# Research Prizes:
# A Mechanism to Reward Innovation in African Agriculture

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**Abstract**

This paper identifies market failures that limit agricultural R&D for Africa and other resource-poor environments, and proposes a mechanism to help circumvent them with cash prizes for the dissemination of successful innovations. The proposed prize institution would use ex-post experiments and farm surveys to document the value of innovations after their initial diffusion, to avoid pre-specification of technologies. Prizes would be offered in proportion to estimated social benefits, and would buy innovations into the public domain so that innovators with marketable technologies would choose not to apply for prizes. A governance structure to ensure credibility and financial sustainability is proposed.

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## 1. Introduction: the use of prizes to remedy market failure for R&D

The flow of new technologies is widely recognized to be a fundamental determinant of economic growth, for whole economies and for agriculture in particular.[1] But the market for investments in research to develop new technologies is limited: by definition, successful research involves the disclosure of something not yet known, which makes it a difficult thing to buy.

The most widely studied factor limiting the market for research is the public-goods character of disclosure: it is non-rival, and often non-excludable. The free use of new ideas helps modern economies sustain the growth we observe, but may leave potential innovators unwilling to supply research. A more subtle constraint is the asymmetry of information between researchers and beneficiaries. To add value, researchers must know something that others don't. Potential beneficiaries may not know what they're missing from having too little research, and so be unwilling to demand more of it.[2]

Several distinct kinds of institutions have been used to overcome the market failures associated with research activities, and thereby promote innovation and the spread of new ideas. Since antiquity people have organized scientific academies then universities and

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[1] A particularly valuable historical exposition of the role of technology in economic growth is Mokyr (1992). For agriculture in Africa, Lusigi and Thirtle (1997) show that agricultural R&D spending accounts for a significant fraction of subsequent output growth, while McMillan and Masters (2003) show agricultural R&D spending to be a much more robust correlate of subsequent growth than price or tax policy.

[2] The public-goods problem associated with research is one of the oldest questions in economics, whereas formal analysis of the asymmetric-information problem in research begins with Wright (1983).

specialized institutes to spread innovations in the public domain, and since at least the 15th century governments have offered temporary monopolies to innovators in private firms.

Despite over 500 years of tinkering with ways to reward innovation, the estimated expected return to both public and private research remains well above its costs, suggesting persistent underinvestment – and research priorities remain controversial, suggesting possible misallocation. It is difficult to determine the quality and value of research, so both public and private research institutions must divert significant resources from productive investment to oversight, administration and legal transaction costs.

Patent protection can help align researchers' incentives with market demands, but leads to market failures of its own: the exercise of monopoly rights reduces marketed supply, and asymmetric information or other problems reduce demand. These can easily generate a "tragedy of the anti-commons", as excessively broad or long-lived patents actually reduce the development and application of new technologies.[3]

To help complement public funding and patent protection, a third mechanism has recently come to public attention. A popular book (Sobel 1996) tells the story of how, in the 18th century, a self-educated clockmaker developed newly reliable and accurate techniques, in pursuit of a cash reward offered by the British Parliament for a way to calculate longitude at sea. Later the French government offered a prize for food preservation, which led to the discovery of how to prevent spoilage in glass bottles. In the 20th century, a series of privately-funded prizes helped advance aviation technology, including particularly the

[3] This term "anti-commons" is due to Heller and Eisenberg (1998). Scotchmer (1991) offers a particularly concise and accessible explanation of how patent breadth and length might influence the pace of innovation, and Lerner (2002) provides an empirical test of whether strengthening patent law is associated with a subsequent increase in patent applications, finding little or no effect.

Orteig prize for the first non-stop flight from New York to Paris claimed by Charles Lindbergh in 1927, the Kremer prizes for human-powered flight claimed by a team led by Paul MacCready in 1977 and 1979.[4]

Currently, Michael Kremer (2001) and colleagues are arguing for research prizes to be offered for pharmaceutical research on diseases associated with poverty, such as malaria and tuberculosis. Kremer argues that high-payoff research on diseases of the poor is not being pursued in either the public or private sectors – but could be elicited by a public pre-commitment to purchase desired innovations at a price that reflects their estimated social value. Kremer argues that current institutions do not develop vaccines for malaria, tuberculosis, HIV/AIDS or other diseases because pharmaceutical research capability resides primarily in private firms, who could not earn enough revenue from market sales to recover the R&D costs of such vaccines.

The market failures that limit pharmaceutical R&D for tropical diseases are similar to those that limit research on tropical agriculture. Perhaps the most fundamental reason why private R&D may not pursue technologies suitable for adoption by low-income users is the credit constraint faced by potential adopters. If they have limited savings or collateral, they may be unable to borrow against future income to pay license fees, even if everyone knows that adoption would be profitable. Other market failures are also more severe in low-income settings, as governments may be less willing or less able to protect intellectual property rights, or to use public funds to pay for research. For all these reasons, private R&D continues to target the medical and agricultural needs of higher-income technology

[4] Numerous prizes have not yet been claimed, such as the $10 million being offered for the first private space flight meeting certain specifications (www.xprize.org).

users, leaving a particularly large gap between the social and private payoffs to research in low-income regions. [5]

Kremer and Zwane (2002) extended the idea of pharmaceutical-research prizes for use in the agricultural sector. As with their earlier proposal, the central idea is to offer a portfolio of prizes, promising specific awards for meeting pre-specified technical criteria. The example cited in the paper is a prize to reward the developer of blast-resistant finger millet seeds, which they estimate would be worth approximately US$92 million per year (Kremer and Zwane 2002, page 19). As with Kremer's earlier prize proposals, the mechanism involves a precommitment to purchase the final product (in this case, seeds), rather than a one-time payment that puts the innovation into the public domain.

