The Contribution and Value of Public Agricultural Research for Agricultural Productivity

Philip Pardey

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Department of APPLIED ECONOMICS
UNIVERSITY OF MINNESOTA

INSTEPP INTERNATIONAL
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Research – Productivity Relationships 101

Basic Conceptual Constructs

1. Local and non-local R&D spending gives rise to stocks of research knowledge

2. Knowledge stocks give rise to technical changes that preserve past or promote new productivity growth

3. Productivity improvements generate economic value to producers and consumers

    - Consumers: Safer, more abundant (cheaper) food

    - Producers: Lower (than otherwise) unit costs of production

What Does the Returns to Ag. R&D Evidence Tell Us?

- Are the returns to agricultural R&D declining and development dependent?

- What would be the returns to global agricultural R&D if we all headed Griliches?

  or

- Is 60% per year really the returns to food and agricultural R&D?

- Is the returns-to-research evidence “representative” of the sector it purports to evaluate?

A Conundrum

Global Returns to Food and Ag R&D

InSTePP returns-to-research database (version 3.0) includes 2,829 evaluations (or 3,426 estimates) from 492 studies published from 1958 to 2015.

93% of the evaluations are IRRs

Mean IRR = 58.7 %py

Median IRR = 39.0%py


COMMENT

TECHNOLOGY The geeks and entrepreneurs of commercial space travel p304 | ECOLOGY Trees, a lesson in standing tall by standing together p306 | CHINA Sponge cities to retain run-off, control flooding, and reuse storm water p307 | OBITUARY Seymour Papert, father of educational computing p308

A wheat test plot in Maryland.

Agricultural R&D is on the move

Big shifts in where research and development in food and agriculture is carried out will shape future global food production, write Philip G. Pardey and colleagues.

The geographical distribution of food and agricultural research and development (AgR&D) is changing. Our analysis of more than 50 years of data indicates that the governments of middle-income nations are investing more than those of high-income ones for the first time in modern history. The numbers also suggest that, globally, private-sector spending on AgR&D is catching up with public-sector spending. Meanwhile, the gap between spending by high-income and low-income countries is widening.

Investments in R&D are inextricably intertwined with growth in agricultural productivity and food supplies[1]. But it takes decades', not months or years, for the consequences of these investments to be fully realized. Today's R&D investment decisions will cast shadows forward to 2050 and beyond, making the trends we report here especially significant for the future of food production.

DATA GATHERING

To track shifts in where AgR&D occurs worldwide, we revised and updated the various data series on spending maintained by the University of Minnesota's International Science and Technology Practice and Policy (InSTePP) Center in St Paul. Successive versions of these series have been developed over decades by collating and harmonizing data obtained from many government and international agencies, private firms and unpublished sources, and using statistical approaches developed to infer missing observations[2]. Our global update took 6 years, and involved direct input from more than 60 collaborators at national and international statistical and scientific agencies.

Extensive details on the construction of our data series are available online (see go.nature.com/2cc9db). In short, the data include new and revised estimates of the amount of AgR&D spending by universities and government agencies for USCom-

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Global (Public) Spending on Food and Ag R&D

- 24% (9 of 24) rich countries spent less in 2011 than 1980
- 28 low and middle-income countries (mainly in SSA), also scaled back spending
- For the remaining 95 countries worldwide whose real spending has increased, 37% (35 out of 95) had lower growth rates in the 2000s than in both the 1990s and the 1980s.

Declining Returns Over Time?

