# Recalibrating the Reported Rates of Return to Food and Agricultural R&D

***Xudong Rao , Terrance M. Hurley and Philip G. Pardey***

***Department of Applied Economics, University of Minnesota, Saint Paul, MN 55108***

*Selected poster prepared for presentation at the Agricultural & Applied Economics Association's 2012 Annual Meeting, Seattle, Washington, August 12-14, 2012*

# Recalibrating the Reported Rates of Return to Food and Agricultural R&D


Department of APPLIED ECONOMICS

Xudong Rao, Terrance M. Hurley and Philip G. Pardey

*Department of Applied Economics, University of Minnesota, Saint Paul, MN 55108*


## Introduction

More than half a century has passed since Zvi Griliches published the first formal estimate of the returns to food and agricultural R&D in *the Journal of Political Economy*. Since then economists have published a large number of similar estimates. Alston et al. (2000) reported 292 studies with 1,886 evaluations of the payoffs to agricultural R&D in terms of the internal rate of return (*IRR*) or benefit-cost ratio (*BCR*). The average *IRR* was 73.1% per year, which is indicative of persistent underinvestment. But rather than ramping up these investments, growth in agricultural R&D spending for each of the past four decades has slowed worldwide and particularly in rich countries. One explanation for this apparent underinvestment is that rate of return estimates have simply been dismissed as unbelievably high, implying economists got it wrong.

Alston et al. (2011) argued that economists did get it wrong and have systematically overstated the returns to R&D due to their reliance on the *IRR* and its assumption that the financing rate of an investment equals the reinvestment rate of return earned by its beneficiaries. To correct this bias, they proposed relaxing this assumption and employing the modified internal rate of return (*MIRR*) (Hirshleifer 1958). For U.S. Department of Agriculture and state agricultural experiment station R&D investments from 1949 to 2002, they found the *IRR* (22.7%) was more than twice the *MIRR* (9.9%).

## Objectives

The purpose of this research was to reexamine past estimates of the rates of return to food and agricultural R&D in light of the *MIRR* to see if a similar pattern emerges across the literature. Specific objectives included:

- Assemble a comprehensive database of estimates of the rate of return to food and agricultural R&D.
- Use the information available from past studies to estimate the *MIRR* when feasible.
- Compare the *IRR* and *MIRR* estimates under alternative assumptions regarding the reinvestment rate.

## Data

The database assembled for this project includes 2,186 evaluations of returns to R&D published in 359 studies from 1958 to 2011. Of these, 95 percent reported the *IRR*, 26 percent reported a *BCR*, and 21 percent reported both. Most reported the time over which the benefits and costs of investments were evaluated. Most also reported the discount rate for computing *BCR*s when they were reported. Investments covered in the dataset include those sponsored by governments, non-governmental organizations, and private companies. These investments covered a wide range of commodities from many regions of the world. The sources include studies published in books, journals, and a large amount of grey literature (e.g., evaluation reports and studies published by various international and national agencies).

Calculation of the *MIRR* requires information on the cost and benefit profiles, which are seldom reported. However, these profiles can be estimated given the time frame and estimates of the *IRR* and *BCR* — information that was reported by a quarter of the studies and 302 (13.8%) of the evaluations. Table 1 compares the distributions of the *IRR* and *BCR* for this subsample to the overall sample.

***Table 1 Internal Rate of Return (IRR, in percentage) versus Benefit-Cost Ratio (BCR)***

| | | Obs. | Mean | S.D. | Min. | 1st Quantile | Median | 3rd Quantile | Max. |
|---|---|---|---|---|---|---|---|---|---|
| ***IRR*** | Overall | 2077 | 74.3 | 196.3 | -47.5 | 24.0 | 43.0 | 74.0 | 5645.0 |
| | **Subsample** | **302** | **51.8** | **59.8** | **0.1** | **18.9** | **32.9** | **75.6** | **677.0** |
| ***BCR*** | Overall | 568 | 23.3 | 30.7 | 0.0 | 3.2 | 11.0 | 31.9 | 199.0 |
| | **Subsample** | **302** | **29.0** | **30.6** | **0.1** | **6.9** | **20.4** | **40.1** | **176.0** |