The prize-giving institution we propose differs from that of Kremer and Zwane in three main respects. First, our proposed institution would specify the computational procedure for determining the awards, rather than the technological characteristics of the innovations to be rewarded. Second, our proposed prizes would be one-time payments that buy the innovation into the public domain, rather than purchase a finished product that would remain patent-protected. Finally, our proposed mechanism would be funded on a pay-as-you-go basis and governed jointly by donors and potential claimants, to limit the time-consistency and credibility problems often associated with prize schemes. These three institutional innovations are tailored to the particular challenges and opportunities of research in agriculture as opposed to other sectors, which are detailed in Section 2 below. Section 3 details the proposed institutional mechanism and explains how it would help

[5] Tom Lehrer (1959) recounts the story of a doctor who "became a specialist, specializing in diseases of the rich" and was thereby able to capture a share of their fortune.

align incentives facing researchers and funding agencies with the needs of technology users, and Section 4 concludes.

## 2. The market for agricultural R&D

Although the economic payoff to agricultural R&D is well-documented, a variety of market failures severely restrict investment in it – particularly to develop technologies appropriate for very low-income farmers. Kremer and Zwane (2002) provide a clear exposition of the problem, showing in particular that while industrialized countries re-invest over 2 percent of agricultural GDP in research, developing countries typically invest less than one-fourth as much. The gap in levels of public agricultural R&D (Table 1) is less wide than the gap in private spending (Table 2), if only because private agricultural R&D levels are near zero in many developing countries.

**Table 1: Annual public agricultural R&D spending as a percentage of agricultural GDP (%) in most recent year**

| Region | No. of countries | Public ag. R&D as a fraction of ag. GDP (%) |
|---|---|---|
| Developed countries | 18 | 2.39[a] |
| USA | | 2.22[c] |
| Sub-Saharan Africa[1] | 17 | 0.58[b] |
| Asia & Pacific[2] | 15 | 0.55[b] |
| China | | 0.42[d] |
| Latin America & Caribbean | 26 | 0.54[b] |
| West Asia & North Africa | 13 | 0.52[a] |
| CGIAR | 42 | 0.19[e] |

Source: Kremer and Zwane (2002), who cite James (1996), Alston, Pardey, and Roseboom (1998).
Notes: (1) Excludes South Africa. (2) Excludes China and Japan. Data are for years [a]1981-85, [b]1991, [c]1992, [d]1993, [e]1997. Authors' calculation of CGIAR research intensity based on CGIAR Annual Report (1999) and data from World Bank (1999). The denominator of this calculation is the sum of agricultural value added in all non-transition economies classified by the World Bank as low income. The numerator is total annual member contributions to CGIAR.

**Table 2: Private agricultural R&D expenditure in selected countries as a percentage of agricultural GDP (%) in 1995**

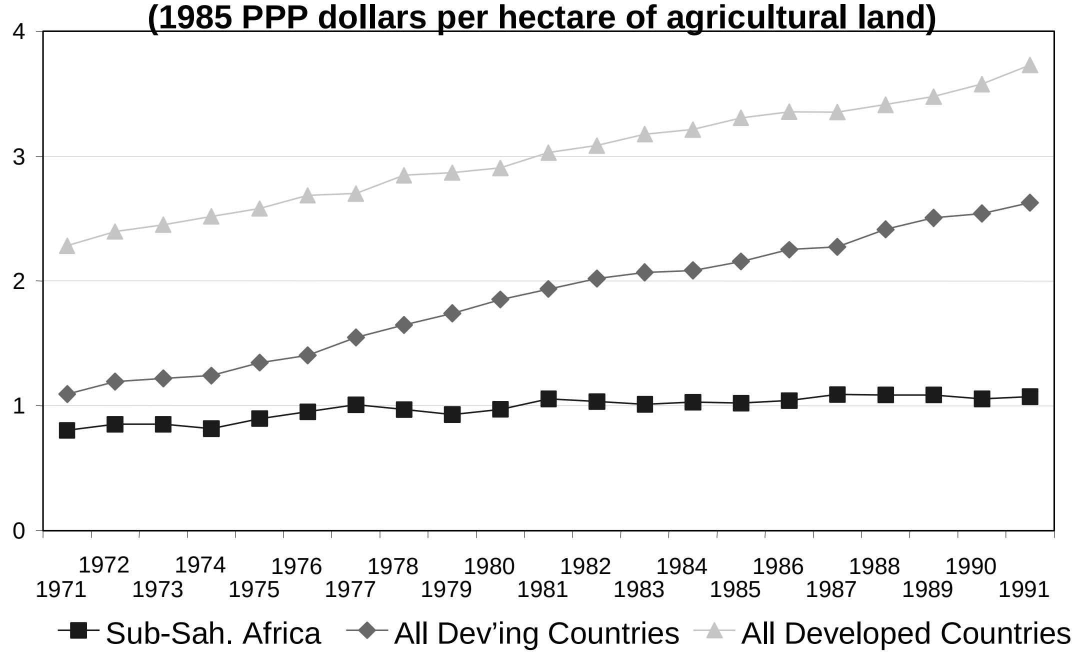
| Country | Private ag. R&D as a fraction of ag. GDP (%) |
|---|---|
| United Kingdom | 3.71 |
| United States | 2.67 |
| Australia | 0.49 |
| Colombia | 0.41 |
| Malaysia | 0.15 |
| Thailand | 0.10 |
| Philippines | 0.06 |
| India | 0.03 |
| Indonesia | 0.01 |
| Chile | 0.01 |

Source: Kremer and Zwane (2002), who cite Pray and Umali-Deininger (1998); expenditure per unit of agricultural GDP based on data from World Bank (1999).

Taking account of both public and private R&D, agriculture is slightly more research-intensive than other sectors in industrialized countries, which spent an average of 2.2 percent of total GDP on research in 1999 (OECD 2003). Agriculture's relative research-intensity cannot be explained simply in terms of political support for farmers in general, if only because funding for agricultural research does not appear to be closely correlated with other kinds of agricultural subsidies, and also because the economic returns to agricultural R&D are not lower than the returns to other kinds of research. The most plausible explanation for the relative research-intensity of agriculture is simply that farming offers relatively high returns to science-based innovation, with constant opportunities to improve the genetic potential of crops or animals as well as the purchased inputs farmers might use, given changes in farmers' economic and ecological conditions.

