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SUSTAINABLE AGRICULTURAL DEVELOPMENT: THE ROLE OF INTERNATIONAL COOPERATION

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Financing Agricultural Research in the Presence of International Benefit Spillovers: The Need for Institutional Coordination and Innovation

INTRODUCTION

The financing of agricultural research presents a unique policy problem. While research is often funded by national or subnational governments, the benefits of research often spill across the boundaries of the government financing the research. Many observers of international agricultural research have noted that the spillover problem exists and that policy changes are needed if an internationally optimal level of investment in research is to be provided (Judd, *et al.*, 1987; Idachaba, 1981; Ruttan, 1987b). Some empirical studies have attempted to measure international benefit spillovers (Evenson, 1977; Davis, *et al.*, 1987; Edwards and Freebairn 1984), and others have attempted to establish criteria for allocating research resources (Idachaba, 1989, p. 6; Paz, 1981; Norton and Pardey, 1987; Fishel, 1971; de Castro and Schuh, 1977; Carter, 1985). None of these studies has addressed two central policy questions: what policy tools are available for achieving an optimal level of investment in research and what institutional innovations are required to make these policy tools operable? This paper uses public finance theory to address these questions. First, the sources of international benefit spillovers will be examined. Second, public finance theory will be used to examine the policy tools available for achieving institutional coordination in financing research. Third, empirical estimates of international benefit spillovers will be reviewed. Finally, the policy implications of this research will be examined, with special emphasis on the institutional innovations needed to finance an optimal level of agricultural research.

SOURCES OF INTERNATIONAL SPILLOVERS IN AGRICULTURAL RESEARCH

Since agricultural technology must be adapted to the ecological conditions in which it is used, agricultural research is often a location-specific enterprise that must be conducted in the same ecological conditions in which production takes place (Ruttan, 1982). At the same time, research that yields significant increases in the supply of farm products will ultimately provide a large portion of its benefits to consumers as the supply of farm products shifts along an inelastic demand for such products (Ruttan, 1982). As a result of this combi-

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nation of location specificity and diffused benefits, agricultural research can provide three types of international benefit spillovers:

- (1) benefits can accrue to consumers outside the investing country when research increases production and causes prices to decline in world markets;
- (2) benefits can accrue to producers and consumers outside the investing country when research produces new technology that can be adopted by producers outside the investing country (either with or without further adaptive research); and
- (3) benefits can accrue to many individuals outside the investing country when research produces scientific knowledge that enhances research in other (sometimes unrelated) areas of science (Davis *et al.*, 1987).