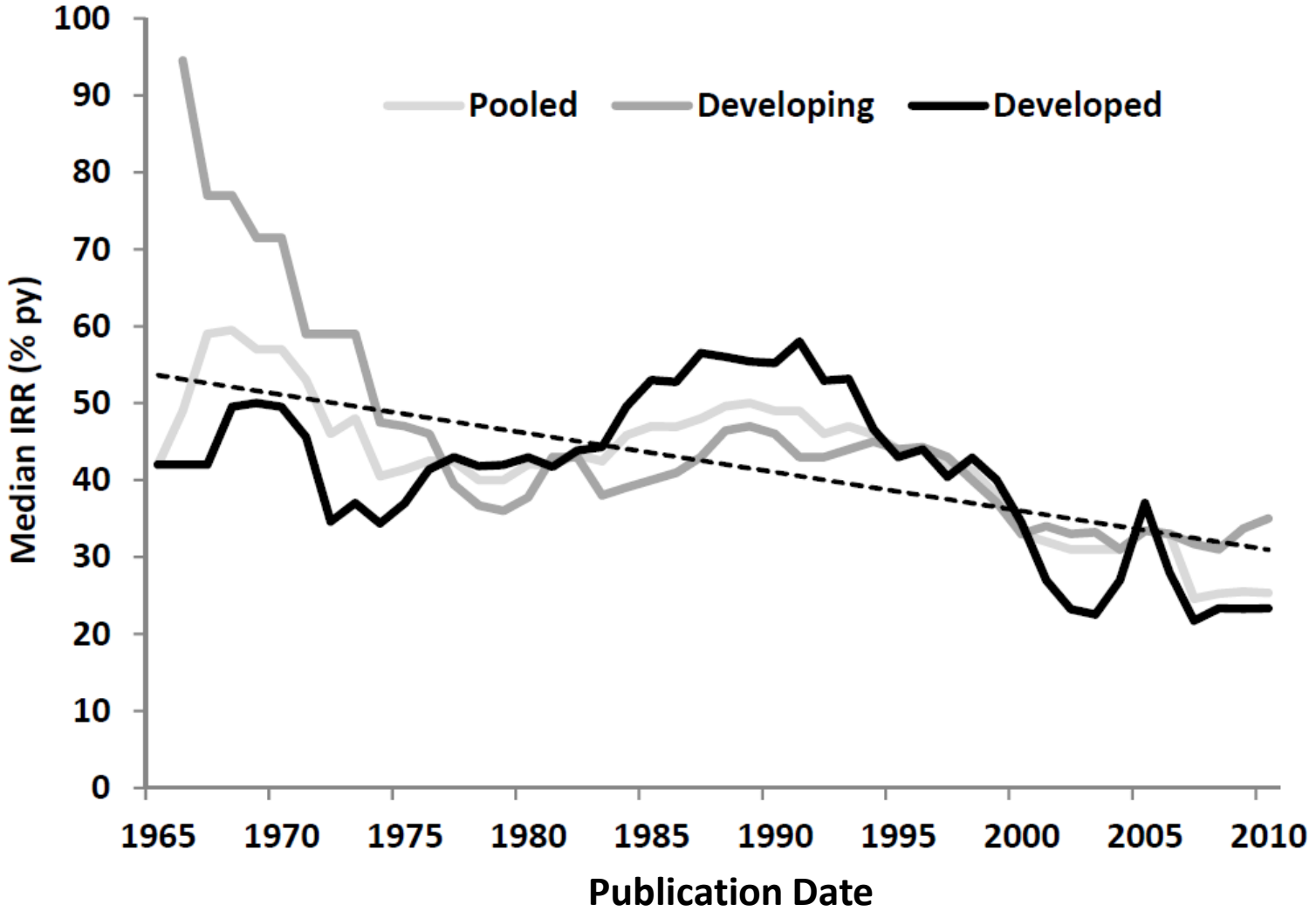
"The widespread retreat from investing in public agricultural R&D is a policy choice that is consistent with returns to R&D that have declined over time, making public investments in agricultural R&D a (relatively) less attractive option in recent years compared with earlier decades."

(Hurley et al. 2017)

"Some suggest that the rate of return to agricultural R&D ought to be expected to decline over time, owing to some loose notion of diminishing returns or the view that the easy problems have already been solved… On the other hand, others have said that new information and biotechnologies offer the potential for an unprecedented technological revolution."