Developing countries as a group are catching up to industrialized countries in their agricultural R&D efforts – but rapid growth is concentrated in a few large countries, notably China and India. Sub-Saharan Africa, in contrast, has seen its share of world agricultural R&D fall, from about 8 percent of public R&D in 1976 to about 6 percent in 1995, with a sharper decline in its share of total R&D (Pardey and Beintema 2001). These declines in relative R&D levels make it increasingly difficult for Sub-Saharan Africa to catch up to other regions' productivity levels. And Sub-Saharan Africa's R&D levels were quite low to begin with, at the start of the modern "green revolution" crop-breeding effort. Africa's R&D intensity as a share of agricultural GDP was comparable to that of other low-income regions (Table 1), but on a per-hectare basis (Figure 1) African agricultural research was lower than average in the early 1970s and has since remained roughly constant while other countries' R&D investment rates grew.

**Figure 1 Public Research Expenditure per Unit of Land, 1971-91**
**(1985 PPP dollars per hectare of agricultural land)**




Source: Computed from IFPRI and FAOStat file data.

Investment differentials might be a matter of comparative advantage, if one country's research could be applied in another. But geographical spillovers are often limited (Jaffe, Trajtenberg and Henderson 1993), particularly towards Africa (Johnson and Evenson

2000). The constraints on spillovers include differences in institutions, but also biophysical differences between Africa and the tropical parts of Asia or Latin America.

One important biophysical barrier to agricultural technological spillovers into Africa is that the African continent is geologically older, with fewer river systems and less soil accumulation than other major regions. Two of the resulting differences between African and Asian soils are illustrated in Table 3: a much larger fraction of Africa's agricultural area has low ability to transfer nutrients to plants (measured as cation exchange capacity, or CEC) and/or to low ability to hold moisture for plants. These factors do not make agricultural R&D unproductive, but do affect the characteristics of the technologies that would be successful.

**Table 3. Selected Soil Fertility Constraints in Agriculture (as percent of agricultural area)**

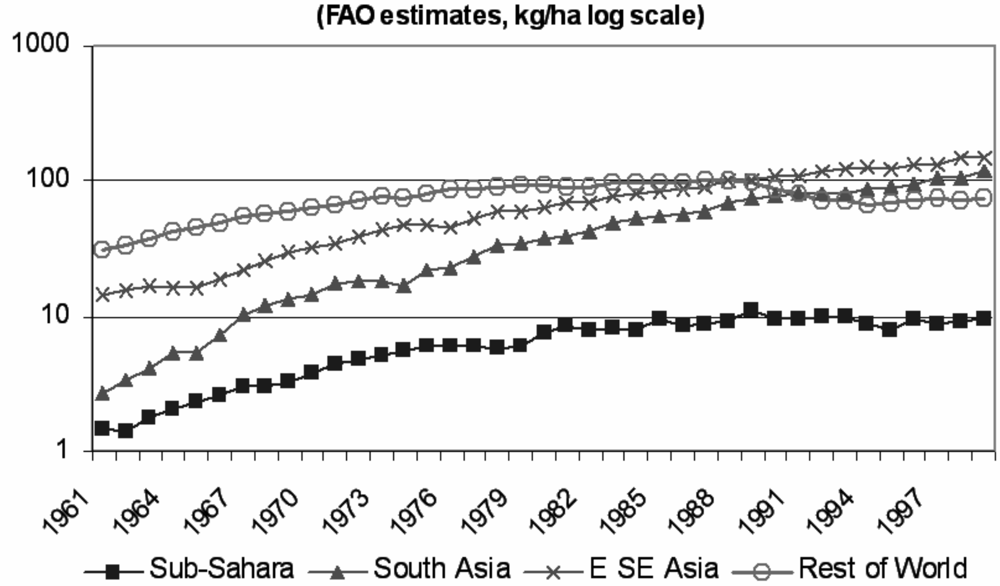
| | Low Cation Exchange Capacity | Low Moisture Holding |
|---|---|---|
| ***SSA*** | ***15.9*** | ***23.2*** |
| Southeast Asia | 2.3 | 6.0 |
| South Asia | 0.7 | 7.9 |
| East Asia | 0.1 | 1.8 |
| ***Global Total*** | ***4.2*** | ***11.3*** |

Source: IFPRI file data, courtesy of Stanley Wood.
Note: Constraints characterized using the Fertility Capability Classification (Sanchez et al., Smith).

Africa's limited investment in local R&D, combined with its unusual agroecology and limited spill-in from R&D conducted elsewhere, has left it with limited stocks and flows of new technology. Part of Africa's technological lag is undoubtedly due to its governments' heavy taxation of agriculture, which has inhibited farmers' willingness to invest in all sources of increased supply. Where farmers have been more heavily taxed, there has been lower agricultural productivity growth (Fulginiti and Perrin 1999). But much of the lag can also be explained by low R&D investment.

Some insight into the relative importance of policy incentives versus R&D effort can be identified by the characteristics of different technologies. In particular, purchased fertilizer costs a significant fraction of crop value and must be obtained from off-farm markets, whereas the marginal production cost of seeds for a new variety are little more than the cost of making seeds for an old variety, and the new variety's seeds can usually spread easily from farmer to farmer. As a result, we expect fertilizer to be more sensitive to price policies and market institutions, while new seed adoption is more sensitive to R&D effort. Figure 2 illustrates Africa's fertilizer use rates, relative to those of other regions. It began lower and grew more slowly than that of South Asia during the 1960s, when fertilizer-to-grain price ratios were falling, but more importantly it stopped growing in 1981 and has not grown significantly since then.