THE ROLE OF INSTITUTIONAL COORDINATION IN FINANCING AGRICULTURAL RESEARCH

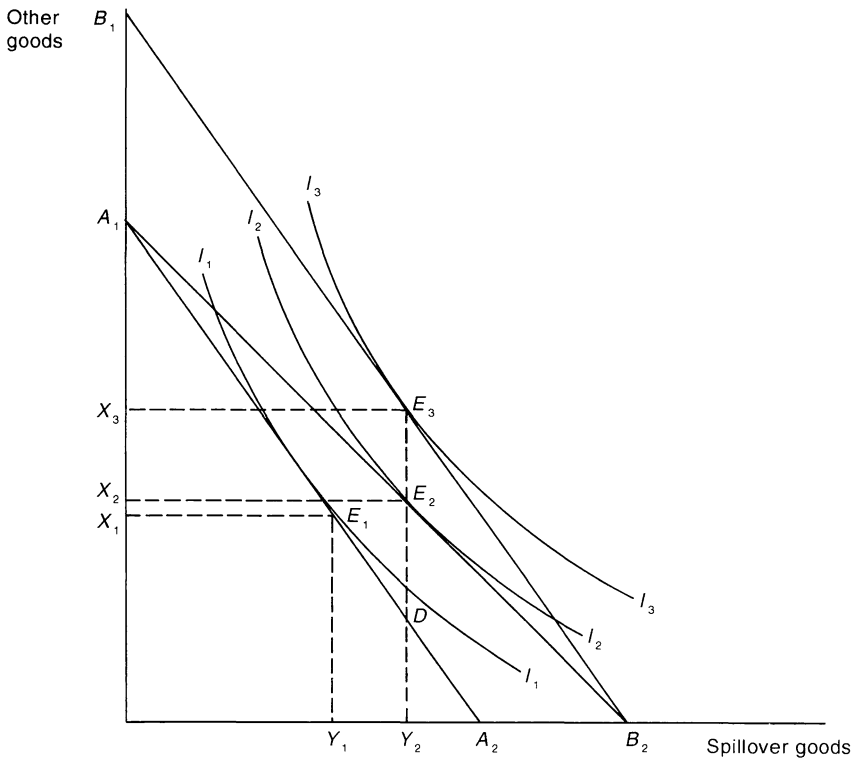
The question raised by A.C.Pigou (1946) remains a central problem in public policy: under what circumstances should government intervene to align private and social costs (or private and social benefits)? Modern public finance theory recognizes that this question is not simply a matter of whether government should provide public goods, but also of which unit of government should do so. This question arises because some goods cannot be classified into the polar cases of pure private or public goods. Instead, there are a number of 'non-private' goods whose benefits are available to individuals in unequal amounts (as opposed to a pure public good which is available to all individuals in an equal amount). In addition, the problem of under-investment in non-private goods is further complicated when the problem of 'imperfect mapping' arises (Breton, 1965).

If a good is perfectly mapped, the benefits of that good will accrue only to those within the boundaries of the government financing the good. Assuming that the government of that jurisdiction can determine the preferences of its citizens, it will provide the optimal quantity of the perfectly mapped good. On the other hand, if the benefits of the good are imperfectly mapped, or spill across the jurisdictional boundaries of the financing government to those outside the jurisdiction, the investing government, like the investing individual in Pigou's analysis, will under-invest in the good. A higher level of government can encourage the provision of a socially optimal quantity of the spillover-generating good by providing a subsidy to the lower level unit of government.

An analysis of two types of subsidies is shown in Figure 1 (Scott, 1952; Boadway and Wildasin, 1984). A jurisdiction of government (a national government in the case of agricultural research) is assumed to allocate its budget (represented by the budget line A_1A_2) between the consumption of a public good that generates benefit spillovers in other countries (such as agricultural research) and all other goods (either private goods consumed by citizens or public goods that create no benefits outside the jurisdiction). The country's

indifference curve I_1 indicates that its welfare is maximized at point E_1 , and the quantities purchased will be Y_1 and X_1 . Another unit of government (such as an international grantor¹) may wish to provide a subsidy to compensate the country for the benefits that spill across its boundaries.

The subsidy could take the form of an unconditional, lump-sum grant. Such a grant has no restrictions on its use and may be allocated by the recipient for any purpose. Thus some of the grant will be allocated to the spillover-generating public good and some will be allocated to non-spillover public goods or to private goods (via a reduction in taxes in the recipient community). Such a grant is shown in Figure 1 as a shift in the recipient's budget line from A_1A_2 to B_1B_2 . The recipient's new allocation will be Y_2 of the spillover-generating good and X_3 of other goods.



Source: Boadway and Wildasin (1984).

FIGURE 1 Comparison of an unconditional lump-sum grant and a conditional matching grant

As an alternative to a lump sum, the grant could take the form of a conditional matching payment. In this case, the grant will only be received on the condition that (1) the recipient use the grant for consumption of the spillover-generating good, and (2) that the recipient match the grant at a specified rate with its own funds. Assuming the original slope of the budget line is β and that the matching rate (defined as the number of international dollars granted for each national dollar invested in the spillover-generating good) is established such that δ is the share of the cost of the good Y paid by the grantor, the new budget line will have a slope of $\beta(1 - \delta)$ and will rotate from A_1A_2 to A_1B_2 . The recipient's new allocation will be X_2 and Y_2 . Thus, if Y_2 is the socially optimal level of the public good, the grantor can achieve this level of output at least cost by use of a conditional matching grant (that is, the grantor's cost of achieving output Y_2 is DE_3 if a lump-sum grant is used, but only DE_2 if a matching grant is used). This result arises because the lump-sum grant produces only an income effect, while the matching grant reduces the recipient's price of the spillover-generating good, thereby creating a price effect and providing a more powerful incentive for the recipient to increase its spending on the spillover-generating good. Several studies of grant programmes in the USA confirm that lower-level jurisdictions of government do respond to such price effects and, as a result, recipient spending is stimulated more by a matching grant than by a lump-sum grant of equal size (Gramlich, 1977).²

