Are Agricultural R&D Returns Declining and Development Dependent?

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Abstract

There is widespread professional consensus that agricultural research and development (R&D) realizes high economic returns, though there is also concern that these returns have been declining over the past few decades and are unevenly distributed among different regions in the world. This study examines both the time trend (i.e., increasing or decreasing) and regional developmental differences in the reported returns to agricultural R&D. Using a newly updated and expanded global database of estimated returns to agricultural R&D and a robust statistical methodology, our findings suggest that after accounting for methodological changes and other study factors that have varied over time, the contemporary returns to agricultural R&D investments are as high as ever. Furthermore, this study provides evidence that regional developmental differences are attributable to more than differences in the focus of research, or among researcher or research methodology.

Keywords: internal rate of return, benefit-cost ratio, research and development

JEL codes: Q16, Q18, O22

1. Introduction

There is widespread professional consensus that, overall, the economic returns to research in general and agricultural R&D (research and development) in particular are high (Hall et al. 2010; Hurley et al. 2014a).[1] Notwithstanding this consensus, growth in public investment in agricultural R&D has waned in more recent years in many countries around the world. Pardey et al. (2016) report that, after adjusting for inflation, spending on publicly performed agricultural R&D in 24 percent (9 of 37) of the high-income countries was lower in 2011 than in 1980. Likewise, over the same period, 28 low- and middle-income countries (mainly in Sub-Saharan Africa) scaled back spending on public R&D directed towards their agricultural sectors. For the remaining 95 countries worldwide whose investments in agricultural R&D have continued to increase, 37 percent (35 out of 95) had lower growth rates in 2000s than in both the 1990s and the 1980s. Hurley et al. (2014a) suggests this behavior is consistent with the notion that policymakers simply ignore or dismiss the economic evidence, perhaps considering the reported rates-of-return to agricultural R&D to be implausibly high.[2] Other researchers have offered other explanations such as the elevated importance of other criteria in influencing public expenditures (Gardner and Lesser 2003; Rausser and Goodhue 2002).

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. Whether or not the returns to agricultural R&D are likely to decline over time is open to speculation (Alston et al. 2000, p. 77).

> "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."

Hurley et al. (2016, Figure 6) reports *prima facie* evidence that the returns to agricultural R&D have indeed declined over time, with research evaluation studies published in the past decade (2006-2015) reporting a median internal rate of return (IRR) of 25.4 percent per year compared with a median IRR of 49.5 percent per year for studies published in earlier years (1959-1972). However, one can question the appropriateness of using publication dates to judge such hypotheses rather than when an investment was initiated or the midpoint of the investment period. Moreover, precisely what is being evaluated, and the details of those evaluations, change over time in ways that confound simple interpretations of these trends. Here we pick apart the empirical evidence and reveal that first impressions appear false, as our analysis reveals little evidence that the returns to agricultural R&D in recent years are any higher or lower, on average, than the payoffs to research done in the recorded past.

A related question with equally important policy implications is: Are the returns to agricultural R&D substantially higher or lower in developed versus developing countries? Again, there are in-principal arguments why one might expect differences in the returns to R&D when countries are grouped by per capita income. Relative to the size of their agricultural sectors, rich (high-income) countries invest more on agricultural R&D than poorer (low- and middle-income) countries, so if diminishing returns prevail, one might expect the returns, ceteris paribus, to be lower in rich versus poorer 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 rich vs poorer country returns to R&D. Presaging the results presented and discussed below, we do find *prima facie* evidence of differences in rates of return between richer and poorer regions of the world. These differences can be attributed partly to systematic differences in the characteristics of the studies conducted in richer and poorer regions of the world and partly to differences in how these characteristics relate systematically to the rate of return estimates.

2. Data Development, Description, and Analysis

To assess the changing temporal and regional structure of the rates of returns to agricultural R&D, we draw on the International Science and Technology Practice and Policy (InSTePP) Center's returns-to-research database, version 3.0. This version of the database includes 2,827 evaluations of agricultural R&D projects gleaned from a worldwide compilation of 492 published returns-to-research studies since Griliches (1958) through to 2015. Version 3.0 updates version 2.0, which contained 2,242 evaluations drawn from 372 studies and is described in Hurley (2014b). The update mainly consists of new literature published worldwide since 2011 (the terminal date of version 2.0 entries) plus a targeted effort to include additional relevant literature published in sub-Saharan Africa, and Latin America and the Caribbean.

The primary metric used to summarize rates of return to agricultural R&D is the internal rate of return (IRR)— 93 percent of all evaluations.[3] Another key metric is the benefit-cost ratio (BCR)— 28 percent of all evaluations. Around 21 percent of evaluated investments have both the IRR and BCR reported. Given the predominant use of the IRR in the literature, our analysis focuses on this metric, which is summarized in Figure 1 for both developed and developing regions of the world. While the mean IRR is higher for the developed countries (65.9 versus 53.8 percent per year), the median is lower (34.0 versus 41.1 percent per year) due to less rightward skew in the estimates for developing countries. This summary suggests IRR estimates are quite varied in general, and across developed and developing regions of the world in particular. To better understand this variation, we explore how different characteristics of the evaluated investments, the evaluator, and evaluation methodology are systematically associated with the estimated IRRs by extending the meta-analysis of Alston et al. (2000) with more robust methods in addition to analyzing more studies and evaluations overall.

The Alston et al. (2000) meta-analysis of rates-of-return to agricultural research used an ordinary least squares (OLS) model and identified more than 20 variables that are significantly associated with the reported IRR estimates. Meanwhile, the authors caution of potential distortions in their estimates that could arise from heteroskedasticity and inter-dependence among individual IRR estimates. Of particular concern is the abundance of studies that report multiple IRR estimates that share common study-level characteristics and even the same data on the investments.[4] 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.

To address the clustering nature in the compiled IRR estimates, this study estimates a two-level, mixed-effect (i.e., both fixed and random effect), random intercept model using STATA 12's *xtmixed* command with study level clusters.[5] Specifically, let y_{ij} represent the *j*th estimate obtained from the *i*th study and assume that y_{ij} is determined by the following model

$$y_{ij} = \alpha_0 + u_i + \boldsymbol{X}_{ij}\boldsymbol{\beta} + e_{ij}$$

where α_0 is a constant term, u_i is a term capturing random differences across primary studies, and hence $\alpha_0 + u_i$ is the composite intercept for the *i*th study. The error term e_{ij} captures random differences across individual IRR estimates and is assumed to be independent of u_i. With the associated parameter vector $\boldsymbol{\beta}$ which is assumed to be fixed across primary studies, the vector of $\boldsymbol{X}_{ij}$ contains variables from both the study level and estimate level that can account for variations in y_{ij}.[6] Finally, for model estimation, both u_i and e_{ij} are assumed to be normally distributed and uncorrelated with $\boldsymbol{X}_{ij}$.[7]

In the empirical model, the dependent variable y_{ij} is the percentage-form reported IRR estimate after the inverse hyperbolic sine (IHS) transformation. While preserving negative- and zero-valued observations, the IHS transformation resembles the logarithmic transformation and allows interpreting coefficients as (semi-) elasticities (Burbidge et al. 1988).[8] The purpose of the nonlinear transformation of IRR estimates is twofold. First, some of the methodology-related factors, such as lag lengths and functional form, will affect the estimated IRR in a predictably nonlinear way. Second, the original IRR estimates are non-symmetrically distributed with a lengthy right tail, while the IHS transformation of the estimates is more symmetric and appears more consistent with our normality assumptions, though formal tests reject normality, which motivates some additional robustness tests.