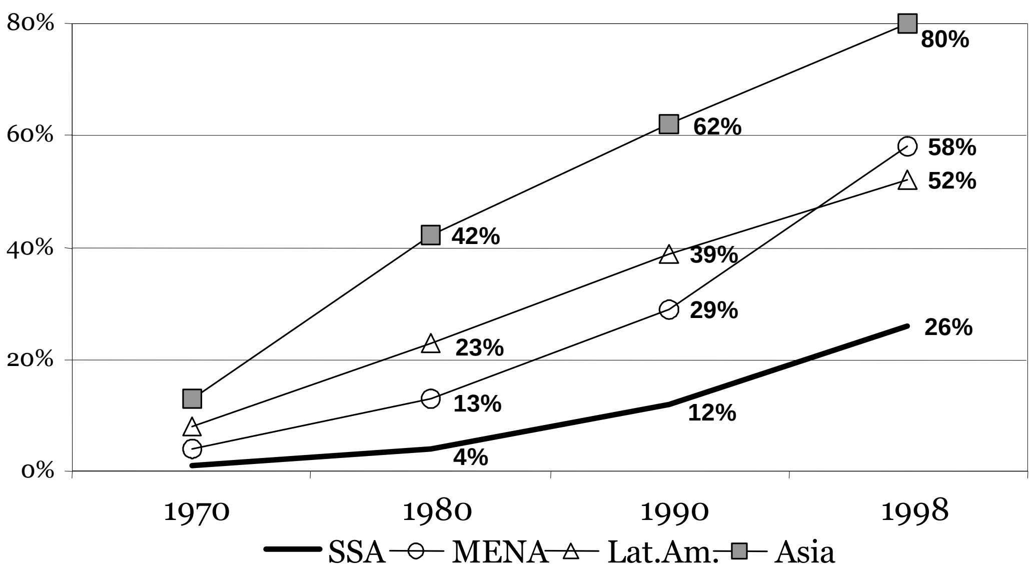
**Figure 2.**
**Total Fertilizer Use per Unit of Arable Land, 1961-99**
**(FAO estimates, kg/ha log scale)**




Source: Author's calculations, from FAOStat (2003) data.

One reason for Africa's low plateau in fertilizer use rates is clearly the unfavorable relative prices caused by restrictive government policies, and also by high transport costs for inbound fertilizer relative to outbound agricultural products. Another reason could be unfavorable fertilizer response rates, due to low rainfall and limited irrigation potential as well as the soil characteristics illustrated in Table 3. But in any case, Africa's changes in fertilizer adoption rates are very different from its pattern of new variety adoption, which is illustrated in Figure 3 below.

**Figure 3. New Variety Adoption by Region**




Source: Drawn from data in R.E. Evenson and D. Gollin, eds., *Crop Variety Improvement and its Effect on Productivity: The Impact of International Research* (Wallingford, UK: CAB International, 2003).

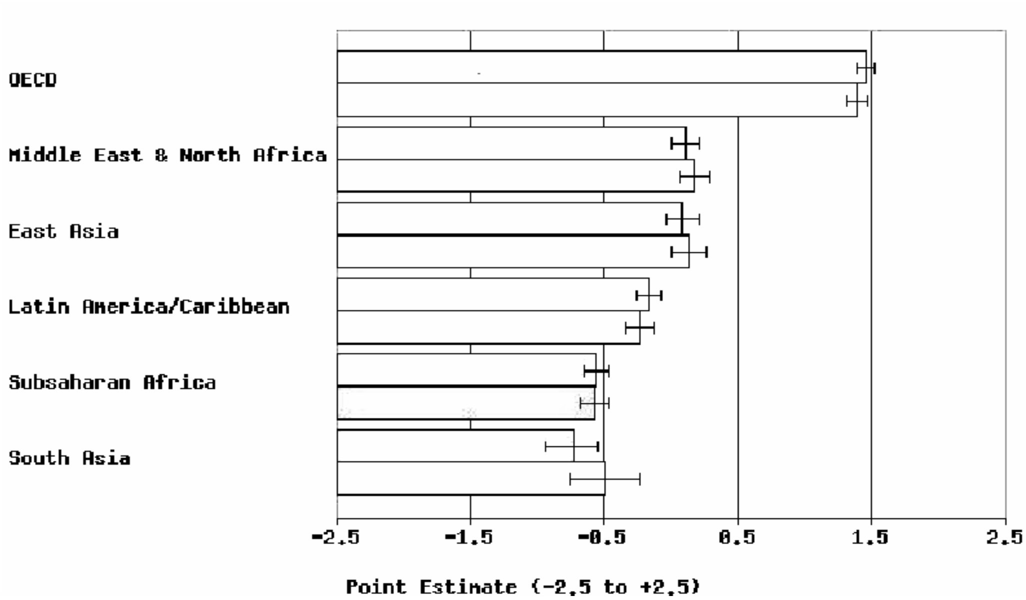
Figure 3 shows that Africa had almost no new variety adoption during its period of fertilizer-use growth, and has only now reached adoption rates that were seen in Asia and Latin America a generation ago. Clearly, very different factors are at work in the use of new seeds than in the use of fertilizer. Seed use may be affected by price policies and market institutions, but new seeds are relatively inexpensive and often move through nonmarket channels. The aggregate adoption data and abundant case study evidence reveals that Africa's environment does not make new varieties as such unproductive: new seeds can be better than old seeds in any location. Africa's uniqueness limits spill-ins from research done elsewhere, but the economic return to agricultural R&D done within Africa is, as it is elsewhere, well above the cost of capital. The continent has been lagging technologically in large part because it has had relatively little R&D of a nature that is appropriate to its farmers. Analysis of the market failures that limit R&D activity can help explain this lag, and then suggest a remedy.

*Market failures affecting R&D in private firms*

The virtually complete absence of private R&D in the poorest countries is widely attributed to undefined or unenforced intellectual property rights. Without IPR enforcement, imitation of innovations and spillover of knowledge to other firms is likely to limit the profit any firm can draw from its investment in research.

In Africa, of course, government failures run far deeper than weak IPRs: many African countries have weak rule of law in every domain, with limited legislative, judicial or police capacity to define or enforce any kind of legal construct. Recent survey data on the extent of rule of law across countries is summarized in Figure 4 below.