## Methods

Setting the date of the initial and final R&D investments to 0 and $T_c$, and the date of the initial and final benefits from these investments to $T_b$ and $T$, the *MIRR* can be defined implicitly by

$$\text{(1)} \quad \frac{B}{C}\sum_{t=T_b}^{T} w_t^b(1+\rho)^{T-t} = \sum_{t=0}^{T_c} w_t^c(1+MIRR)^{T-t}$$

where $C$ and $B$ are the aggregate nominal costs and benefits accruing from the investment; $\mathbf{w^c} = (w_0^c, \ldots, w_{T_c}^c)$ and $\mathbf{w^b} = (w_{T_b}^b, \ldots, w_T^b)$ are the distributions of these aggregate costs and benefits over time; and $\rho$ is the reinvestment rate. While $T_c$, $T_b$ and $T$ are readily available in most studies, and $\rho$ is typically taken as exogenous in *MIRR* calculations, the specific cost and benefit profiles (i.e., $\mathbf{w^c}C$ and $\mathbf{w^b}B$) are not typically reported.

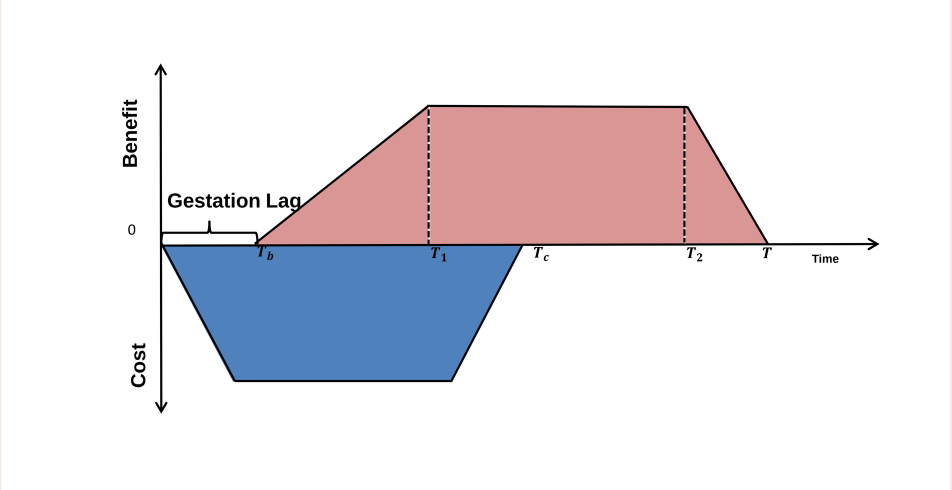
Calculating the *MIRR* is not feasible if there is no information on the cost and benefit profiles. Fortunately, knowing *IRR*, *BCR*, $T_c$, $T_b$, $T$, and the discount rate ($\delta$) used to calculate the *BCR* does provide information that can be used to estimate these profiles. To see how, note that the definitions of the *IRR* and *BCR* imply

$$\text{(2)} \quad \frac{B}{C} = \frac{\sum_{t=0}^{T_c} w_t^c(1+IRR)^{-t}}{\sum_{t=T_b}^{T} w_t^b(1+IRR)^{-t}}$$

$$\text{(3)} \quad BCR - \frac{\sum_{t=0}^{T_c} w_t^c(1+IRR)^{-t}\sum_{t=T_b}^{T} w_t^b(1+\delta)^{-t}}{\sum_{t=T_b}^{T} w_t^b(1+IRR)^{-t}\sum_{t=0}^{T_c} w_t^c(1+\delta)^{-t}} = 0.$$

This reduces the problem to finding the distributions for $\mathbf{w^c}$ and $\mathbf{w^b}$ that satisfy equation (3). While conceptually straightforward, this problem is computationally impractical. This computational impracticality can be overcome by approximating $\mathbf{w^c}$ and $\mathbf{w^b}$ with

***Figure 1 Trapezoidal Distribution of Benefits and Costs***




a flexible family of distributions that can be characterized by a parsimonious parameter space.