Moreover, $\boldsymbol{X}_{ij}$ are derived from factors that represent characteristics of the IRR measure, analysts who perform the IRR evaluations, R&D projects being evaluated, and the evaluation methodology (see Alston et al. 2000, pp. 33-37). Characteristics of the IRR measure included whether it was in real or nominal terms, an ex-ante or ex-post evaluation, a private or social measure, and whether it was for research, extension or both types of activities. Characteristics of the analyst included whether the first author had a government, university, international research center, private organization or some other affiliation, and whether the evaluation was self-performed or independent. Characteristics of the research and evaluation methodology included whether the performer was a government, university, international research center, international research funding body, or private organization; the focus was agriculture generally, crops, livestock, natural resources and forestry, aquaculture and fishery, or something else; the scope was basic or applied; the nature was public, private or both; the institutional orientation was an individual project, program, institution wide, or multi institution; the evaluation was published in a refereed journal; supply shifts were estimated econometrically; supply and demand shifts were implicit, pivotal, or parallel; the data were industry or experimental; spill-ins, spill-outs or both spill-ins and spill-outs were measured; and farm program, exchange rate, deadweight tax, environmental, or other distortions were considered.

Most of the control variables above are either dichotomous or categorical and are thus converted into corresponding sets of dummy variables. In addition, we include four non-categorical explanatory variables—the year when the R&D investment was initiated and the publication date of the IRR evaluation in order to capture the temporal effects in the reported IRR estimates, and the gestation lag and research lag (both measured in years) of the evaluated R&D projects in order to control for different evaluation assumptions. Lacking unreported information for all the explanatory variables, the regression sample contains 1,745 IRR estimates from 308 distinct studies.

To disentangle the potential discrepancies in the reported internal rate of return estimates between developed and developing countries, we split the regression sample into two sub-samples by the geographical location of the research performers of the evaluated R&D projects. Developed countries in our data set include those such as Australia, Canada, Europe, and the United States (either individual state or the whole country). Developing countries include those from Asia/Pacific, Sub-Saharan Africa, Latin America/the Caribbean, and West Asia/North Africa. In this way, the regression sample consists of 685 IRR estimates for developing countries and 1,060 for developed countries, compared with the 1,066 (developing) versus 1,395 (developed) split in the full sample. A chi-square test is employed to determine if the estimated regression differences between developed and developing countries are jointly significant. [9]

3. Results

Table 1 summarizes the control variables used in the meta-analysis regressions for both the pooled and split, by developed and developing regions, samples. More than one third of the studies reporting IRR estimates appear in refereed journals. The rest come from books, graduate dissertations, conference papers, and a good deal of grey literature, including reports published by various international and national agencies. The preponderance (94 percent) of the IRRs in the database pertains to research carried out by public agencies (including either state or national government or international organizations along with universities). Around half of the reported IRR estimates for publicly performed R&D involve research done jointly, say by a government agency in collaboration with a university, a private company, or an international agency. Universities were involved in 42 percent of the reported IRR estimates. Around 17 percent cover joint public and private research, while 1.4 percent involves privately performed R&D. The CGIAR (international agricultural research) centers account for about 8 percent of the IRRs (and around 18 percent of the studies). Around 38 percent of the IRRs refer to research performed by federal or state agencies (including land grant universities) in the United States. Institutions from Asia-Pacific, Latin America & the Caribbean, and sub-Saharan Africa account for 13, 15 and 11 percent of the IRR estimates respectively. Grouping the countries into income classes, 57 percent of the IRRs pertain to rich countries, with the remaining 43 percent applying to poorer parts of the world.[10] Nearly half (46.6%) of the IRR estimates refer to joint research and extension activities. Around 28 percent evaluated broadly defined research investments that included both basic and applied research. Only a limited number of the IRR estimates (around one percent) focused solely on either basic research or extension. Cereal crop research makes up almost one quarter of the IRR estimates, with maize and wheat research getting the most attention followed by sorghum and millet. Assessments of aggregate investment in “All agriculture” account for one third of the IRRs, followed by livestock which constitutes less than ten percent of the observations. IRRs for a small though non-trivial number of assessments of natural resources, forestry, and joint crop and livestock research are also represented in our database.

The estimation results show that, after accounting for various contextual and methodological factors, neither the beginning year of R&D investment nor the publication date have a statistically significant association with the reported internal rate of return estimate for developed countries, developing countries, or the pooled data (Table 2). This finding contrasts the evident temporal trends when only the time variable is considered (Table 3) and presents convincing evidence that the rates of returns have remained stable over time.

Our model also identifies factors that have significant associations with the IRR estimates. For developed countries, R&D projects targeted at crops or livestock report higher IRRs than those with other commodity focus (e.g., all agriculture and natural resources), while IRRs estimated by authors associated with international funders or unknown affiliations are on average lower than those with other author affiliations (e.g., national government and university). For developing countries, research and extension jointly evaluated have lower IRRs than those evaluated individually. R&D projects with private participators in performing the research have lower IRRs than those with only public participators, while R&D projects jointly funded by public and private sources are more profitable than those funded by either source alone.

Developed countries and developing countries also differ in terms of how the evaluation methodology may affect the IRR estimates. Assuming a parallel supply shift instead of a pivotal shift in estimating the returns tends to lower IRR estimates for developed countries, but makes no significant difference for developing countries. In comparison, assuming a longer gestation lag, i.e., the duration from the initiation of R&D investment until research benefits start to accrue, lowers the IRR estimates for developing countries but not for developed countries. Moreover, specifications on spill-over effects work differently, with developed country IRRs sensitive to inclusion of both spill-in and spill-out effects and developing country IRRs only sensitive to inclusion of spill-out effects.

4. **Robustness**

To build confidence in these results, we determine whether they change with alternative estimation methods, model assumptions, and samples.

Estimation model

In general, three categories of models are available to characterize the inter-dependence among observations: ordinary least squares (OLS) models with clustered standard errors, multilevel models, and panel data models, each with its own merits and pitfalls. Panel data models are the least applicable to our data. This is because more than 39 percent of the studies in the regression sample report only one IRR estimate and the remaining studies vary greatly in terms of the number of IRR estimates (i.e., from two to 200, Figure 2), which undermines estimation efficiency.

