Can U.S. Agriculture Provide Agro-Pharms for Malaria Treatment?

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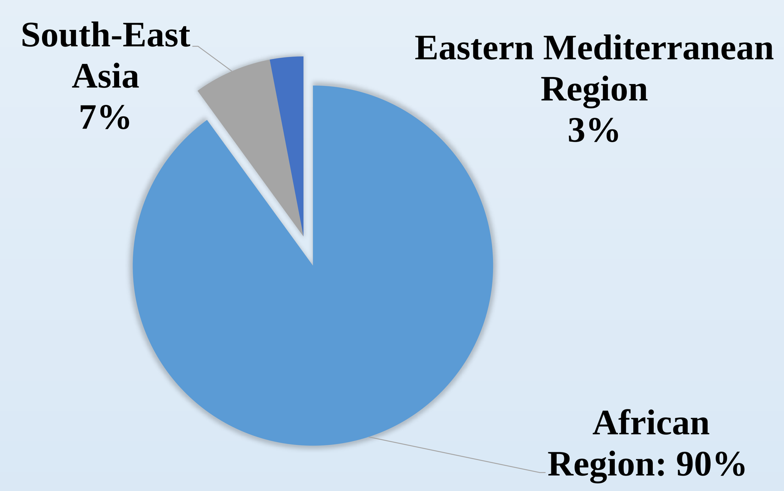
Issue

Malaria

- **New Cases of Malaria Worldwide in 2015**



Source: World Health Organization, 2016

In 2015,

- over **200 million** cases of malaria occurring globally.
- **429,000** deaths with **two-thirds** of the deaths occurring among children under the age of five.
- Malaria estimated on average to kill **one** child every **two** minutes.

Treatment& Key compound

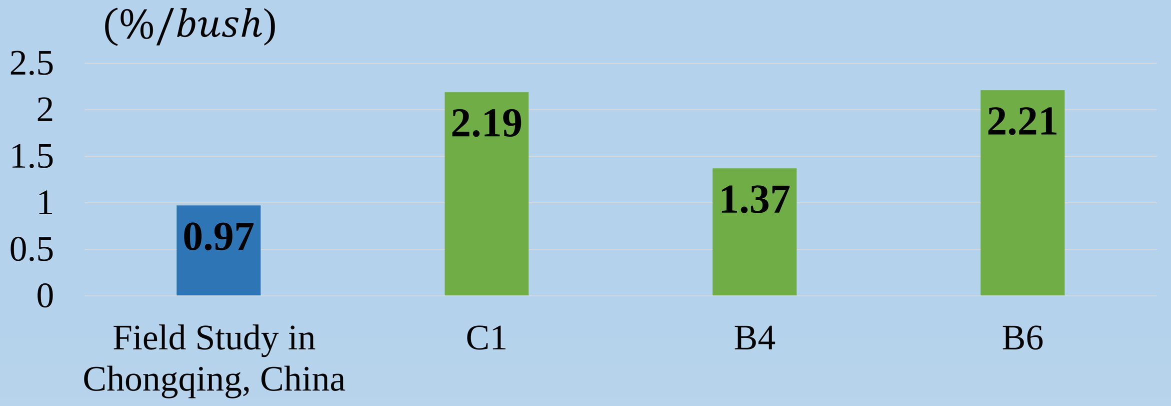
- **Artemisinin combination therapies (ACT):** exhibiting higher efficacy rates in treating malaria, the recommended treatments for malaria by the World Health Organization.
- **Artemisinin**: the key compound for ACTs, isolated from the plant Artemisia annua.
- **Artemisia**: grown predominately in East Asia and East Africa.

Challenges& Potential market

- **Demand**: Despite the success of ACTs, a 30-fold increase in demand over the past decade.
- **Production and cost**: Artemisia naturally low-yielding, and labor intensive.

Developed U.S. high-yielding Artemisia varieties

- University of Georgia and Purdue University experiment stations selecting for high-yielding Artemisia genotypes that exhibit increased biomass and Artemisinin content
- Comparison: Average Artemisinin content in dry leaves ($\%/bush$)



Notes: C1, B4 and B6 stand for bushes with high yielding genotype C1,B4 and B6, respectively, put through cross breeding in the experiment stations

Objective

To determine if the Artemisinin efficiency improvements can result in the development of a commercially viable U.S. agribusiness investment opportunity.

Methods

Real options analysis (ROA) of establishing a U.S. artemisinin agribusiness industry

Assumption

- the price per kilogram of artemisinin, p, follows the geometric Brownian motion

$$dP = \alpha P dt + \sigma P dz \quad (1)$$

where α is the drift, σ is the variance parameter, and dz is the increment of a Wiener process.

Valuing the option to invest

- The value of the option to invest, F(P) results in the Bellman equation at time t

$$\rho F(dt) = E(dF)$$

where the total expected return on the investment is equal to the expected rate of capital appreciation.

- Employing It's lemma

$$\frac{1}{2}\sigma^2 P^2 F''(P) + \alpha P F'(P) - \rho F(P) = 0$$

- The general solution to the equation is then,

$$F(P) = A_1 P^{\beta_1} + A_2 P^{\beta_2}$$

where β_1 and β_2 are the solutions of the equation and only positive root is employed. As mentioned by Dixit and Pindyck (1994), $\beta_1 > 1$ and $\beta_2 < 0$.

- The value matching and smooth-pasting conditions yield the optimal switching price threshold as follows

$$P^* = \frac{\beta_1}{\beta_1 - 1}\delta I$$

where

$$\beta_1 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}}$$

- Compare The optimal decisions rule attained through the ROA with the threshold achieved with NPV Criterion, P' and $P' = \delta I$.