Let $\mathbf{w^c}(\boldsymbol{\alpha}^\mathbf{c})$ and $\mathbf{w^b}(\boldsymbol{\alpha}^\mathbf{b})$ be parameterized distributions for the costs and benefits where $\boldsymbol{\alpha}^\mathbf{c}$ and $\boldsymbol{\alpha}^\mathbf{b}$ are parameter vectors. The problem can then be framed as

$$\text{(4)} \quad \min_{\boldsymbol{\alpha}^\mathbf{c},\boldsymbol{\alpha}^\mathbf{b}} \left| BCR - \frac{\sum_{t=0}^{T_c} w_t^c(\boldsymbol{\alpha}^\mathbf{c})(1+IRR)^{-t}\sum_{t=T_b}^{T} w_t^b(\boldsymbol{\alpha}^\mathbf{b})(1+\delta)^{-t}}{\sum_{t=T_b}^{T} w_t^b(\boldsymbol{\alpha}^\mathbf{b})(1+IRR)^{-t}\sum_{t=0}^{T_c} w_t^c(\boldsymbol{\alpha}^\mathbf{c})(1+\delta)^{-t}} \right|.$$

The problem in equation (4) can be solved for evaluations that include both the *IRR* and *BCR* by assuming the distributions of costs and benefits are trapezoidal as illustrated in Figure 1. With these trapezoidal distributions, the optimization problem can be solved robustly and efficiently using a grid search. Once estimates for $\boldsymbol{\alpha}^\mathbf{c}$ and $\boldsymbol{\alpha}^\mathbf{b}$ are obtained, estimates for *B/C* and *MIRR* follow immediately from equations (1) and (2).

## Results

Figure 2 shows the reported *IRR* and the estimated *MIRR* assuming a reinvestment rate of 5%. Table 2 shows the sensitivity of these results for alternative assumptions regarding the reinvestment rate. Compared to the mean *MIRR*, the mean *IRR* is 2.5 times larger; though the *IRR* is not universally larger than the *IRR*. For low *IRR*s (those less than the reinvestment rate), the *MIRR* tends to be higher. But this is a relatively small percentage (<10% for all three reinvestment rates) of observations. Alternatively, for relatively large *IRR*s, the *MIRR* is smaller, with the difference tending to increase with the *IRR*.

While the *MIRR*s are generally smaller than the *IRR*s, they still suggest a competitive return to investments in agricultural R&D. With a 5% reinvestment rate, 90% of the *MIRR*s exceed 7.1%, while half exceed 17.4%. For 3% and 10% reinvestment rates, 90% exceed 6.0% and 10.3% respectively, while half exceed 16.6% and 19.9%. It is also worth noting that for the *IRR*s, 90% exceed 10.1% and half exceed 33%.

