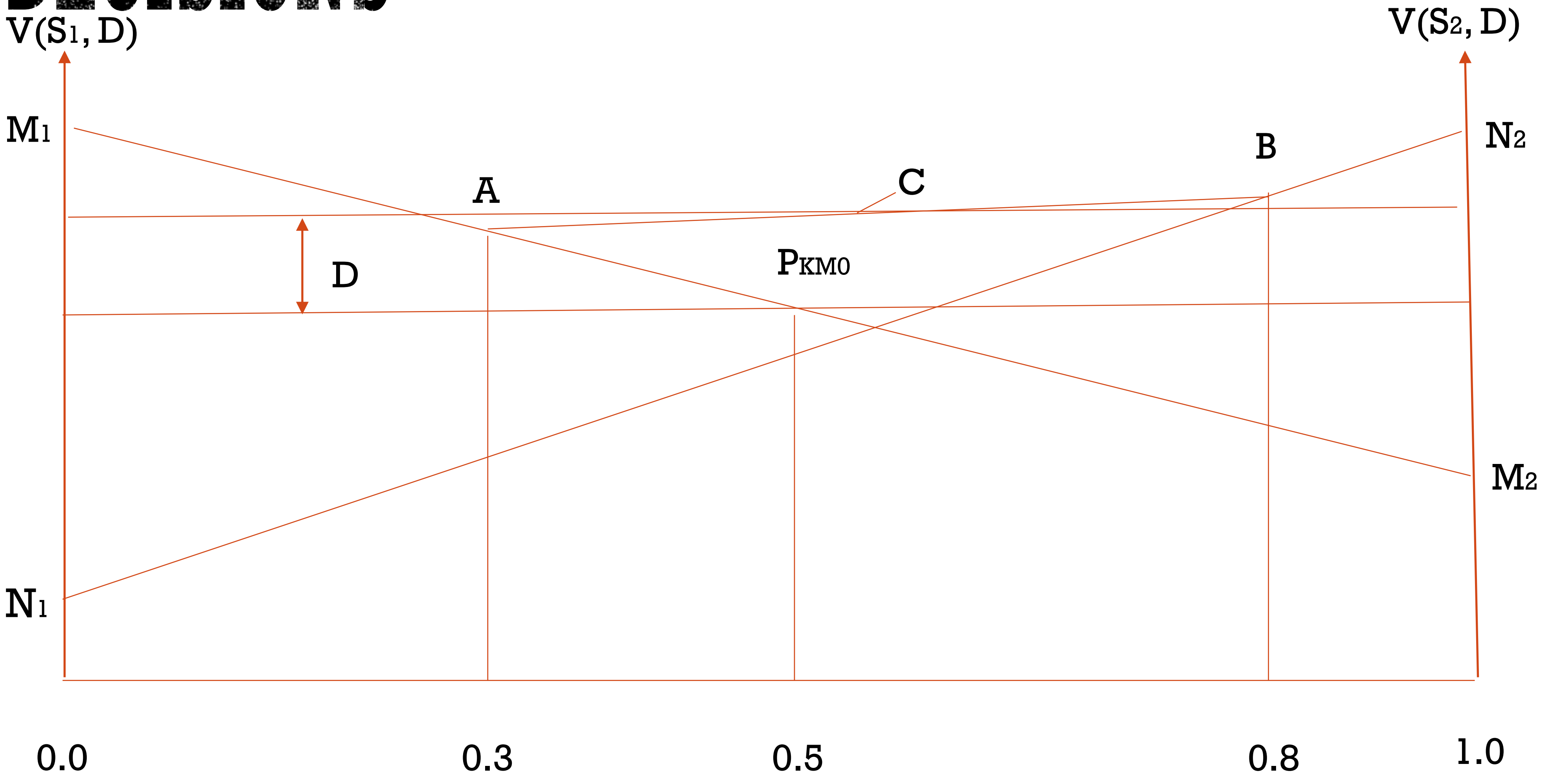
- If IPs are effective, then there is an 80 % probability that the KM message will convey this information
- It is more difficult to conclude/convey the message that IPs are ineffective so there is a 60% probability that the KM message will convey this ineffectiveness
- Apply Bayes' theorem to get posterior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

POSTERIOR PROBABILITIES OF DECISION MAKERS

	KM message	
True "state"	Effective	Ineffective
S_1: Effective	.7	.2
S_2: Ineffective	.3	.8

- If KM conveys message that IPs are effective, then π=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 π=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