To find the optimal matching rate for financing agricultural research, a model of optimal public investment will be employed (Harford, 1977). For each country, the model is defined by two equations:

$$NIB_i = B(R_i) - C(R_i) \quad (1)$$

$$NNB_i = \alpha_i B(R_i) - (1 - \delta_i) C(R_i), \text{ where:} \quad (2)$$

- NIB_i = the net international benefit from research conducted in country i ;
- NNB_i = the net national benefit from research conducted in country i ;
- $B(R_i)$ = the benefit function of agricultural research conducted in country i ;
- $C(R_i)$ = the cost function of agricultural research conducted in country i ;
- α_i = the share of research benefits that accrue to country i as a result of agricultural research conducted in i ;
- δ_i = the share of the cost of agricultural research conducted in nation i paid by the international grantor;
- R_i = funds spent on agricultural research in country i .

The optimal share of the cost of research in country i that should be paid by the international grantor can be determined by maximizing the national and international net benefit equations. Differentiating equations (1) and (2) provides the international and national conditions for optimal research spending:

$$\frac{dB}{dR_i} - \frac{dC}{dR_i} = 0 \quad (3)$$

$$\alpha_i \frac{dB}{dR_i} - (1 - \delta_i) \frac{dC}{dR_i} = 0. \quad (4)$$

Solving (3) and (4) simultaneously and rearranging provides the international grantor's optimal share of the cost of research conducted in country i :

$$\delta_i = 1 - \alpha_i \quad (5)$$

Thus the share of the cost of research paid by the international grantor varies directly with the proportion of marginal research benefits that spill out of country i . Equation (5) can also be expressed as the optimal matching rate for a conditional matching grant:

$$m_i = \delta_i / (1 - \delta_i) \quad (6)$$

Thus, to achieve the internationally optimal level of investment in agricultural research, the international grantor should provide country i with m_i dollars for each dollar of agricultural research provided by country i . When this condition is met, the marginal benefit of research that accrues to country i is equal to the marginal cost of research paid by its taxpayers, and the marginal benefit of research that accrues outside the country is equal to the marginal cost paid by the international grantor.

EMPIRICAL EVIDENCE OF RESEARCH BENEFIT SPILLOVERS

Few studies have attempted to measure the international spillovers produced by national investments in agricultural research. Edwards and Freebairn (1984) used economic surplus models to estimate the international welfare effects of wheat and wool research conducted in Australia. Their results indicated that anywhere from 2 per cent to 98 per cent of the total benefits of such research accrued to consumers or producers outside Australia. These estimates were extremely sensitive to (a) the relative elasticities of supply and demand and (b) the applicability of such research to production in other countries (that is, when producers in other countries can adopt the technology developed by research, the spillover benefits are much larger than when no outside adoption is possible).

Davis *et al.* (1987) also used economic surplus models to estimate the distribution of benefits that would result from research that yielded a 5 per cent reduction in the cost of producing 12 major commodities. Their results indicated that between 64 per cent and 82 per cent of the total benefits of such research would accrue to producers and consumers outside the country financing the research.³ As with the Edwards and Freebairn study, differences in the spillover patterns among commodities were the result of differences in either the relative price elasticities of supply and demand or the size of the geographic area over which the research was assumed to be applicable.