***Figure 2 Comparison of IRR and MIRR using a Reinvestment Rate of 5%***

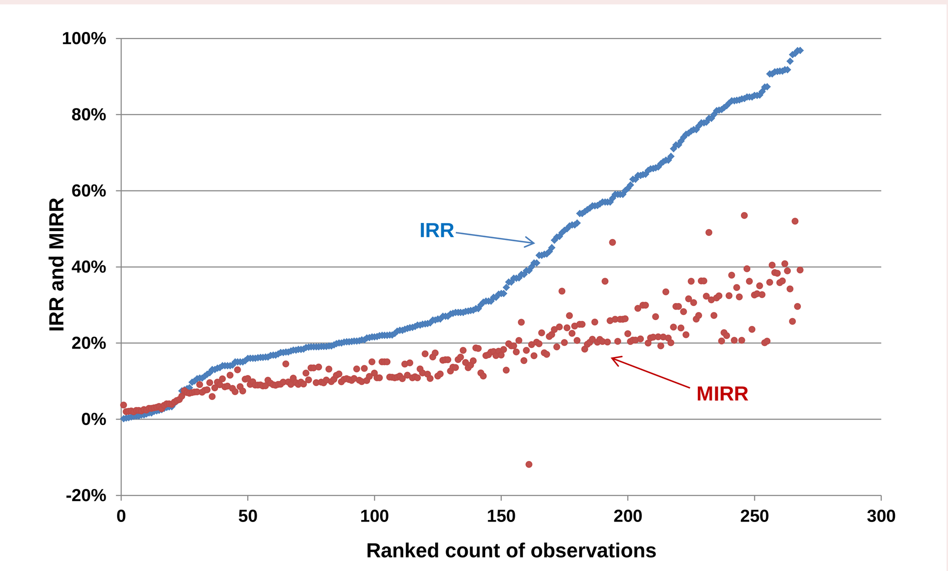



***Table 2 Sensitivity Test on Reinvestment Rate (ρ)****

| | *IRR* (percentage) | *MIRR* (percentage) | | |
|---|---|---|---|---|
| | | $\rho$ = 3% | $\rho$ = 5% | $\rho$ = 10% |
| **Mean** | **52** | **18** | **20** | **22** |
| **Minimum** | **0** | **-11** | **-12** | **3** |
| **1st Quantile** | **19** | **9** | **10** | **13** |
| **Median** | **33** | **16** | **17** | **20** |
| **3rd Quantile** | **76** | **25** | **26** | **29** |
| **Maximum** | **677** | **268** | **269** | **273** |
| **No. of Obs. with *IRR* <= *MIRR* (Percentage of total sample)** | | **17 (5.7%)** | **22 (7.3%)** | **29 (9.7%)** |
| **No. of Obs. with *IRR* > *MIRR* (Percentage of total sample)** | | **283 (94.3%)** | **278 (96.7%)** | **271 (90.3%)** |

*Our grid search for the best-fit distributions included 302 observations. Unique distributions were identified for all but two observations, which had *BCRs* equal to 1 and a discount rate equal to the IRR.

## Discussion & Conclusion

Over the past half century economists have published many estimates of the returns to food and agricultural R&D. The result of this effort suggests the investments have paid handsomely. Despite estimates of high returns, agricultural R&D spending growth has slowed or stalled. Alston et al. (2011) challenged previous estimates of the *IRR* due to the implausible assumption that the cost of financing these investments equals the rate of return to beneficiaries. They further showed how the *MIRR*, which does not rely on this assumption, yields estimates that are about half the size of the *IRR* for agricultural *R&D* in the United States.

This research reexamined estimates of returns to R&D using the *MIRR* to see if a similar pattern emerges throughout the literature. The results are even more striking, with the *IRR* 2.5 times larger than the *MIRR* on average. While reexamining all previous studies was not possible, the results are conservative because the difference in *IRR* and *MIRR* tends to increase as the *IRR* increases, and the studies that were reexamined had lower *IRR*s than others on average. While the *MIRR*s are typically lower than the *IRR*s, they still suggest that the vast majority of investments yielded a competitive rate of return.

The evident failure of economic evidence to sway R&D decisions has profound consequences. Alston, Babcock and Pardey (2010) concluded that there has been a widespread slowdown in agricultural productivity growth, consistent with a prior and persistent ratcheting down in agricultural R&D spending growth. If R&D-induced shifts in global food supplies fall short of demand for agricultural output, affordable access to food will be further curtailed, with inevitable adverse consequences for the chronically hungry worldwide.

## References


Alston, J.M, M.A. Andersen, J.S. James, and P.G. Pardey (2011). The economic returns to U.S. public agricultural research. *American Journal of Agricultural Economics* 93(5):1257-1277.

Alston, J.M., B.A. Babcock and P.G. Pardey (2010). Shifting Patterns of Global Agricultural Productivity: Synthesis and Conclusion. *The Shifting Patterns of Agricultural Production and Productivity Worldwide* (eds. Alston, Babcock and Pardey). MATRIC, Iowa State University, Ames, IA. pp447-480

Alston, J.M., C. Chan-Kang, M.C. Marra, P.G. Pardey, and T.J. Wyatt (2000). *A Meta-Analysis of Rates of Return to Agricultural R&D: Ex Pede Herculem?* Research Report No. 113, Washington D.C.: IFPRI.

Griliches, Z. (1958). Research Costs and Social Returns: Hybrid Corn and Related Innovations. *Journal of Political Economy* 66(5):419-431.

Hirshleifer, J. (1958). On the Theory of Optimal Investment Decision. *Journal of Political Economy* 66(4):329-352.



**ACKNOWLEDGEMENTS**

This study was prepared with support from the International Science and Technology Practice and Policy (InSTePP) Center at the University of Minnesota and the Gates Foundation-funded HarvestChoice project.


INSTEPP HarvestChoice BETTER CHOICES, BETTER LIVES