**Figure 4.**
**Average "Rule of Law" index by region, 2000-01 (upper bar) and 1997-98 (lower bar)**
(index averages, with standard deviation)




Source: calculated from D. Kaufmann, A. Kraay and P. Zoido, 2002.
*Governance Matter II: Updated Governance Indicators for 2000-01.*
(www.worldbank.org/wbi/governance)

Personal rule (or the absence of rule of law) is not totally inconsistent with private investment in other areas, so it is helpful to look for other constraints that might limit private R&D in the African context. Beyond IPR enforcement, a second constraint on private R&D is asymmetric information about the value of research. In addition to the intrinsic qualities of the innovation itself, the seller may have private knowledge of its applicability or economic value. Since users can't observe these things, they must take them on trust – so the demand for new technologies depends on the credibility of the seller. This is a classic market-for-lemons problem, which results in low or zero market activity unless a third party intervenes to reveal quality in a credible manner (Akerlof 1970).

A third constraint on private R&D activity would be credit markets and collateral. Even when potential users know that an innovation would be profitable, they might not be able to borrow against those future earnings to finance adoption if they have inadequate savings or other assets to use as collateral. As a result, innovations that cannot easily be financed out of a household's disposable income are unlikely to be adopted.

The fourth kind of constraint involves transaction costs between IPR holders. A marketable final product may embody more than one proprietary innovation, and the bargaining process among IPR holders may be so costly that relatively few trades are made. Most notably, genetic constructs owned by foreign firms might profitably be bred into locally adapted crop varieties in numerous jurisdictions, but the high fixed costs of transaction might prevent its use in jurisdictions with a relatively small potential market.

*Policy failures affecting R&D in public institutions*

Given the severity and variety of market failures affecting private R&D in low-income countries, it is not surprising that significant levels of private research activity have not emerged in Africa. Public R&D faces a different but similarly severe set of own constraints, which are also particularly restrictive in Africa.

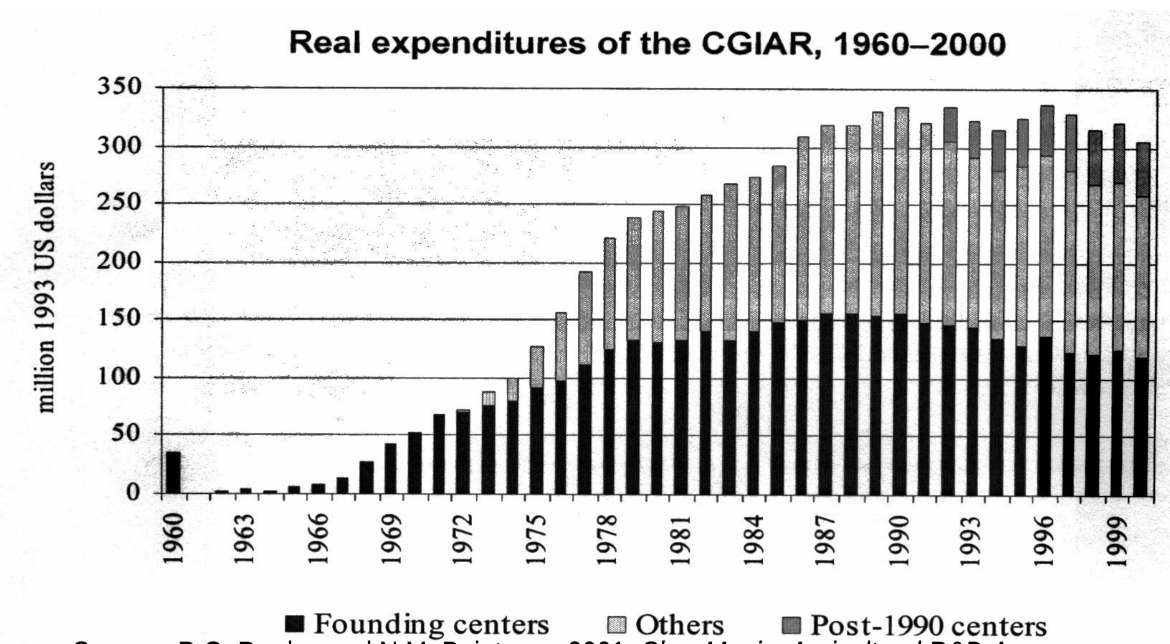
A first constraint on the level and orientation of public R&D is the problem of spillover across jurisdictions. Part of Africa's colonial legacy is that much of the continent has been subdivided into many very small countries, often on the order of 10-20 million people. The problem is compounded by the fact that country borders were often drawn without respect to population groupings or agroecological boundaries. Thus, the R&D performed in countries such as Bostwana will generate large benefits for the semi-arid parts of neighboring countries such as Zimbabwe, as it has in the case of sorghum varieties, while Zimbabwe's population is spread over several very different agroecological zones, each of which has very different R&D needs.

A further constraint on public R&D investment arises within jurisdictions, as agricultural R&D faces particularly severe collective-action problems from rational ignorance and free-ridership. The benefits of agricultural R&D are spread over a large number of people who gain from lower food costs or higher returns to farm land and labor. If each beneficiary would gain less from increased investment than it would cost them to learn about and lobby for it, they have no individual incentive to do so. Such "rational ignorance" (Downs 1957) is likely to be a particularly severe constraint on public support for agricultural R&D in the poorest countries, where farm-income gains are spread over a majority of the population. The large size of the farm sector also facilitates free-ridership.

A more subtle constraint on public R&D activity arises from the time-consistency problem: investment in R&D is irreversible, and its productivity depends on future decisions which the current government may not control. McMillan and Masters (2003) use this problem to help explain the puzzle of why some African governments, which have historically extracted a relatively large share of farm productivity through high taxes, did not invest more in agricultural R&D. Given their high tax rates, these governments could have recovered an unusually large fraction of the productivity gains from research – but if they could not commit to sustaining a given policy regime over time, farmers may fear future expropriation and so not respond to current incentives.