The OLS model with clustered standard errors differs from the random intercept multilevel model in that the former assumes no correlation in intercepts for the IRR estimates from the same study, an assumption that can be tested by the intra-class correlation (ICC) statistic. Comparing the OLS estimates with MLM estimates for the pooled sample and the disaggregated samples (Table 4), we spot differences in parameter estimates, including those for the initiation date of R&D investment and the publication date of R&D evaluation study. Such comparisons suggest how the results may rest crucially on the model assumptions. The ICC statistics with the corresponding 95 percent confidence intervals (i.e., 0.245 with CI [0.192, 0.307] for the pooled sample, 0.339 with CI [0.247, 0.445] for the developed country sample, and 0.107 with CI [0.589, 0.187] for the developing country sample) imply that conditional on the fixed-effects explanatory variables IRR estimates are positively correlated within the same study, which motivate the MLM model as the benchmark instead of the OLS model.

Endogeneity

The major drawback of multilevel models, including the one used in this study, is the commonly assumed lack of correlation between the explanatory variables $\boldsymbol{X}_{ij}$ and the random heterogeneity across studies, represented by u_i (Nelson & Kennedy 2009). This assumption will be violated when there are unobservable explanatory variables that are correlated with included explanatory variables. Within the limitations of data at hand, we follow the procedure discussed by Wooldridge (2001) and explore how this alternative scenario may affect our major findings. More specifically, we include $\overline{\boldsymbol{X}_i}$, the average of $\boldsymbol{X}_{ij}$ within primary study i to represent the peer effect, in addition to $\boldsymbol{X}_{ij}$ and compare the estimates with those from our main model.

Table 5 compares the estimates using random intercept multilevel models with and without cluster means for the pooled samples. Some explanatory variables, such as "crops" and "international funder", report similar coefficient estimates and statistical significance between the two models, while some variables report very different estimates. However, for the primary variable of interest, the beginning year of costs, returns a coefficient not significantly different from zero for both models and across the different samples, keeping the major finding of this paper intact.

Subsample with multi-IRR studies

Another important methodological issue of multilevel models is having a sufficient sample size at each level in order to derive reliable estimates, although there are currently few sample size guidelines referenced in the literature. Focusing on two-level models, Clarke and Wheaton (2007) find that when singleton groups (or clusters), i.e., groups with only one observation, are included in multilevel models, bias in the variance estimates is larger than without them. They assert that at least ten observations per group for at least 100 groups are needed for the estimated intercept variance to approach the true values. Further, Bell et al. (2010) discovered that the proportion of singletons in their simulated samples has little impact on estimates when there are a large number of groups. However, with a smaller number of groups, a higher proportion of singletons will lead to reduced accuracy in estimates for group-level explanatory variables.

To investigate the potential influences on our main findings, we exclude the 115 singleton rate-of-return studies from our regression sample and derive a subsample of 1,630 IRR estimates from 193 distinct studies. In the subsample, the number of IRR estimates ranges from two to 200, with a median of 16 and a mean of 45 (Figure 2). Using the same criteria to distinguish between rich and poorer countries, this sub-sample contains 1,038 IRR estimates from 96 studies for developed countries and 592 IRR estimates from 97 studies for developing countries. We run the same random-intercept multilevel model on both the pooled and disaggregated subsamples. In spite of the differences for some variables, this sub-sample finds no declining temporal trends in reported IRR estimates (Table 6).

4. Conclusion

The purpose of this article was to explore two questions: (i) Have the returns to agricultural R&D been declining over time? and (ii) Have the returns to agricultural R&D differed systematically between developed and developing world? To answer these questions, we first expanded the meta-analysis of returns to agricultural R&D conducted by Alston et al. (2000) with a more exhaustive sample of literature published in Sub-Saharan Africa, Latin America and the Caribbean. Further, we exploited a more robust statistical methodology to reveal both the time trend and regional developmental differences in the reported returns to agricultural R&D.

When assessing the temporal stability of the returns-to-research estimates, we question the appropriateness of using publication dates *per se* to judge the time trend and include the initial year of R&D investment as a more reasonable measure of timing. Meanwhile, we account for contextual and methodological factors that also contribute to the variation in the reported rate-of-return estimates. Our primary model finds 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 – the contemporary returns to agricultural R&D investments appear as high as ever.

For the second question, we find that, overall, developing countries have a higher median IRR (41.1 percent per year) than developed countries (34.0 percent per year). Further the IRR variation within each group is attributable to not only the contextual and methodological differences between the two subsamples of IRR estimates but also the structural differences in the association between IRR estimates and contextual and methodological factors. For example, R&D projects targeted at crops or livestock in developed countries report higher IRRs than those focused on other commodities (e.g., “all agriculture” and natural resources), while this commodity-related difference is not evident in developing countries. Developed-country IRRs are sensitive to the inclusion of both spill-in and spill-out effects, while developing-country IRRs were only sensitive to the inclusion of spill-out effects.

Our major findings are robust to alternative models and assumptions. Therefore, this study should be able to provide sufficient evidence to dissipate any concerns over the possibly declining returns to agricultural R&D investments and question the slower growth or even scaling back in public support for agricultural R&D over the past several decades in many countries. Further, the structural differences revealed in this study raises questions regarding potentially inefficient allocations of R&D investments across research targets and regions of the world.

Endnotes

[1] In this article, “agriculture” is used as shorthand for “food and agriculture.”

[2] The authors argue that the implausibility may be associated with the choice of an internal rate of return (and the implicit estimation assumptions therein) as the statistic of choice to summarize the streams of costs and benefits attributed to the research being evaluated, and propose the use of modified internal rates of return or benefit-cost ratios as alternative summary statistics. We set aside these measurement issues for the purpose of this analysis without materially affecting our findings.

[3] There has been some effort recently to encourage the literature to move away from the IRR as the primary metric (Alston et al. 2011, Hurley et al. 2014).

[4] Among the 420 distinct studies that report at least one internal rate of return (IRR) measure, 255 studies (i.e., 60.7 percent) report more than two IRR estimates. In the regression sample to be defined below, 194 (i.e., 62.8 percent) out of the 309 distinct studies report more than two IRR estimates.

[5] These models are also known as hierarchical linear and mixed models.

[6] Although less flexible than models permitting random slopes as well as random intercepts, the random-intercept model we estimate here is the most common application of multilevel models in economics (Nelson and Kennedy 2009), considering the requirements on sample size and computation.

[7] We will consider relaxing this uncorrelated error assumption in the robustness analysis below.

[8] The IHS approximates the log transformation well when the original values are not too close to zero. This is why we transformed the IRR estimates into the percentage form.

[9] The multilevel model used in this study estimates cluster-robust standard errors. In this situation, the likelihood ratio (LR) test will likely report invalid results (Wooldridge 2001).