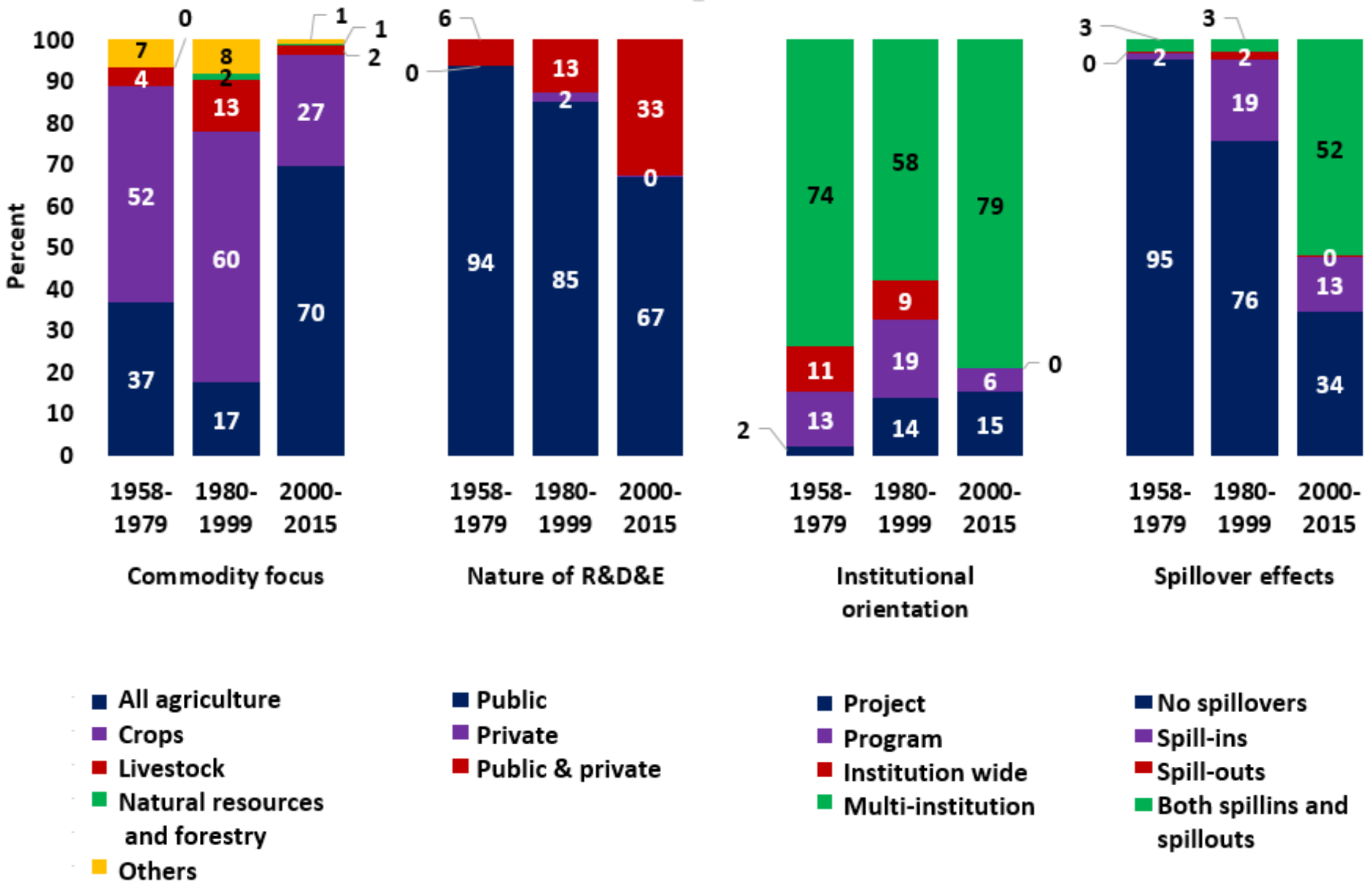
(Alston et al. 2000, p.7)

Trends in Reported IRR's, at Face Value



Note: IRRs plotted by year ending of a 10-year moving average of the respective medians.