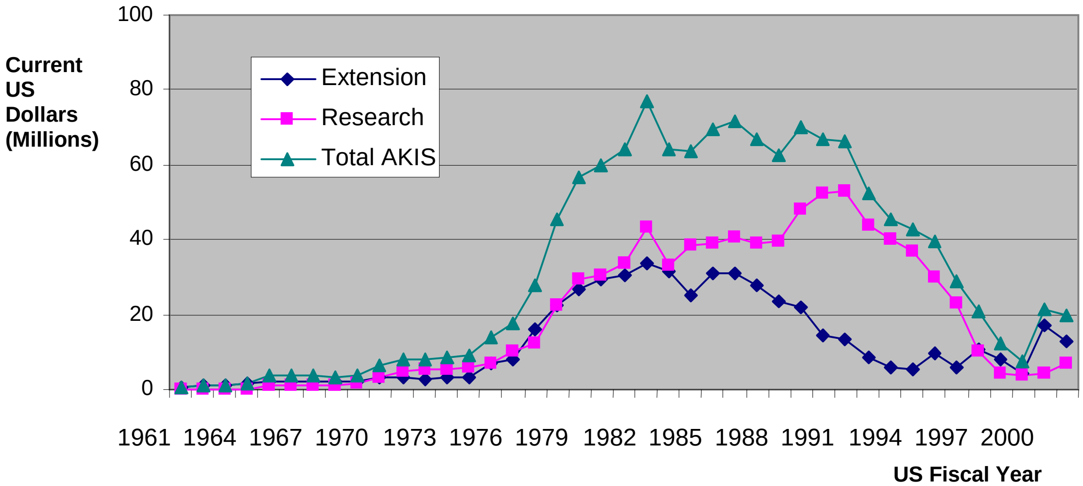
All of these constraints help explain why there is likely to continue to be relatively low effective demand or supply for agricultural research from within Africa – despite the fact that increased R&D investment would be a powerful engine of growth for the continent. Recognizing this, donors have generally been willing to intervene by providing research directly. The "invention" of the CGIAR in the 1960s was a signal event in the history of global public goods, as donors worked together to solve their collective action problems in a new way. As shown in Figure 5, however, support waned in the 1990s, perhaps in part as a direct result of the CGIAR's success in attracting a larger number of donors (each of whom would be more tempted to free-ride on the efforts of others), targeting an increasing variety of objectives (which raises the difficulty of coordination). Figure 6 reveals an even more extreme rise and then fall in agricultural R&D support from USAID – particularly given that these data are in nominal dollars, so in real terms the decline after 1993 was even more precipitous than it appears on the graph.

Figure 5.




Source: P.G. Pardey and N.M. Beintema, 2001. *Slow Magic: Agricultural R&D A Century after Mendel.* Washington, DC: IFPRI.

**Figure 6. USAID Funding for Research and Extension Activities in Africa**




Source: Gary Alex (2003), unpublished file data

The decline in donor support for R&D in Africa during the 1990s was linked to a general distrust of government institutions and a desire to provide aid directly to the private sector, as well as a belief that agriculture and agricultural technology were not central to the development process. USAID's recent reversal of this decline in 2001 may or may not represent a shift in thinking on these questions, but in any case it seems clear that some new institutional approaches would be helpful in mobilizing a renewed effort to support agricultural research in Africa.

### 3. A prize mechanism for agricultural R&D in Africa

The institution proposed in this paper aims to help remedy market failures in R&D for Africa, by aligning incentives to researchers and donors with the needs of beneficiaries. In this section, we outline the key features of the proposal, then explain in more detail how prizes would be computed and how the mechanism would affect incentives.

***Key features of the proposal***

*(1) Pay for social gains, without pre-judging which technologies are needed*

The proposed institution would award a fraction of the social benefits generated by an innovation, whose value would be estimated using a pre-specified protocol for field trials and farm surveys. The institution would *not* pre-specify the technologies to be rewarded. This proposed approach helps remedy the asymmetric information problem, allowing researchers to exploit their private knowledge or serendipitous discoveries, rewarding them only after rigorous testing proves the innovation's value. Testing would be conducted by the applicant, at their cost, as part of their R&D effort. This system would be much like the drug approval process in the United States, where the FDA specifies how applicants can document the safety and efficacy of their innovation -- but in agriculture, field trials and farm surveys could go further, estimating the economic value of the new technology. A suggested protocol to measure economic value is sketched later in this section.

*(2) Make one-time payments, so innovators self-select whether to apply*

The proposed prizes would be one-time payments that buy the innovation into the public domain. This approach rewards those who supply socially valuable innovations, circumventing the credit constraints that might prevent low-income farmers from paying for otherwise profitable innovations, the market failures associated with spillovers and free-ridership, and the hold-up effect of patents on subsequent innovations. This aspect of the proposal is much like the Kremer (1998) mechanism for patent buy-outs, but in this case the amount of the prize is estimated from technological data rather than through an auction process. The proposed approach forces innovators to self-select whether they will apply for the prize, based on their private knowledge of the potential marketability of their technology. Innovators who anticipate being able to exclude free-riders and capture a significant fraction of the measurable social gains from their technology will prefer to retain private control over it, and only those who believe that their innovation is demonstrably valuable but not marketable will choose to pursue a prize.

*(3) Adjust payout rates, to equilibrate supply of funds with demand for prizes*

Offering prizes is only a partial remedy for market failure. The proposed institution is a complement rather than a substitute for other forms of research funding. Establishments that are now funded through research contracts or patent revenues would see the prizes as a potential additional source of revenue, providing a marginal incentive to produce valuable but non-marketable technologies for which they currently obtain little reward. Beyond their incentive effect, the prizes would also help channel resources to talented or well-placed researchers whose successes are well-documented. By drawing a clear link between research funding and social gains, the prize mechanism could well attract much more donor interest in R&D. If so, and this mechanism were to attracts donors faster than prizes were paid out, the fraction of estimated social benefits that is to be awarded could be raised – and conversely, if the payout rate is too fast, then the proportion paid could be reduced. In any case, the prizes would be a strong complement to other support for R&D, operating as a kind of matching-funds scheme conditional on program success, thus inducing other funding sources to spend more on R&D programs they thought could win a prize. It is difficult to predict these effects, but some plausible magnitudes would be that prize awards are 20 percent of the estimated social benefits from an innovation, and that the prize mechanism is used to channel about $100 million per year, on the order of one-tenth of all agricultural R&D in Africa.