Therefore, we conduct a Wald test instead. To do that, we create a dummy variable for developed countries and interaction terms of this dummy and all the other explanatory variables in the model. Then we conduct a joint significance test on the coefficients of all the interaction terms. The test returns a value of 129.16 for the chi-square statistics with a p-value < 0.001, thus rejecting the null hypothesis that there is no structural break between the two sub-samples.

[10] In this study, rich countries include North America, Australia, New Zealand, Japan and Western Europe. All other countries are classified as poorer countries.

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Table 1 Frequencies of various internal rate of return characteristics

			Full sample			Regression sample		
			Developed country	Developing country	Pooled	Developed country	Developing country	Pooled
Sample size			N=1,395	N=1,066	N=2,461	N=1,060	N=685	N=1,475
Characteristics of the rate of return (ROR) measure	Real or nominal ROR	Real	1,130	770	1,900	961	547	1,508
		Nominal	195	196	391	99	138	237
	Ex-post or ex-ante ROR	Ex-ante	198	193	391	52	118	170
		Ex-post	1,197	873	2,070	1,008	567	1,575
	Average or marginal ROR	Average	433	752	1,185	237	575	812
		Marginal	953	314	1,267	823	110	933
	Private or social ROR	Private	91	50	141	76	43	119
		Social	1,304	1,016	2,320	984	642	1,626
	ROR to research or extension	Research only	642	520	1,162	421	291	712
		Extension only	36	40	76	34	8	42
		Both research and extension	717	506	1,223	605	386	991
Characteristics of the analyst	First author affiliation	Government	251	268	519	187	161	348
		University	847	521	1,368	591	361	952
		International research center	199	126	325	197	65	262
		International research funding body	9	17	26	6	4	10
		Private organization	45	13	58	37	13	50
		Unknown	44	121	165	42	81	123
	Self-evaluation or not	Independent evaluation	1,137	482	1,619	915	290	1,205
		Self-evaluation	87	265	352	65	201	266
		Unclear	170	309	479	80	194	274

Characteristics of the research	Type of research performer	Government	979	904	1,883	812	581	1,393
		University	737	82	819	550	57	607
		International research organization	0	175	175	0	81	81
		Private sector	297	96	393	288	90	378
		Others	218	94	312	154	50	204
	Commodity focus	All agriculture	746	76	822	635	18	653
		Crops	366	876	1,242	209	591	800
		Livestock	177	43	220	129	25	154
		Natural resources & forestry	26	4	30	23	1	24
		Aquaculture & fishery	1	1	2	0	0	0
		Others	79	66	145	64	50	114
	Scope of R&D&E	Non-basic	1,382	1,060	2,442	1,055	685	1,740
		Basic	12	3	15	5	0	5
	Nature of R&D&E	Public	1,012	972	1,984	720	610	1,330
		Private	2	35	37	1	33	34
		Public and private	381	59	440	339	42	381
	Institutional orientation of research	Single project	103	212	315	68	175	243
		Program	49	316	365	45	249	294
		Institution wide	107	65	172	58	38	96
		Multi-institutions	1,135	471	1,606	889	223	1,112
	Type of publication	Non-journal	749	772	1,521	571	548	1,119
		Refereed journal	646	293	939	489	137	626
	Econometric supply shift	Non-econometric	576	775	1,351	394	549	943
		Econometric	816	287	1,103	666	136	802
	Shift in supply and demand	Implicit surplus	1,159	541	1,700	908	269	1,177
		Pivotal supply shift	119	250	369	55	191	246
		Parallel supply shift	106	270	376	86	220	306
		Pivotal demand shift	11	5	16	11	5	16
	Type of data	Industry data	1,016	597	1,613	845	385	1,230

		Experimental data	372	442	814	215	300	515
	Spillover effects considered	Not considered	734	899	1,633	496	623	1,119
		Spill-ins considered	271	120	391	214	41	255
		Spill-outs considered	17	17	34	16	5	21
		Both spill-ins and spill-outs	369	22	391	334	16	350
	Distortions considered	Not considered	1,193	818	2,011	923	495	1,418
		Farm program distortions	58	74	132	40	47	87
		Exchange rate distortions	1	106	107	1	80	81
		Deadweight losses from taxation	55	0	55	0	0	0
		Environmental impacts	84	3	87	84	2	86
		Other distortions	0	0	0	0	0	0

Note: Counts do not always total to the respective full sample size because certain information is not always reported by studies.

Table 2 Multilevel model regression: developed vs. developing vs. pooled samples

VARIABLES	Pooled	Developed	Developing
Beginning year of costs	0.000228	0.000374	-0.00666
	(0.000207)	(0.000275)	(0.00487)
Nominal ROR	-0.00285	-0.171	0.0445
	(0.139)	(0.322)	(0.169)
Nominal * 1970s	0.344	0.243	0.712
	(0.233)	(0.379)	(0.464)
Ex post study	-0.102	-0.107	-0.241
	(0.139)	(0.225)	(0.169)
Marginal ROR	-0.0642	-0.168	0.0710
	(0.104)	(0.107)	(0.178)
Social ROR	0.275	0.242	0.120
	(0.192)	(0.215)	(0.443)
Extension only	-0.208	-0.209	-0.0595
	(0.356)	(0.465)	(0.315)
Research & Extension	-0.257***	-0.0624	-0.398***
	(0.0956)	(0.134)	(0.111)
University researcher	0.139	0.257	0.0344
	(0.113)	(0.183)	(0.160)
International researcher	-0.107	-0.658	-0.0928
	(0.157)	(0.404)	(0.185)
International funder	-0.604***	-0.850***	-0.715
	(0.234)	(0.286)	(0.535)
Private sector researcher	-0.333	-0.156	-0.430
	(0.211)	(0.251)	(0.364)
Unknown affiliation	-0.0648	-0.335	0.0452
	(0.152)	(0.292)	(0.179)
Self evaluation	0.288**	0.319	0.246
	(0.118)	(0.237)	(0.176)
Unclear evaluation type	0.188	0.115	0.0525
	(0.115)	(0.213)	(0.146)
University research performer	0.0793	0.0194	0.300
	(0.106)	(0.147)	(0.184)
Intl institute research performer	-0.0815		-0.0559
	(0.131)		(0.144)
Private research performer	-0.0656	0.121	-0.579**
	(0.171)	(0.193)	(0.258)
Unknown research performer	-0.134	-0.198	0.0560
	(0.130)	(0.175)	(0.230)
Crops	0.275**	0.474**	0.291
	(0.118)	(0.184)	(0.245)
Livestock	0.226	0.319*	0.485
	(0.166)	(0.172)	(0.342)
Natural resource & forestry	-0.248	0.0258	0.0484
	(0.310)	(0.341)	(0.326)
Other commodity	0.199	0.351	0.0287
	(0.181)	(0.220)	(0.318)