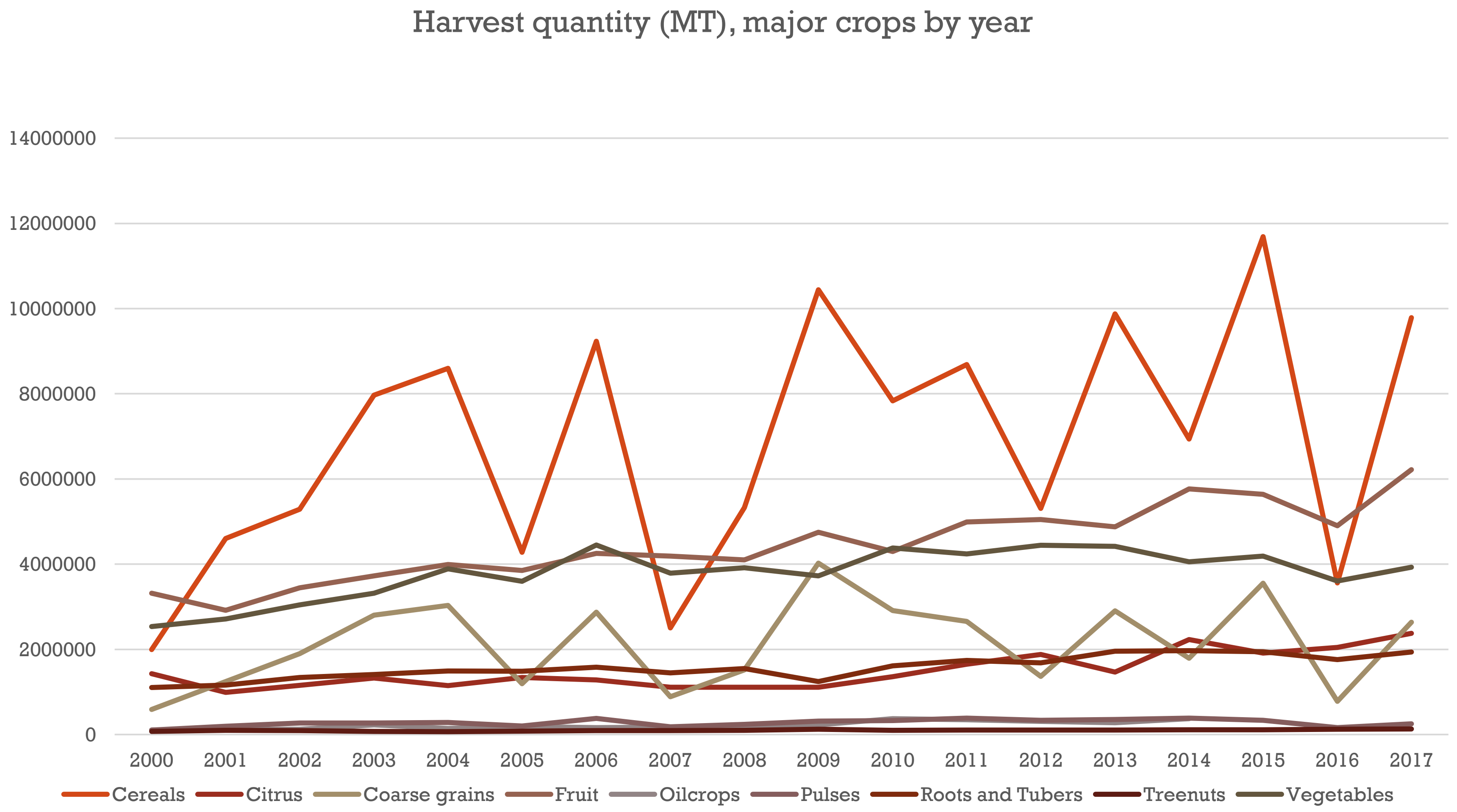
THREE ELEMENTS DETERMINE THE VALUE OF KM

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)