*(5) Adjust the protocol for measuring impact, to elicit appropriate proposals*

To estimate the value of an innovation, researchers will need experimental data on quantity changes, survey data on the extent of adoption, market data on relevant prices, and a method to interpret these data in terms of economic benefits. Details of a proposed approach are provided in the following section, but a first question that arises is the time horizon of benefits to be included. If the award covers only documented past benefits, then awards will be too small and innovators will wait to long before applying for an award. If the award covers all future benefits, then the estimation includes too many unverifiable conjectures. A plausible approach is to allow claims for about three years of projected future benefits. In practice, changing this time period might not much affect the size of the prizes: it would alter the size of all estimated benefits, and hence change the proportion of those benefits that could be paid in prizes.

*(6) Use an equitable governance structure, to be credible and sustainable over time*

The proposed prize mechanism would be funded by donors, and governed jointly by donors and by potential claimants. This approach helps remedy the time-consistency and credibility problems often associated with prize schemes, when potential researchers do not trust that the prizes will actually be paid as promised. We propose that the prize-giving institution's staff and policies be chosen by a board composed of one-third donors to the prize fund, one-third research entities that are potential prize recipients and one-third independent members. In the donors' election, each might cast votes in proportion to their level of contribution to the prize fund. In the researchers' election, each might cast votes proportionally to their level of effort in African agricultural research, measured perhaps by the number of full-time agricultural scientists working in the field. The independent members might be required to receive a majority of votes cast in both types of election. A governing board of twelve members serving staggered four-year terms would allow each group to replace one board member every year, and a ban on receiving an award while sitting on the board would help limit self-dealing and ensure that, since institutions must rotate off the board to receive an award, incumbent board members would have a strong incentive to set time-consistent and transparent policies. The initial staff of the award authority would be small – perhaps an Executive Secretary and a few scientists, plus a budget to convene expert panels, as the U.S. FDA does when a particular drug-approval question requires specialist knowledge. Financial matters, both the investment of fund balances and the actual disbursement of awards, could be managed by a third party such as the World Bank.

***The computation of prizes and the attribution problem***

The exact procedures for computing awards would improve with experience, but a reasonable starting place is the impact-assessment methods outlined in Alston, Norton and Pardey (1995). In implementing this approach, perhaps the hardest conceptual hurdle is what Alston and Pardey (2001) call the attribution problem, which Scotchmer (1991, page 34) identifies as similar to "double marginalization" in industrial organization.

When calculating the marginal value of one research investment, by definition all other decisions must be taken as given, but many research investments are complements. For example, introducing a Bt variety in a given region might generate a net present value of ten million dollars. If a suitable variety were already freely available, then inserting the Bt gene into it would be worth ten million dollars. But if it is Bt genes that are freely available, then it is bringing the suitable variety that is worth ten million dollars. Scotchmer notes: "It is impossible to give the surplus to both parties" (page 34). Asking what share of the ten million dollars should be attributed to Bt, and what share should be attributed to the underlying variety, is like asking which blade of a scissors does the cutting. In the industrial-organization context, negotiations over the surplus can be a source of market failure. In the impact-assessment context, arguments over attribution are mainly a semantic problem, regarding the definition of which research project is being assessed.

Given the attribution problem, impact assessments of small applied research projects often show huge percentage rates of return, because many sunk costs are taken as given. The estimated rate of return falls as the costs included in the calculation expand. Both rates are correct, they just answer different questions. Similarly, adding up the net present value of the economic surplus gains attributable to various individual research projects would yield a sum far larger than the total surplus of the sector, again because they are answers to different questions.

In the IPR context, the attribution problem is "solved" by reviewing and possibly granting patents on a first-to-invent basis (in the US) or to the first applicant to file for it (in other countries). This leaves the holders of complementary patents to negotiate privately over their joint profits, with the familiar double-marginalization result.

When awarding prizes, the attribution problem could be addressed in the same way as for patents, by reviewing and possibly granting awards on a first-to-invent or first-to-file basis. But with prizes, granting the award would buy out the innovation into the public domain, so no further distortion would result – by the same mechanism as the patent buy-outs proposed by Kremer (1998).

The scope of the benefits that can be claimed by a prize applicant depends partly on what evidence is brought in the application, and partly on what other claims have already been made by others since the same benefits could not be counted twice. This is analogous to the scope of protection that can be claimed in a patent filing, which depends both on the evidence in the filing and on what has been claimed on prior patents. At the start of the process, the first applicants could make very wide claims, attempting to take credit for gains that other prize applicants might later be able to contest. It would therefore be desirable for the initial phase to involve simultaneous consideration of applications collected over an entire year or more, and perhaps also to specify a procedure for suits and appeals when additional evidence is uncovered, as is done for example in the U.S. through the Patent Office's Board of Patent Appeals and Interferences.

The following elements would form the basis for a claim: (a) *experimental data*, from on-farm or market trials, to establish the physical productivity differences between the innovation and prior art; (b) *economic data*, from market surveys or secondary data, to establish the relative prices of the inputs and outputs whose quantities are affected by the innovation; (c) *adoption data*, from sample surveys or aerial photography or other sources, to establish the extent to which the innovation is used in a given market; and (d) *model structure and parameters,* inferring what is locally unobservable from economics research conducted elsewhere.

Model structure and parameters would be specified, as a matter of policy, by the prize authority. A starting point for the model and its parameters might be a partial-equilibrium model with a parallel shift of the supply curve, for which supply and demand elasticities are taken from a pre-specified set of estimates. The resulting model yields a very specific sequence of calculations, incorporating each kind of data listed above to compute the annual gross benefits and their net present value, as documented in Alston, Norton and Pardey (1995). This sequence of calculations is relatively transparent, and is no more complex than a company balance sheet.[6] To the extent that the prize authority finds this model inadequate, however, they could ask for a different set of calculations. Although some formulas are probably more accurate than others in reflecting the (unknown) "true model" of the economy, the incentive effect of the prize system is unlikely to be much affected by the use of one model and set of parameters than another. The key factor is that awards would be proportional to the basic data described in (a), (b) and (c) above, therefore helping to align researcher institutes' objectives with the interests of farmers and other potential beneficiaries.