Evenson (1977) used a production function model to measure the international spillovers that result from cereal grains research.⁴ His results indicated

that between 55 per cent and 69 per cent of the marginal benefits of cereal grains research conducted in developed countries accrue outside the country financing the research. Between 47 per cent and 82 per cent of the marginal benefits of cereal grains research conducted in developing countries accrue outside the country financing the research.

These results suggest that research benefit spillovers can be significant and that individual countries are unlikely to provide an internationally optimal level of investment in research. In such an environment of pervasive spillovers, institutional innovations are required if these positive externalities are to be internalized by national policy makers.

THE NEED FOR INSTITUTIONAL INNOVATIONS: SOME GUIDELINES FOR POLICY MAKERS

If an internationally optimal level of research investment is to be achieved, cost-sharing arrangements must be developed to coordinate research investments and compensate countries for the benefit spillovers they create. Public finance theory, combined with past empirical studies of research spillovers, provides several guidelines for designing these institutional innovations.

The share of the marginal cost of research paid by the international grantor should reflect the share of the marginal benefits of research that accrue outside the country in which the research is conducted

As indicated by equation (5), the international grantor should compensate the investing country according to the share of the research benefits that accrue outside its borders. This suggests that three factors would influence the share of the cost of research paid by the international grantor. First, the cost share paid by the international grantor will be greater when a greater share of the investing country's production is exported. Since a large share of research benefits accrues to consumers, research spillovers to foreign consumers will be greater when a larger share of the product is exported. Second, the cost share paid by the international grantor will be greater when the research is applicable by agricultural producers over a wider geographic area. When producers outside the investing country adopt the technology developed by research, benefits are created for both producers and consumers in the adopting countries (and perhaps for consumers in many countries if the commodity is exported by the adopting countries). Once again, benefits are spread beyond the borders of the investing country and a larger international investment is required. Third, basic research that is likely to provide widely dispersed benefits when it is adapted for use in a wide range of production regions, or that may enhance research in other areas of science, will also require the international grantor to bear a larger share of the cost of such research. While some observers have suggested that higher levels of government should finance basic research and lower levels of government should finance applied research (Idachaba, 1981, p. 106), it must be reiterated that public finance

theory suggests that both applied and basic research must be funded through a cost-sharing system if an optimal level of investment is to be achieved, since both exhibit significant spillovers. From a public finance perspective, the problem of financing an optimal level of investment is the same; the only difference in these two types of research is the share of the cost paid by the international grantor.

When research is partially funded by a sub-national level of government, a three-tier cost-sharing system should be used to finance research

Since research is often funded in part by sub-national governments, especially in geographically large nations, any institutional innovations could also require a three-tier cost-sharing system. Evenson and Kislev (1975) estimated that 29 per cent of the benefits of research conducted by state governments in India accrue to states other than the one in which the research was conducted. Similarly, empirical studies indicate that 33 per cent to 68 per cent of the benefits of research conducted by the state agricultural experiment stations in the United States accrue outside the state in which the research was conducted (Ruttan, 1982). To solve this spillover problem, matching grants could be provided to the states by both the national government and the international grantor. In a three-tier cost-sharing system, each level of government (state, national and international) would pay the share of the marginal cost of research that equals the share of the marginal benefits of research that accrue within its jurisdictional boundaries (Harford, 1977).⁵

Matching grants could be used as a means of building political support for research and strengthening research institutions in developing countries

Although the spillover problem exists for both developed and developing countries, matching grants can play a dual role in strengthening the national agricultural research systems of many developing countries. The first role is that of compensating the developing countries for the research spillovers they create. The spillover problem is especially burdensome in developing countries that face severe resource constraints and that cannot afford to finance research that provides significant benefits outside their borders (Ruttan, 1987b.). A matching grant system would be the most efficient means of internalizing the research spillovers created by these countries.