Basic research	0.0798	0.439	
	(0.292)	(0.336)	
Private R&D	0.0788	-1.041***	0.617
	(0.290)	(0.327)	(0.494)
Public and Private R&D	0.0979	-0.0709	0.725***
	(0.154)	(0.166)	(0.273)
Publication date	-0.00693	-0.00423	0.000497
	(0.00504)	(0.0103)	(0.00786)
Program evaluated	-0.147	-0.429**	-0.0531
	(0.108)	(0.173)	(0.151)
Institution-wide	0.0635	0.200	0.115
	(0.189)	(0.318)	(0.265)
Multi-institutions	0.0487	-0.208	0.0704
	(0.123)	(0.258)	(0.161)
Refereed publication	-0.0475	-0.0778	0.0600
	(0.0883)	(0.127)	(0.126)
Econometric supply shift	0.124	0.180	0.102
	(0.139)	(0.203)	(0.200)
Pivotal supply shift	0.0939	-0.237	0.178
	(0.107)	(0.184)	(0.148)
Parallel supply shift	-0.169	-0.433*	-0.0587
	(0.109)	(0.237)	(0.126)
Pivotal demand shift	-0.188	-0.740	-0.0206
	(0.231)	(0.477)	(0.369)
Experimental data for supply shift	0.116	-0.0761	0.233
	(0.118)	(0.170)	(0.146)
Research lag	-0.00227	-0.00976	-0.000113
	(0.00405)	(0.00693)	(0.00650)
Gestation lag	-0.0440***	-0.0331*	-0.0533***
	(0.0114)	(0.0194)	(0.0117)
Spillins	-0.0368	-0.202	0.0667
	(0.240)	(0.449)	(0.176)
Spillouts	0.317**	0.273*	0.494**
	(0.136)	(0.152)	(0.196)
Both spillins and spillouts	0.369*	0.700**	-0.0693
	(0.221)	(0.318)	(0.334)
Farm program distortion	-0.409	-0.00862	-0.448
	(0.374)	(0.290)	(0.558)
Exchange rate distortion	-0.518	0.306	-0.618*
	(0.344)	(0.417)	(0.352)
Environmental impact distortion	-0.236	0.232	-0.298*
	(0.290)	(0.515)	(0.159)
Constant	17.63*	12.28	16.61
	(10.05)	(20.51)	(14.38)
Observations	1,745	1,060	685
Number of groups	308	118	190

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Some variables are automatically left out of regression because of collinearity.

Table 3 Time trend in IRR estimates by publication date

Estimation Model	Explanatory Variables	Full sample			Regression sample		
		Developed country N=1,395	Developing country N=1,066	Pooled N=2,461	Developed country N=1,060	Developing country N=685	Pooled N=1,745
OLS	Publication date	-0.0195***	-0.0187***	-0.0193***	-0.0251***	-0.0187***	-0.0229***
		(0.00197)	(0.00423)	(0.00193)	(0.00187)	(0.00532)	(0.00199)
	Constant	43.12***	41.63***	42.71***	54.46***	41.46***	49.99***
		(3.926)	(8.433)	(3.838)	(3.738)	(10.59)	(3.974)
MLM	Publication date	-0.0133***	-0.0132***	-0.0124***	-0.0163***	-0.0141***	-0.0151***
		(0.00472)	(0.00413)	(0.00316)	(0.00421)	(0.00452)	(0.00301)
	Constant	30.75***	30.65***	29.11***	36.72***	32.49***	34.53***
		(9.393)	(8.237)	(6.304)	(8.367)	(8.991)	(5.997)

Note:

- Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.
- Full sample refers to the InSTePP ROR database version 3.0, which collects 2,627 internal-rate-of-return (IRR) estimates from 461 distinct primary studies. Regression sample refers to the subset of IRR observations that report non-missing values for all the variables to be included in the regression models later in this paper. For this paper, we exclude the 166 IRR estimates from 50 primary studies that report "multinational" or "global" as the research performer.
- The dependent variable is the internal rate of return estimates (in percentage) after the inverse hyperbolic sine transformation.
- OLS stands for the ordinary linear square models; MLM stands for the multilevel models. MLM models in this table are estimated by the Stata command *xtmixed*, assuming ROR observations are clustered by primary studies.

Table 4 Comparison of OLS models with multilevel (MLM) models

	Pooled		Developed		Developing	
VARIABLES	OLS clustered	MLM	OLS clustered	MLM	OLS clustered	MLM
Beginning year of costs	0.000395	0.000228	0.000568*	0.000374	-0.00871*	-0.00666
	(0.000297)	(0.000207)	(0.000308)	(0.000275)	(0.00491)	(0.00487)
Nominal ROR	-0.0245	-0.00285	-0.390	-0.171	0.0848	0.0445
	(0.153)	(0.139)	(0.304)	(0.322)	(0.184)	(0.169)
Nominal * 1970s	0.428	0.344	0.0749	0.243	1.107**	0.712
	(0.335)	(0.233)	(0.269)	(0.379)	(0.519)	(0.464)
Ex post study	-0.0341	-0.102	0.0970	-0.107	-0.312*	-0.241
	(0.166)	(0.139)	(0.304)	(0.225)	(0.183)	(0.169)
Marginal ROR	0.0977	-0.0642	-0.0650	-0.168	0.167	0.0710
	(0.160)	(0.104)	(0.174)	(0.107)	(0.206)	(0.178)
Social ROR	0.394*	0.275	0.343	0.242	-0.00184	0.120
	(0.202)	(0.192)	(0.243)	(0.215)	(0.416)	(0.443)
Extension only	-0.125	-0.208	-0.151	-0.209	0.0271	-0.0595
	(0.298)	(0.356)	(0.434)	(0.465)	(0.345)	(0.315)
Research & Extension	-0.249***	-0.257***	-0.0950	-0.0624	-0.451***	-0.398***
	(0.0933)	(0.0956)	(0.133)	(0.134)	(0.112)	(0.111)
University researcher	0.0770	0.139	0.165	0.257	0.00438	0.0344
	(0.131)	(0.113)	(0.180)	(0.183)	(0.179)	(0.160)
International researcher	0.0129	-0.107	-0.262	-0.658	-0.0300	-0.0928
	(0.167)	(0.157)	(0.378)	(0.404)	(0.198)	(0.185)
International funder	-0.634*	-0.604***	-1.110***	-0.850***	-1.002	-0.715
	(0.376)	(0.234)	(0.417)	(0.286)	(0.612)	(0.535)
Private sector researcher	-0.534**	-0.333	-0.105	-0.156	-0.633*	-0.430
	(0.217)	(0.211)	(0.267)	(0.251)	(0.347)	(0.364)
Unknown affiliation	-0.0691	-0.0648	-0.434	-0.335	0.0178	0.0452
	(0.162)	(0.152)	(0.339)	(0.292)	(0.197)	(0.179)