## 4. Conclusions

This paper provides a brief survey of the key market and policy failures that plague resource allocation for agricultural R&D, particularly in Africa, and proposes a new institution to help improve resource allocation. The proposed institution contains a number of features that make it particularly well-suited to African agriculture, where technical change usually takes the form of many incremental and location-specific innovations as opposed to a few blockbuster technologies, and where many important innovations are not marketable even with stronger IPRs.

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[6] This paper's author has taught over 60 researchers in African research institutions to do these estimates, using a standard methodology adapted from Alston, Norton and Pardey (1995). The training materials and several of the case studies produced in a series of seven workshops over the 1994-2002 period is available on CD-ROM and through the web, at http://www.agecon.purdue.edu/staff/masters/ImpactCD/ImpactInfo.htm

The size of the prize fund would be expected to vary over time. On the endowment side, donors could start small, and then add funds over time if they found that the mechanism was successful in identifying and supporting the most successful research ventures. On the award-disbursement side, payouts would vary over time as the applications came in. Most likely there would be few applications at first, since it would take time for researchers to assemble the data needed to apply, so fund balance would rise and then might remain roughly constant if inflows matched outflows.

If the prize mechanism proved unattractive to donors, then inflows would slow and payouts would gradually erode the balance until the experiment ended. If the prize mechanism proved unattractive to researchers, then the board could adjust the award formulas to increase the payout. In sum, the award authority would be a kind of marketplace through which to balance the demand and supply for research: if the approach proved attractive to both researchers and donors, then annual inflows and outflows would both grow.

Researchers' expectations about the fund's future solvency or payout procedures, and donors' expectations about the kinds of research their money would reward, would depend entirely on the fund's performance from year to year. Unlike the Kremer (2001) vaccine-purchase fund, it would not be necessary or even desirable for the fund to accumulate a large cash balance at the outset, because the flow of agricultural research to be rewarded is not an all-or-nothing proposition. In agriculture unlike vaccine research, progress typically involves a large number of incremental improvements in specific crops and adoption domains, each of which can be rewarded separately as they are documented in applications for research awards.

The new institution we propose would help to complete the market for R&D, aligning the incentives facing researchers in both public institutions and private firms with the needs of potential beneficiaries. The mechanism is intended to complement rather than replace existing institutions, serving as the channel for perhaps 10 percent of total funds for agricultural R&D in Africa. Researchers in existing institutions, when offered the possibility of applying for a prize, would seize opportunities to develop valuable but non-marketable innovations – and the prize mechanism would channel resources to researchers with a proven record of success. In this way, the proposed institution would strengthen the link between donor funds and successful innovation, perhaps raising the level of support for R&D as well as improving the efficiency with which R&D funds are spent.

**Reference Cited**

Akerlof, George A., 1970. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *Quarterly Journal of Economics*, 84(3): 488-500.

Alston, J.M., G.W. Norton and P.G. Pardey, 1995. Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Ithaca, NY: Cornell University Press.

Alston, J.M. and P.G. Pardey, 2001. "Attribution and other problems in assessing the returns to agricultural R&D." *Agricultural Economics* 25(2-3, Sept.):141-152.

Downs, Anthony, 1957. *An Economic Theory of Democracy*. New York: Harper.

Fulginiti, Lilyan E. and Richard K. Perrin. 1999. "Have Price Policies Damaged LDC Agricultural Productivity?" *Contemporary Economic Policy* 17(4, October): 469-475.

Jaffe, Adam, Manuel Trajtenberg and Rebecca Henderson, 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* 108(3, August): 577-598.

Johnson, D.K.N. and R.E. Evenson, 2000. "How Far Away is Africa? Technological Spillovers to Agriculture and Productivity." *American Journal of Agricultural Economics*, 82(3, August): 743-49.

Heller, M.A. and Eisenberg, R.S. 1998. "Can patents deter innovation? The anticommons in biomedical research." *Science* 280 (May 1st): 698-701.

Kremer, Michael (1998). "Patent Buy-Outs: A Mechanism for Encouraging Innovation." *Quarterly Journal of Economics* 113(4, November): 1137-1167.

Kremer, Michael, 2001. "Creating Markets for New Vaccines", in Adam Jaffe, Joshua Lerner and Scott Stern, eds., *Innovation Policy and the Economy* (Volume 1). Cambridge: The MIT Press. <http://www.nber.org/books/innovation.>

Kremer, Michael and Alix Peterson Zwane, 2002. "Encouraging technical progress in tropical agriculture." http://are.berkeley.edu/courses/envres_seminar/zwane.pdf.

Lehrer, Tom, 1959. *An Evening Wasted with Tom Lehrer*. London: Decca Records.

Lerner, Josh, 2002. "Patent protection and innovation over 150 years." NBER Working Paper no. 8977. Cambridge, MA: NBER.

Lusigi, A. and Thirtle, C., 1997. "Total Factor Productivity and the Effects of R&D in African Agriculture." *Journal of International Development* 9(4, June): 529-38.

McMillan, M. and W.A. Masters, 2003. "An African Growth Trap." *Review of Development Economics* 7(2): 179-191.

Mokyr, Joel, 1992. *The Lever of Riches: Technological Creativity and Economic Progress*. New York: Oxford University Press.

Pardey, P.G. , J. Roseboom and B.J. Craig, 1999. "Agricultural R&D Investments and Impacts," in J.M. Alston, P.G. Pardey and V.H. Smith, Paying for Agricultural Productivity. Baltimore: Johns Hopkins University Press.

Pardey, Philip G. and Nienke M. Beintema, 2001. "Slow Magic: Agricultural R&D a Century After Mendel." Food Policy Report No. 13 (36 pages). Washington, DC: IFPRI.

Scotchmer, Suzanne, 1991. "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law." *Journal of Economic Perspectives*, 5(1): 29-41.

Sobel, Dava, *Longitude.* New York: Walker and Co., 1995.

Wright, Brian D., 1983. "The Economics of Invention Incentives: Patents, Prizes, and Research Contracts." *American Economic Review* 73(Sept.): 691-707.