Some observers contend that the major problem faced by the agricultural research systems of many developing countries is the lack of a political constituency to provide long-term political support for agricultural research (Eicher, 1989, p. 37; Ruttan, 1987b, p.92). Thus the second role for matching grants would be that of building a national constituency in support of stronger national research systems in developing countries. The experience of developed countries (for example, Japan and the USA) indicates that a cost-sharing system can provide the needed incentive for a local constituency to develop and support agricultural research. This local constituency can then play a

major role in defining the research agenda and obtaining resources to support the research system (Ruttan, 1989, p.200; Pray 1988). Such a cost-sharing system would also provide greater funding stability than is currently available in many project-funding systems used by international donors (Ruttan, 1987a, 1987b, 1989; Trigo, 1987).

Institutional innovations are also needed to finance the international grantor's budget for research

Although this paper has focused on the policy options for allocating research resources, it has not considered the means of providing the resources to be used by the international grantor. Musgrave (1986) contends that a combination of direct consumer taxes and an *ad valorem* tax on cost payments would be the most equitable means of financing a public good that creates international spillovers and reduces all private costs equally. Such a tax would allocate the cost of the international granting agency according to the benefit principle (that is consumers and producers would pay for agricultural research according to the share of benefits accruing to each group). Given the lack of an international institutional structure for levying such taxes, the establishment of a resource base for the international grantor would be the most challenging problem faced by policy makers.

IS INTERNATIONAL COORDINATION OF RESEARCH INSTITUTIONS POSSIBLE?

Although the problem of financing agricultural research in the presence of research spillovers is widely recognized and the economic prescriptions for financing research are available, the task of establishing the necessary coordinating institutions is formidable. No institutions of the sort outlined above are available at the international level. The international research centres have had some success in spawning regional research programmes directed at the common problems of developing countries (Ruttan, 1987b), but these efforts do not provide an adequate level of research funding or a *coordinated system* for internalizing research externalities or financing research in the presence of benefit externalities. Similarly, research funding provided by foundations or national donors is likely to be episodic rather than a continuing, systematic means of internalizing research externalities and developing national and local support for research.

The first major problem in designing such institutions is the need to develop effective power-sharing arrangements that preserve national (or national and local) autonomy in establishing a research agenda and still maintain effective financial coordination of research. National policy makers, quite rightly, can be expected to protect their autonomy in establishing the research agenda. Because of the location-specific nature of agricultural production and the many unique ecosystems in agriculture, local autonomy in establishing the research agenda is necessary if users' problems are to be articulated to re-

search managers and political decision makers. At the same time, an international granting agency would demand accountability for any funds granted to national research institutions and must be able to articulate international research priorities that require attention at the national level. Some nations with multi-level systems of government have been able (with mixed success) to reconcile these tensions within their own research systems, but the prospects for political jealousy and opportunistic behaviour are escalated by an order of magnitude when the problem of international coordination is considered.

Second, we must recognize that no system of coordinating institutions can ever achieve more than a rough measure of equity in financing research. The problems of establishing reliable measures of research benefit spillovers are substantial and, under the best of circumstances, such estimates are likely to be highly sensitive to the assumptions underlying such analysis.⁶ Nevertheless, agricultural economists must continue to pursue this line of work if we are to make a meaningful contribution to the research policy debate and to the design and development of appropriate supporting institutions.

Finally, larger political obstacles must be overcome before the problem of international research will be placed on the policy agenda in many countries. The need to build local political support for research institutions is not yet appreciated by many policy makers, and domestic agricultural research – let alone international research coordination – is rarely viewed as a high priority. In addition, agricultural research must ultimately compete with many other public investment opportunities for funding. In some cases, these alternative investments may also require international coordination of benefit externalities, and efforts to coordinate these investments may have a higher priority than agricultural research investments.

CONCLUSION

The theoretical and empirical results presented in this paper indicate that the achievement of an optimal level of investment in agricultural research will not be possible unless significant investments are made in institutional innovations that internalize the international benefit spillovers created by research. These innovations must establish coordinated cost-sharing arrangements that provide appropriate incentives for financing research, while still maintaining national autonomy in establishing the research agenda based on the problems articulated by diverse local constituencies. Such a system may be the only means of promoting an efficient level of research investment, adapting research to local conditions and establishing the political base necessary for the long-run survival of research institutions.