Data

- Monthly artemisinin price series are employed from February 2014 through May 2016, which results in 28 observations. Artemisinin prices ($\$/kilogram$) are from Assured Artemisinin Supply System (A2S2, 2016).
- Artemisia biomass data from field trial plantings at the University of Georgia.

Results

Table 1. Summary of Artemisinin Contents with 3 Genotypes: B4, B6, C1 ($grams/bush$)

Genotype	Sample Mean
B4	5.684
B6	7.675
C1	6.672

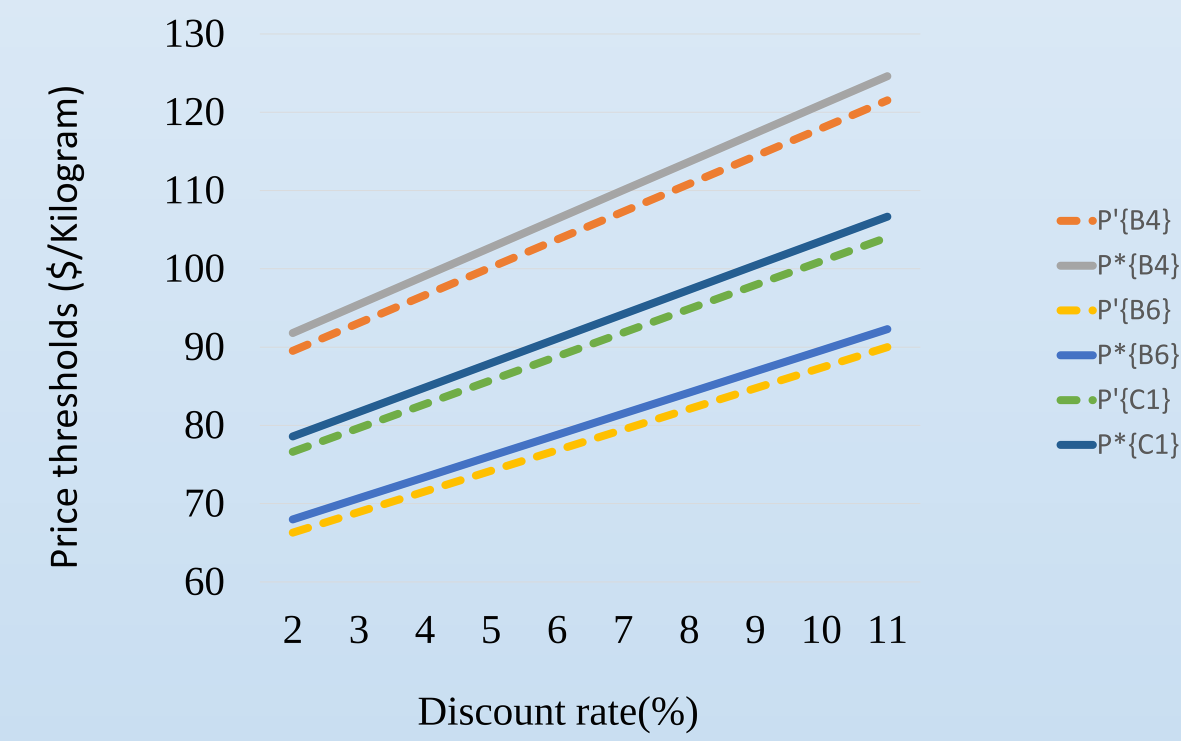
Table 2. Baseline Parameter Values Employed for Artemisia Annua Growers' Investment Decisions

Parameter	Definition	Estimated Value
$\hat{\alpha}_{yr}$	Annual price drift	−23.19%
$\widehat{\sigma^2}_{yr}$	Annual price volatility	1.20%
$\hat{\alpha}_{month}$	Monthly price drift	−3.09%
$\widehat{\sigma^2}_{month}$	Monthly price volatility	0.09%
ρ	Risk-adjusted discount rate	10.07%
δ	The rate of return short-fall on price	33.26%
I	Annual Lump sum cost to invest in the project ($/bush)	2.02
r	Risk free discount rate	5%

Results

Zeke Bryant (2013) employed standard net present value analysis to determine the economic capability and feasibility of producing artemisia in Georgia. The optimal decisions rule attained through the ROA is to exercise the option and enter when the current price is greater than $P^*$and maintain the option otherwise. If the current price is grater than P^*, then it's optimal to invest. It's compared with the threshold achieved with NPV criterion, P'. In terms of NPV, if current price $P > P'$, then enter and produce Artemisia.

Figure 1. Comparison of Price Thresholds under Real Options Analysis (P^*)and NPV Criterion (P')



Conclusion

Current monthly artemisinin price reported by A2S2 suggests the relative low price thresholds leading to highly feasible investments. In such cases, NPV analysis would generally be adequate. Even though the current price is higher than price thresholds under NPV criterion and ROA, A2S2 provides a decreasing trend in price. Less favorable investment opportunities are employed after high feasible ones are exhausted. ROA accounts for uncertainty, irreversibility, and adoption timing in establishing an artemisinin agribusiness industry. Failure to base empirical results on a sound theory will lead to a false positive of recommending development now when delay is instead the optimal choice. Any determination of economic viability should account for these constraints.

ROA provides the possibility of delaying an investment, which may be the optimal solution. As the results indicate, with an 8% discount rate and a market price at $83 per kilogram, NPV results in more aggressive investment in planting Artemisia with genotype B4 while ROA suggests to wait. Employing ROA yields an improved timely investment decision, compared with the NPV method.

Reference

Bryant, Zeke. 2014. "*An economic evaluation of Artemesia annua production.*" < https://getd.libs.uga.edu/>. Accessed May 2017.

Dixit, A. K., and R. S. Pindyck. *Investment Under Uncertainty.* Princeton NJ: Princeton University Press, 1994.

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