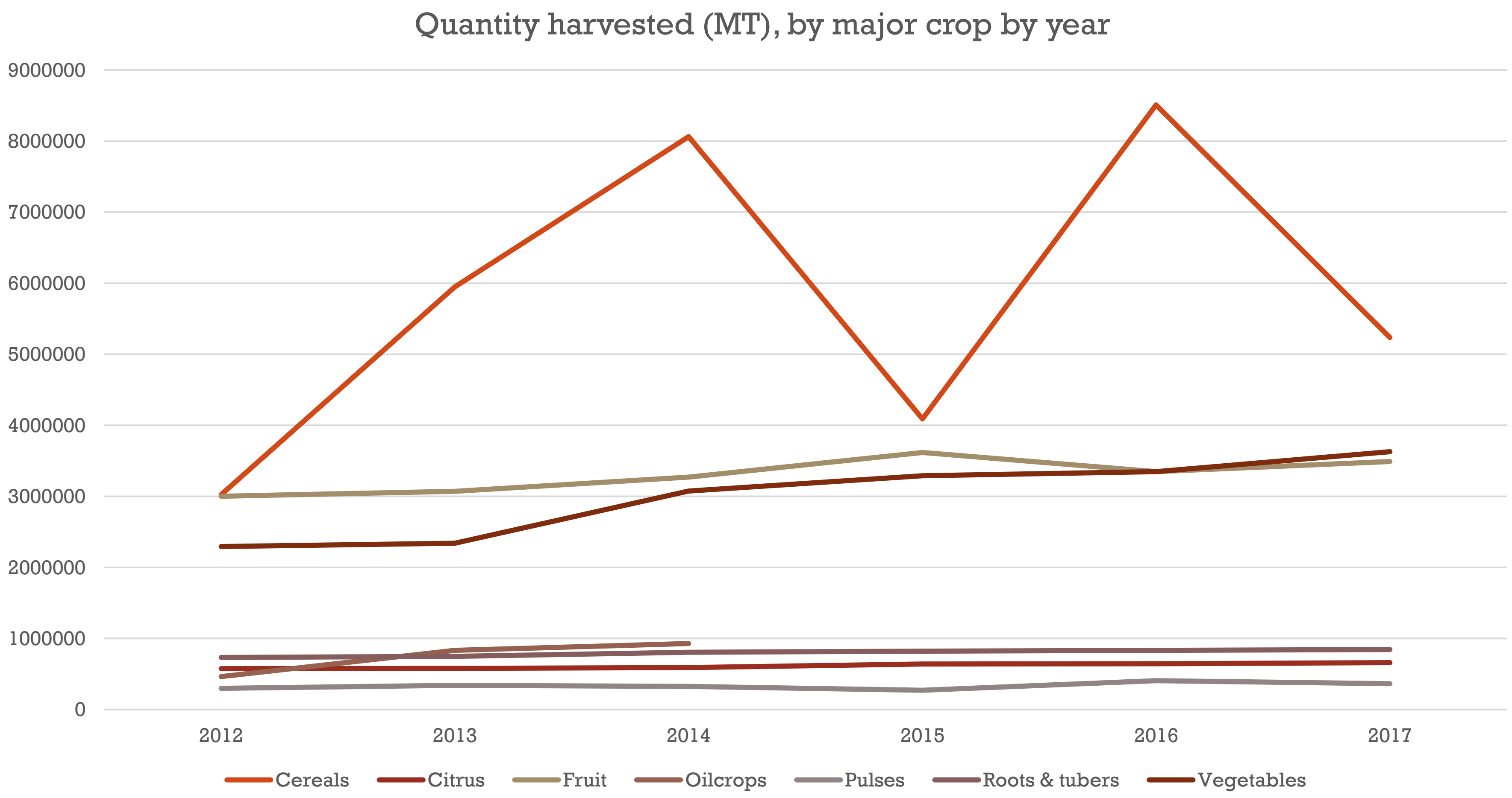
These factors alone determine the value=>

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



QUANTITY PRODUCED BY YEAR, SUDAN



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

Year	Groundnut	Millet	Seed cotton	Sesame	Sorghum	Sugarcane	Sunflower	Wheat
2013	34.5%	8.8%	2.0%	17.2%	26.5%	8.2%	1.1%	1.7%
2014	30.7%	8.5%	2.3%	18.5%	31.0%	5.9%	0.6%	2.5%
2015	30.5%	5.9%	4.8%	15.1%	24.1%	10.7%	1.4%	7.5%
2016	30.8%	10.1%	2.3%	13.9%	32.8%	6.3%	1.0%	2.9%
2017	31.1%	6.9%	2.4%	23.1%	24.1%	7.6%	1.9%	2.9%
2018	36.1%	13.7%	2.5%	18.8%	20.4%	4.7%	0.9%	2.9%
2019	39.4%	6.5%	3.2%	26.4%	15.5%	4.7%	1.0%	3.3%
Average share	33.8%	9.0%	2.7%	19.4%	24.4%	6.4%	1.1%	3.1%

SUMMARY OF SCIENTISTS/TECHNICIANS BY COMMODITY AND AREA OF RESEARCH

Commodity	Genetic resource enhancement	Agronomy & crop management	Policies	Post- harvest management	Other
Wheat	12/15	5/5	-	-	--
Sorghum	12	3	-	-	-
Pearl Millet	4	3	1	2	1
Groundnut	2	3	1	1	1
Sesame	3	2	1	1	-
Sunflower	2	1	-	=	=
Legumes (Faba)	3	-	=	=	-
Legumes (Chickpeas)	-	1 part time	-	-	-
Legumes (Lentils)	1 part time	-	-	-	-
Legumes (Dry beans)	1	2 part time	-	-	-
Gum Arabic	3/2	6/2		2/1	
Cotton					
Hort crops					

RESULTS

Commodity	Total FTE	Share of total	Share of value of production	Value-consistent FTE
Wheat	20	0.312	.034	2
Sorghum	15	0.234	.296	19
Pearl Millet	11	0.172	.099	6
Groundnut	8	0.125	.327	21
Sesame	7	0.109	.214	14
Sunflower	3	0.047	.012	1

RESULTS: BENEFITS UNDER DIFFERENT SCENARIOS

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

SUMMARY

- 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