Self evaluation	0.251*	0.288**	0.369	0.319	0.252	0.246
	(0.147)	(0.118)	(0.330)	(0.237)	(0.206)	(0.176)
Unclear evaluation type	0.166	0.188	0.0756	0.115	0.0913	0.0525
	(0.125)	(0.115)	(0.226)	(0.213)	(0.180)	(0.146)
University research performer	-0.00520	0.0793	0.0516	0.0194	0.247	0.300
	(0.109)	(0.106)	(0.143)	(0.147)	(0.217)	(0.184)
International research performer	0.0155	-0.0815			-0.0319	-0.0559
	(0.134)	(0.131)			(0.153)	(0.144)
Private research performer	0.00874	-0.0656	0.352*	0.121	-0.577**	-0.579**
	(0.162)	(0.171)	(0.211)	(0.193)	(0.267)	(0.258)
Unknown research performer	-0.00442	-0.134	0.0663	-0.198	-0.00476	0.0560
	(0.151)	(0.130)	(0.189)	(0.175)	(0.264)	(0.230)
Crops	0.140	0.275**	0.358*	0.474**	0.300	0.291
	(0.123)	(0.118)	(0.198)	(0.184)	(0.268)	(0.245)
Livestock	0.100	0.226	0.149	0.319*	0.555	0.485
	(0.167)	(0.166)	(0.173)	(0.172)	(0.395)	(0.342)
Natural resource & forestry	-0.190	-0.248	0.155	0.0258	0.0459	0.0484
	(0.371)	(0.310)	(0.387)	(0.341)	(0.354)	(0.326)
Other commodity	0.330	0.199	0.541**	0.351	-0.0322	0.0287
	(0.211)	(0.181)	(0.265)	(0.220)	(0.337)	(0.318)
Basic research	0.424	0.0798	1.107**	0.439		
	(0.490)	(0.292)	(0.455)	(0.336)		
Private R&D	0.281	0.0788	-1.243***	-1.041***	0.598	0.617
	(0.248)	(0.290)	(0.426)	(0.327)	(0.485)	(0.494)
Public and Private R&D	0.114	0.0979	-0.0986	-0.0709	0.729**	0.725***
	(0.143)	(0.154)	(0.187)	(0.166)	(0.302)	(0.273)
Publication date	-0.00985*	-0.00693	-0.00222	-0.00423	0.000692	0.000497
	(0.00581)	(0.00504)	(0.0102)	(0.0103)	(0.00846)	(0.00786)
Program evaluated	-0.200	-0.147	-0.764**	-0.429**	-0.0886	-0.0531
	(0.126)	(0.108)	(0.326)	(0.173)	(0.167)	(0.151)
Institution-wide	0.133	0.0635	0.0152	0.200	0.213	0.115
	(0.220)	(0.189)	(0.366)	(0.318)	(0.254)	(0.265)

Multi-institutions	-0.123	0.0487	-0.617	-0.208	0.0164	0.0704
	(0.146)	(0.123)	(0.408)	(0.258)	(0.165)	(0.161)
Refereed publication	-0.0906	-0.0475	-0.172	-0.0778	0.0667	0.0600
	(0.0951)	(0.0883)	(0.153)	(0.127)	(0.127)	(0.126)
Econometric supply shift	0.174	0.124	0.314	0.180	0.133	0.102
	(0.167)	(0.139)	(0.221)	(0.203)	(0.224)	(0.200)
Pivotal supply shift	0.0860	0.0939	-0.175	-0.237	0.173	0.178
	(0.138)	(0.107)	(0.187)	(0.184)	(0.179)	(0.148)
Parallel supply shift	-0.125	-0.169	-0.497**	-0.433*	0.0385	-0.0587
	(0.138)	(0.109)	(0.234)	(0.237)	(0.146)	(0.126)
Pivotal demand shift	-0.146	-0.188	-0.797	-0.740	-0.0112	-0.0206
	(0.239)	(0.231)	(0.562)	(0.477)	(0.399)	(0.369)
Experimental data	0.278*	0.116	0.0645	-0.0761	0.335**	0.233
	(0.141)	(0.118)	(0.224)	(0.170)	(0.151)	(0.146)
Research lag	-0.00345	-0.00227	-0.0167***	-0.00976	0.00129	-0.000113
	(0.00462)	(0.00405)	(0.00592)	(0.00693)	(0.00707)	(0.00650)
Gestation lag	-0.0323***	-0.0440***	-0.0147	-0.0331*	-0.0528***	-0.0533***
	(0.0109)	(0.0114)	(0.0161)	(0.0194)	(0.0119)	(0.0117)
Spillins	0.262	-0.0368	0.387	-0.202	0.0866	0.0667
	(0.173)	(0.240)	(0.268)	(0.449)	(0.190)	(0.176)
Spillouts	0.488***	0.317**	0.502**	0.273*	0.424*	0.494**
	(0.174)	(0.136)	(0.225)	(0.152)	(0.215)	(0.196)
Both spillins and spillouts	0.146	0.369*	0.476	0.700**	-0.0829	-0.0693
	(0.179)	(0.221)	(0.287)	(0.318)	(0.281)	(0.334)
Farm program distortion	-0.0976	-0.409	0.0384	-0.00862	-0.0980	-0.448
	(0.265)	(0.374)	(0.228)	(0.290)	(0.464)	(0.558)
Exchange rate distortion	-0.948**	-0.518	0.443	0.306	-0.854**	-0.618*
	(0.417)	(0.344)	(0.449)	(0.417)	(0.363)	(0.352)
Environmental impact distortion	-0.727**	-0.236	-0.634	0.232	-0.255	-0.298*
	(0.287)	(0.290)	(0.415)	(0.515)	(0.226)	(0.159)
Constant	22.92*	17.63*	7.902	12.28	20.31	16.61

	(11.74)	(10.05)	(20.45)	(20.51)	(14.72)	(14.38)
Observations	1,745	1,745	1,060	1,060	685	685
R-squared	0.244		0.383		0.224	
Number of groups		308		118		190

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Some variables are automatically left out of regression because of collinearity.