Changes in the Composition of IRR Studies Over Time



Developed vs Developing Country IRRs

On the One Hand

Relative to the size of their agricultural sectors, developed (high-income) countries invest more on agricultural R&D than developing (low- and middle-income) countries, so if diminishing returns prevail, one might expect the returns, *ceteris paribus*, to be lower in developed versus developing countries.

On the Other Hand!

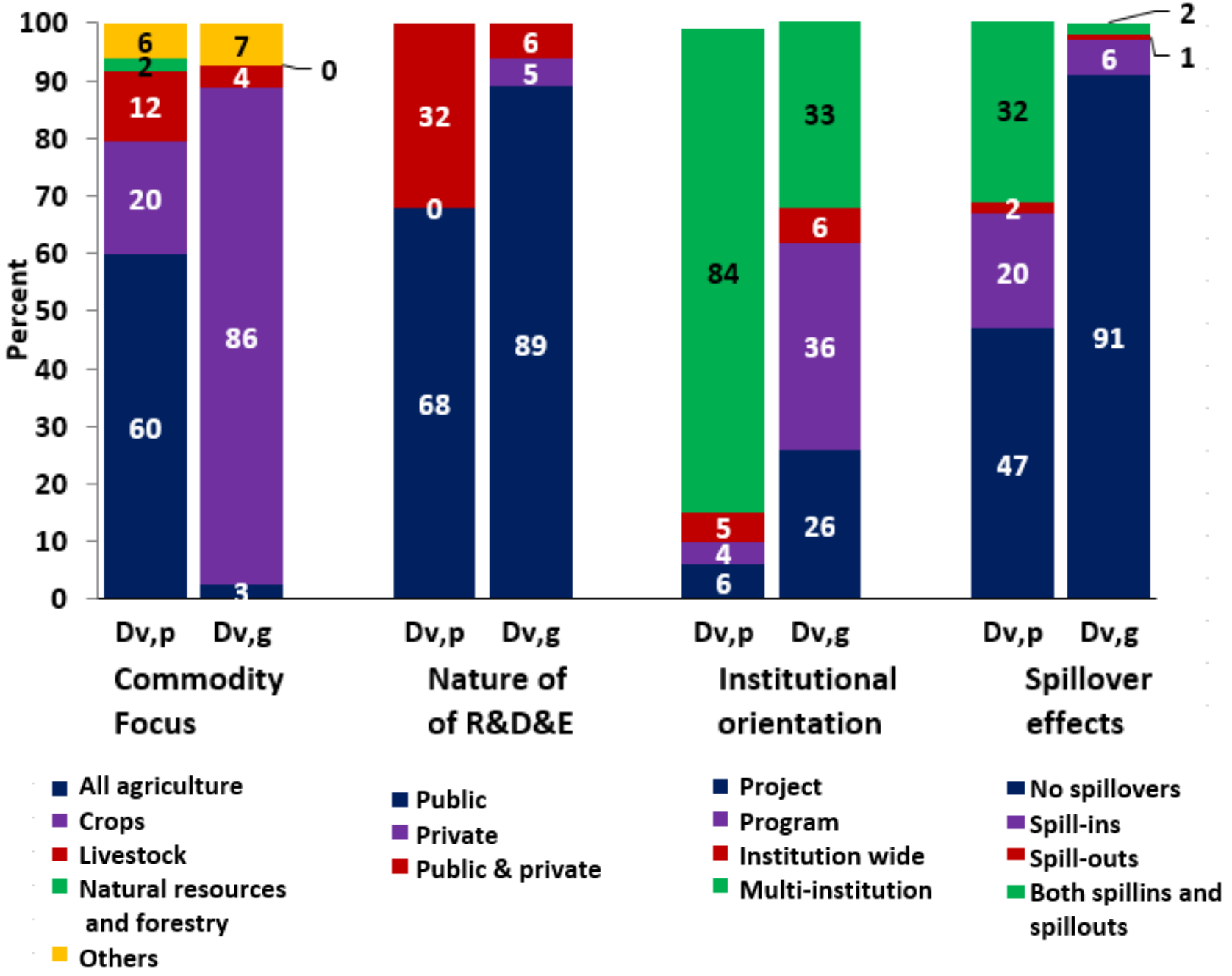
The quality and structure of the resources devoted to R&D (e.g., in terms of the relative size of the research agencies, the training and work experience of the scientists, and so forth) would suggest the reverse relativity on developed- versus developing-country returns.