The problems of international research coordination are likely to increase in importance for both developed and developing countries. Any reduction of trade barriers – through the GATT process, bilateral agreements or free trade areas – will increase the magnitude of research spillovers and heighten the need for coordination in financing research. At the same time, developing countries must establish stronger local constituencies in support of research and the means to overcome political boundaries that are inconsistent with the

geographic boundaries of research spillovers. Economists cannot by themselves cause the creation of international institutions to internalize spillovers, but they can help to avoid institutional misdirection and failure in the original design when and if such institutions are established. Equally importantly, economists can define and give visibility to the problem that politicians and others must understand before nations are likely to act on the problem of spillovers.

NOTES

¹This paper will refer to an 'international grantor' as the institution responsible for providing grants to the national government. No such institution exists at the present time. The final section of this paper will examine the form such an institution might take.

²The Hatch Act research funding system is a matching grant programme designed to compensate states in the USA for the benefit spillovers they create. The national government matches each state dollar spent on agricultural research with one national dollar for research (Knoblauch, *et al.*, 1962).

³The spillover shares (per cent) for the commodities were: rice (65), sugar (68), coconuts (72), groundnuts (73), maize (75), bananas and plantains (75), sweet potatoes (77), sorghum (77), pulses (79), sheep and goats (79), wheat (80), and potatoes (82).

⁴The production function approach uses regression methods to estimate the impact of changes in conventional inputs and public inputs (including research) on output. When specified to include research in other countries, estimates of research benefit spillovers can then be derived from the regression results.

⁵The Smith-Lever system is an example of a three tier cost-sharing system for financing agricultural extension services in the United States (that is, the cost is shared by national, state and county governments through a matching grant system).

⁶Consider, for example, Edwards and Freebairn's estimate (1984) that anywhere from 2 per cent to 98 per cent of the benefits of Australian wheat and wool research can accrue outside the country. This wide range of estimates arises from different assumptions about the elasticities of supply and demand and the applicability of such research to production in other countries.

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DISCUSSION OPENING – HSI HUANG CHEN*

Discussion of the problems of financing agricultural research in the presence of international benefit spillovers leads the authors to conclude that research and innovation must be based on coordinated cost-sharing arrangements which provide appropriate financial incentives. Although I want to qualify that conclusion I have no reason to argue with the basic logic of the paper. However,

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at a global level, my view is that some of the major themes could have an alternative interpretation.

Agriculture has become increasingly integrated into the national and world economy, and this redefines the context in which agricultural research is funded by national governments and international donors. We should distinguish between economic and financial profitability of research so that the investing country can weigh the real value of pursuing research. All too often, however, investing countries base their decisions on financial rather than economic analysis. We know that resource use in research responds to the benefits to be received and that national governments should be more concerned about research returns. In this context, the authors provide some very useful guidelines for designing institutional settings for research. These are of particular interest, given renewed emphasis on cost-sharing arrangements to co-ordinate activity and compensate countries for benefit spillovers.

However, the cost-sharing proposal is theoretically sound but practically weak. It is difficult to estimate benefit spillovers prior to research, or to give relative weights to the various parties who might be affected when the results are finally adopted. Yet it is precisely that flow of benefits which needs to be taken into account in assessing the extent to which cost sharing needs to occur. It is also important to emphasize that analysis needs a long-run focus, since there may be many feedback effects at work influencing the distributive impact of research. My view is that we know too little about techniques of measuring the returns to research, in the long run and at the global level, to make significant progress.

The other interesting issue raised in the paper relates to the key question of raising revenue to fund research, though it was covered only briefly in the section discussing Musgrave's proposal. This is an issue concerning the distinction between efficiency in research itself and its ultimate equity effect. We do not know how much would be raised by a combination of a tax on consumers and a charge on cost payments to impinge on producers, though my own guess is that a levy of only one per cent could yield a large revenue base. I have already remarked on the problems of estimating the magnitude of research benefits in an appropriate way. What I am emphasizing now is the equally important issue of creating an international fund to provide the means of fostering the supply of research effort.