Table 5 Multilevel models with and without cluster means: Pooled sample

VARIABLES	Without cluster means	With cluster means
Beginning year of costs	0.000228	0.00483
	(0.000207)	(0.00906)
Nominal ROR	-0.00285	0.746**
	(0.139)	(0.374)
Nominal * 1970s	0.344	0.159
	(0.233)	(0.288)
Ex post study	-0.102	0.352
	(0.139)	(0.254)
Marginal ROR	-0.0642	-0.229**
	(0.104)	(0.0930)
Social ROR	0.275	0.251
	(0.192)	(0.213)
Extension only	-0.208	-0.157
	(0.356)	(0.443)
Research & Extension	-0.257***	-0.318*
	(0.0956)	(0.183)
University researcher	0.139	0.0401
	(0.113)	(0.107)
International researcher	-0.107	-0.124
	(0.157)	(0.154)
International funder	-0.604***	-0.842***
	(0.234)	(0.315)
Private sector researcher	-0.333	-0.383*
	(0.211)	(0.215)
Unknown affiliation	-0.0648	-0.0727
	(0.152)	(0.156)
Self evaluation	0.288**	0.281**
	(0.118)	(0.122)
Unclear evaluation type	0.188	0.0981
	(0.115)	(0.106)
University research performer	0.0793	0.353
	(0.106)	(0.292)
International research performer	-0.0815	-0.149
	(0.131)	(0.172)
Private research performer	-0.0656	0.551*
	(0.171)	(0.317)
Unknown research performer	-0.134	0.0257
	(0.130)	(0.141)
Crops	0.275**	0.382***
	(0.118)	(0.0758)
Livestock	0.226	0.248*
	(0.166)	(0.142)
Natural resource & forestry	-0.248	0.397*
	(0.310)	(0.206)
Other commodity	0.199	0.439*

	(0.181)	(0.256)
Basic research	0.0798	0.0418
	(0.292)	(0.381)
Private R&D	0.0788	0.204
	(0.290)	(0.304)
Public and Private R&D	0.0979	-0.434***
	(0.154)	(0.0539)
Publication date	-0.00693	-0.0103**
	(0.00504)	(0.00466)
Program evaluated	-0.147	-0.324***
	(0.108)	(0.0882)
Institution-wide	0.0635	-0.0283
	(0.189)	(0.123)
Multi-institutions	0.0487	-0.0149
	(0.123)	(0.130)
Refereed publication	-0.0475	-0.101
	(0.0883)	(0.0866)
Econometric supply shift	0.124	0.139
	(0.139)	(0.281)
Pivotal supply shift	0.0939	-0.203
	(0.107)	(0.142)
Parallel supply shift	-0.169	-0.0699
	(0.109)	(0.188)
Pivotal demand shift	-0.188	-0.838***
	(0.231)	(0.0879)
Experimental data	0.116	0.184
	(0.118)	(0.359)
Research lag	-0.00227	0.00518
	(0.00405)	(0.0109)
Gestation lag	-0.0440***	-0.0970***
	(0.0114)	(0.0265)
Spillins	-0.0368	-1.039***
	(0.240)	(0.289)
Spillouts	0.317**	0.353**
	(0.136)	(0.164)
Both spillins and spillouts	0.369*	0.425**
	(0.221)	(0.194)
Farm program distortion	-0.409	-0.899
	(0.374)	(0.646)
Exchange rate distortion	-0.518	-0.209
	(0.344)	(0.457)
Environmental impact distortion	-0.236	0.244
	(0.290)	(0.685)
Nominal (mean)		-1.272***
		(0.480)
(Nominal*developing) mean		0.573*
		(0.294)
Ex post (mean)		-0.606**
		(0.299)

Marginal (mean)		0.473**
		(0.208)
Private research performer (mean)		-0.685*
		(0.361)
Public and Private R&D (mean)		0.562***
		(0.164)
Pivotal supply shift (mean)		0.374*
		(0.201)
Pivotal demand shift (mean)		0.987***
		(0.269)
Gestation lag (mean)		0.0760***
		(0.0279)
Spillins (mean)		1.396***
		(0.335)
Constant	17.63*	25.09**
	(10.05)	(9.913)
Observations	1,745	1,745
Number of groups	308	308

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Some variables are automatically left out of regression because of collinearity.

Table 6 Comparing full regression sample with multi-IRR sub-sample

	Pooled		Developed		Developing	
VARIABLES	Full regression sample	Multi-IRR sub-sample	Full regression sample	Multi-IRR sub-sample	Full regression sample	Multi-IRR sub-sample
Beginning year of costs	0.000228	0.000262	0.000374	0.000443	-0.00666	-0.00662
	(0.000207)	(0.000201)	(0.000275)	(0.000281)	(0.00487)	(0.00564)
Nominal ROR	-0.00285	-0.0226	-0.171	-0.153	0.0445	0.0541
	(0.139)	(0.175)	(0.322)	(0.339)	(0.169)	(0.224)
Nominal * 1970s	0.344	0.460*	0.243	0.299	0.712	1.132**
	(0.233)	(0.261)	(0.379)	(0.405)	(0.464)	(0.480)
Ex post study	-0.102	-0.0510	-0.107	-0.174	-0.241	-0.263
	(0.139)	(0.155)	(0.225)	(0.256)	(0.169)	(0.196)
Marginal ROR	-0.0642	-0.115	-0.168	-0.210**	0.0710	0.0723
	(0.104)	(0.109)	(0.107)	(0.107)	(0.178)	(0.224)
Social ROR	0.275	0.277	0.242	0.228	0.120	0.269
	(0.192)	(0.200)	(0.215)	(0.216)	(0.443)	(0.419)
Extension only	-0.208	-0.197	-0.209	-0.212	-0.0595	0.0723
	(0.356)	(0.372)	(0.465)	(0.467)	(0.315)	(0.294)
Research & Extension	-0.257***	-0.262**	-0.0624	-0.0139	-0.398***	-0.437***
	(0.0956)	(0.110)	(0.134)	(0.150)	(0.111)	(0.130)
University researcher	0.139	0.142	0.257	0.338	0.0344	-0.0179
	(0.113)	(0.138)	(0.183)	(0.206)	(0.160)	(0.201)
International researcher	-0.107	-0.0127	-0.658	-0.214	-0.0928	-0.0197
	(0.157)	(0.189)	(0.404)	(0.542)	(0.185)	(0.249)
International funder	-0.604***	-0.757***	-0.850***	-0.914***	-0.715	-1.158**
	(0.234)	(0.241)	(0.286)	(0.310)	(0.535)	(0.576)
Private sector researcher	-0.333	-0.536**	-0.156	-0.179	-0.430	-0.959***
	(0.211)	(0.211)	(0.251)	(0.267)	(0.364)	(0.276)
Unknown affiliation	-0.0648	-0.0448	-0.335	-0.238	0.0452	0.0748
	(0.152)	(0.185)	(0.292)	(0.332)	(0.179)	(0.229)
Self evaluation	0.288**	0.343**	0.319	0.291	0.246	0.265