Median IRRs at Face Value

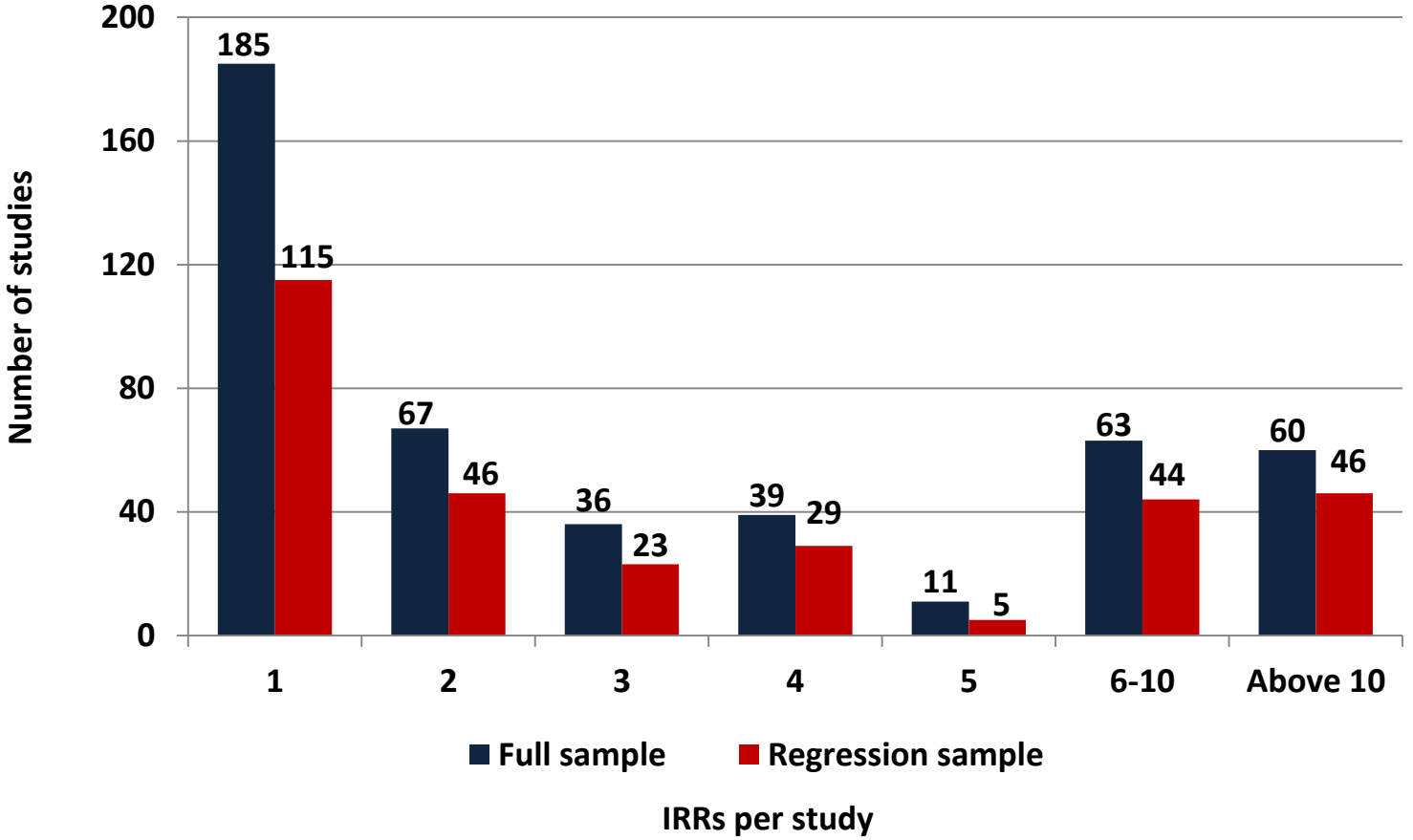
Developing country = 41.1%py

Developed country = 34.0%py

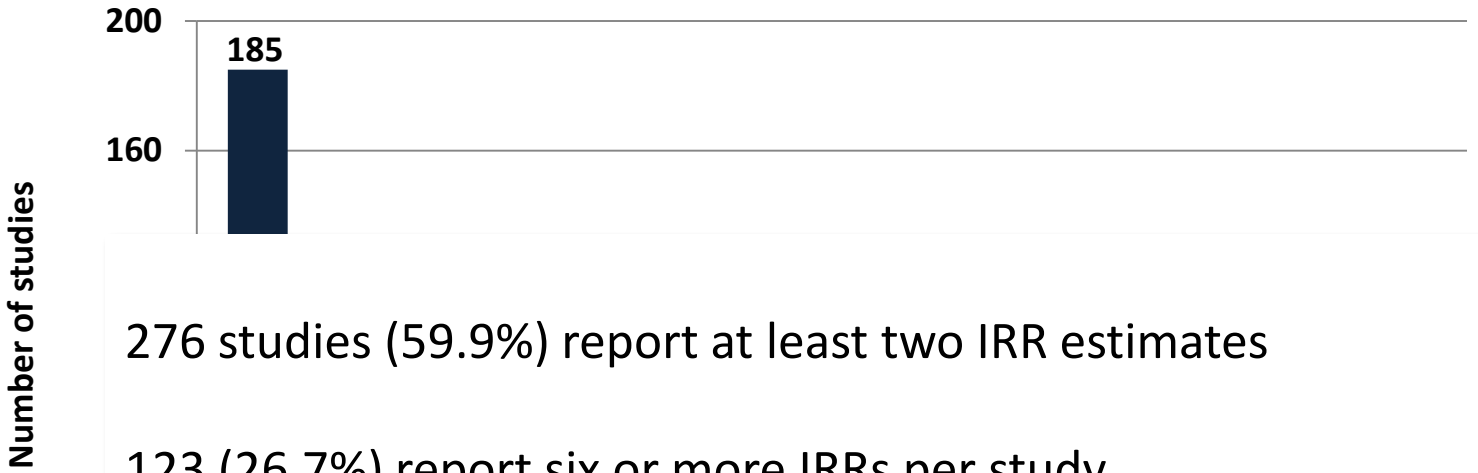
Development Differences in the Composition of IRR Studies



Frequency of IRR Estimates per Study



Frequency of IRR Estimates per Study



276 studies (59.9%) report at least two IRR estimates

123 (26.7%) report six or more IRRs per study

Failure to account for the clustering of observations within groups (i.e., evaluation studies) will lead to overstated statistical significance of coefficient estimates, especially of group-level factors.

- We deployed a hierarchical or mixed, random-intercept model (specifically we used a two-level, mixed-effect specification, i.e., both fixed and random effects)
- Oaxaca decomposition used to discern developed vs developing country differences

Results

Declining Returns?

Our primary results find that neither the initiation year of R&D investment nor the publication date of the R&D evaluation study has a statistically significant association with the reported IRR estimate for developed countries, developing countries, or the pooled data

- We conclude that the contemporary returns to agricultural R&D investments appear as high as ever

Development Dependency?

There are differences in the estimated IRRs between developed and developing countries, but we cannot provide unqualified conclusions regarding the overall implications of these differences.

- Differences in study attributes, such as who, what and how the study was performed tend to result in higher IRR estimates in developed countries
- Differences in the marginal effects of the attributes results in higher IRR estimates in developing countries

The Conundrum Continued

Are the Reported Returns to R&D Believable?

"This will never do!" he protested. "No one will swallow these figures!" The report revealed that for every single dollar that had been spent for scientific research in the Department of Agriculture, the nation was reaping an annual increase of nearly a thousand dollars in new wealth.

"Cut it down to $500," insisted Wilson. "That's as much as we can expect the public, or Congress, to believe."

(McMillen 1929, p.141 account of "Tama Jim" Wilson, then USDA Secretary)

With a return of 39.0% per year, the U.S.'s $4.1 billion investment in agricultural R&D in 2000 would generate $58 quadrillion ($\times 10^{15}$) in net benefits by 2050—more than 390 times the projected world GDP in 2050.

(Hurley et al. 2014)

Recalibrating the Returns

Summary Statistic of Choice – IRR

$$PVC\ (\text{IRR}) = PVB\ (\text{IRR})$$

Griliches questioned the sensibility of using an IRR to represent the returns to hybrid corn research noting that his "…objection to this particular procedure is that it values a dollar spent in 1910 at $2,300 in 1933…I prefer to value the 1910 dollar at a reasonable rate of return on some alternative social investment."

(Griliches 1958, p. 425)

An Alternative Summary Statistics – MIRR

$$MIRR = \sqrt[T]{\frac{FVB(\delta^r)}{PVC(\delta^c)}} - 1$$

where

δ^r = reinvestment rate of benefits

δ^c = borrowing discount rate

Imputing MIRRs (and BCRs)

Step 1: Used methodology in Hurley et al. (2014) to approximate MIRRs for the sub-set of 412 evaluations in the InSTePP database that reported both a BCR, an IRR, and the time-related information (i.e., T^c, T^b, and T).

Step 2: Deployed regression methods to identify the best-fitting relationship between the reported IRRs and the approximated MIRRs while accounting for differences in T^c, T^b, and T.

Step 3: Used regression results to project MIRRs for all reported IRR estimates that did not report sufficient information to approximate an MIRR using Step 1 and were within the support of the regression analysis

The Global Returns to Food and Ag R&D – The New Norm?

	N	Mean	Min	Median	Max
IRR	2,165	58.7	7.4	38.98	1,736
MIRR	2,165	17.9	9.09	17.04	51.62
BCR	2,165	51.3	0.89	7.46	15,173.0

$T^e = 30$ and $\delta = 0.1$ (10%)

Representativeness of the Evidence

(Relative to R&D Spending)

- Public R&D is substantially over-represented, whereas private R&D is heavily under-represented.
- High and upper-middle income countries are slightly under-represented, whereas lower-middle and low income regions over represented.
  - A few countries are heavily over-represented in the evaluation evidence, notable the United States, Canada, Australia, New Zealand, and the United Kingdom.
- Three crop categories, wheat, corn and other cereals (including sorghum, millet, barley and oats), are over-represented, whereas rice, fruits, vegetables and nuts, and livestock (including poultry) are under represented.
- CGIAR centers account for about 10% of the evaluations (and around 18% of the studies) even though CGIAR spending ($14.3 billion from 1980 to 2011) accounted for just 1.01% of the corresponding CGIAR plus domestic public and private sector spending.

Talk Topics

- Are the returns to agricultural R&D declining, and development dependent?

No

Yes, but…..

- What would be the returns to global agricultural R&D if we all headed Griliches?

Median IRR = 17%py (vs 39%py)

Median BCR = 7.5:1

- Is the existing evidence "representative" of the sector it purports to evaluate?

No, but…..

Thanks

Are Agricultural R&D Returns Declining and Development Dependent? (2017)

Recalibrating the Reported Returns to Agricultural R&D: What if We All Heeded Griliches? (2017, forthcoming)

Agricultural R&D is on the Move (2016)

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