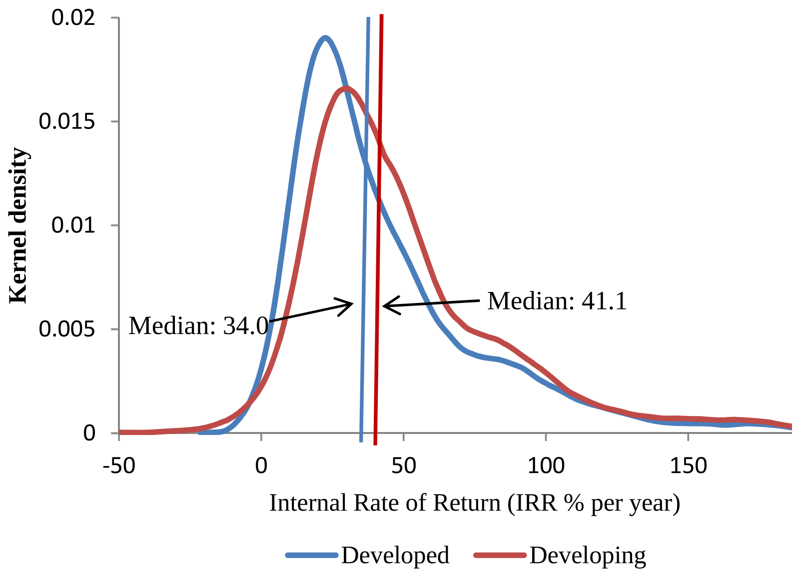
	(0.118)	(0.141)	(0.237)	(0.285)	(0.176)	(0.216)
Unclear evaluation type	0.188	0.169	0.115	0.130	0.0525	0.146
	(0.115)	(0.133)	(0.213)	(0.247)	(0.146)	(0.173)
University research	0.0793	0.0246	0.0194	0.00816	0.300	0.286
performer	(0.106)	(0.128)	(0.147)	(0.195)	(0.184)	(0.224)
Intl institute research	-0.0815	-0.237			-0.0559	-0.197
performer	(0.131)	(0.165)			(0.144)	(0.182)
Private research	-0.0656	-0.0543	0.121	0.0890	-0.579**	-0.632*
performer	(0.171)	(0.188)	(0.193)	(0.221)	(0.258)	(0.375)
Unknown research	-0.134	-0.229	-0.198	-0.256	0.0560	-0.0848
performer	(0.130)	(0.151)	(0.175)	(0.187)	(0.230)	(0.393)
Crops	0.275**	0.231*	0.474**	0.422**	0.291	0.461
	(0.118)	(0.137)	(0.184)	(0.201)	(0.245)	(0.424)
Livestock	0.226	0.169	0.319*	0.277	0.485	0.694
	(0.166)	(0.182)	(0.172)	(0.181)	(0.342)	(0.529)
Natural resource &	-0.248	-0.311	0.0258	0.00797	0.0484	0.298
forestry	(0.310)	(0.324)	(0.341)	(0.358)	(0.326)	(0.576)
Other commodity	0.199	0.226	0.351	0.287	0.0287	0.298
	(0.181)	(0.199)	(0.220)	(0.228)	(0.318)	(0.512)
Basic research	0.0798	0.150	0.439	0.616*		
	(0.292)	(0.275)	(0.336)	(0.354)		
Private R&D	0.0788	0.199	-1.041***		0.617	0.910*
	(0.290)	(0.262)	(0.327)		(0.494)	(0.500)
Public and Private R&D	0.0979	0.0548	-0.0709	-0.0857	0.725***	0.678
	(0.154)	(0.172)	(0.166)	(0.178)	(0.273)	(0.436)
Publication date	-0.00693	-0.00445	-0.00423	0.00271	0.000497	0.00177
	(0.00504)	(0.00642)	(0.0103)	(0.0135)	(0.00786)	(0.00986)
Program evaluated	-0.147	-0.201	-0.429**	-0.475**	-0.0531	-0.0787
	(0.108)	(0.146)	(0.173)	(0.190)	(0.151)	(0.196)
Institution-wide	0.0635	0.136	0.200	0.204	0.115	0.370
	(0.189)	(0.239)	(0.318)	(0.351)	(0.265)	(0.335)
Multi-institutions	0.0487	0.0299	-0.208	-0.171	0.0704	0.0706

	(0.123)	(0.179)	(0.258)	(0.304)	(0.161)	(0.283)
Refereed publication	-0.0475	-0.0620	-0.0778	-0.126	0.0600	0.142
	(0.0883)	(0.105)	(0.127)	(0.142)	(0.126)	(0.157)
Econometric supply shift	0.124	0.235	0.180	0.243	0.102	0.195
	(0.139)	(0.174)	(0.203)	(0.231)	(0.200)	(0.241)
Pivotal supply shift	0.0939	0.0896	-0.237	-0.193	0.178	0.172
	(0.107)	(0.119)	(0.184)	(0.195)	(0.148)	(0.176)
Parallel supply shift	-0.169	-0.126	-0.433*	-0.371	-0.0587	0.0218
	(0.109)	(0.133)	(0.237)	(0.257)	(0.126)	(0.184)
Pivotal demand shift	-0.188	-0.294	-0.740	-0.578	-0.0206	-0.0403
	(0.231)	(0.285)	(0.477)	(0.538)	(0.369)	(0.470)
Experimental data for	0.116	0.250	-0.0761	-0.00810	0.233	0.385**
supply shift	(0.118)	(0.155)	(0.170)	(0.172)	(0.146)	(0.191)
Research lag	-0.00227	-0.00169	-0.00976	-0.0124*	-0.000113	0.00405
	(0.00405)	(0.00465)	(0.00693)	(0.00750)	(0.00650)	(0.00791)
Gestation lag	-0.0440***	-0.0519***	-0.0331*	-0.0344	-0.0533***	-0.0713***
	(0.0114)	(0.0149)	(0.0194)	(0.0238)	(0.0117)	(0.0131)
Spillins	-0.0368	-0.143	-0.202	-0.319	0.0667	0.00966
	(0.240)	(0.263)	(0.449)	(0.447)	(0.176)	(0.229)
Spillouts	0.317**	0.339**	0.273*	0.291*	0.494**	0.543**
	(0.136)	(0.143)	(0.152)	(0.153)	(0.196)	(0.235)
Both spillins and	0.369*	0.145	0.700**	0.434	-0.0693	-0.442
spillouts	(0.221)	(0.256)	(0.318)	(0.373)	(0.334)	(0.395)
Farm program distortion	-0.409	-0.433	-0.00862	-0.0351	-0.448	-0.377
	(0.374)	(0.405)	(0.290)	(0.302)	(0.558)	(0.622)
Exchange rate distortion	-0.518	-0.554	0.306		-0.618*	-0.595*
	(0.344)	(0.356)	(0.417)		(0.352)	(0.346)
Environmental impact	-0.236	-0.245	0.232	0.142	-0.298*	-0.268
distortion	(0.290)	(0.316)	(0.515)	(0.592)	(0.159)	(0.177)
Constant	17.63*	12.66	12.28	-1.527	16.61	13.65
	(10.05)	(12.79)	(20.51)	(26.91)	(14.38)	(17.47)

Observations	1,745	1,630	1,060	1,038	685	592
Number of groups	308	193	118	96	190	97

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Some variables are automatically left out of regression because of collinearity.

Figure 1 Distributions of reported internal rates of return, developed vs. developing countries



	Developed	Developing
No. of obs.	1,395	1,066
Minimum	-14.90	-100.00
1st quartile	20.60	26.50
Mean	65.94	53.77
3rd quartile	61.96	66.0
Maximum	5,645.00	1,000.00

Figure 2: Number of IRR estimates per study