Setting Research Priorities in the Public Sector: A Suggested Framework for the AARC Center

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Abstract. *An argument can be made for public support of pre-commercial research and development (R&D) when private industry, acting in response to market incentives, underinvests in socially desirable projects Research projects meeting this criterion must still compete for scarce public funds The Alternative Agriculture Research and Commercialization (AARC) Center was mandated by Congress to support pre-commercial R&D in new uses of agricultural commodities This article develops a three-phase scoring model to evaluate and prioritize AARC Center proposals*

Keywords. *pre-commercial R&D, market failure, AARC Center*

As budgets tighten in all levels of government, public agricultural research systems are being asked to do more with less The study of economics involves the assessment of alternative investments given scarce funds, so economists are well-suited to assist researchers with priority-setting methods and processes As Stuby (1991) observes, priority setting in general "is a legitimate part of positivistic, rationalistic science and management" He adds, however, that not all priority setting is rational or positivistic Generic, systemic problems must be resolved, including the difficulty of reducing complex issues to their elemental properties and of ordering multidimensional projects Multidimensionality is of particular concern in agricultural research given the unidimensional character of most priority-setting procedures This article examines these issues with respect to the newly established Alternative Agricultural Research and Commercialization (AARC) Center

The 1990 Farm Bill (title XVI, subtitle G) provides government support for "pre-commercial" development of nonfood and nonfeed uses of agricultural commodities The stated purpose of subtitle G is to help develop and produce marketable products other than food, feed, or traditional forest or fiber products, commercialize new nonfood, nonfeed uses of agricultural commodities, and direct research and commercialization efforts toward agricultural commodities that can be raised by family-sized agricultural producers (See appendix) Fulfillment of subtitle G is to be directed by the AARC Center

The Center may provide financial assistance in the form of loans, interest subsidy payments, venture capital, and repayable grants The AARC Center may also establish peer review committees with agricultural, scientific, technical, or other expertise, whose duties shall be to provide analysis and recommendations, on scientific, technological, and policy matters Thus, the legislation explicitly encourages the Center to review all prospective programs and projects Peer review is a necessary first step in preventing the AARC Center from adding to the widely publicized government "pork barrels" of the past (Cohen and Noll, 1991)

This article develops a three-phase scoring framework to help guide the peer review process for the AARC Center The first phase involves an initial screening of applications to ensure compliance with the basic program The principal investigators of those applications that meet the basic requirements are contacted for a more complete proposal in phase 2 Those proposals that are "recommended highly" or "recommended with comments" in phase 2 would be evaluated in phase 3 The highest ranked proposals in phase 3 are designated as semi-finalists and their ranking submitted to the Board Funding decisions would then be made by the Board

The evaluation criteria developed here borrows from methods used by various USDA organizations (Agricultural Research Service, Cooperative State Research Service, Cooperative State Research Service/Small Business Innovation Research Program, Economic Research Service, and Office of Energy), other Federal Government departments (Department of Commerce/Advanced Technology Program, Department of Commerce/Engineering Research Centers, and Department of Energy), State organizations (the Ben Franklin Partnerships in Pennsylvania and the North Carolina Experiment Station), and private industry (Archer Daniels Midland and Farmland Industries)

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An Economic Rationale for Government Support of Research and Development

The United States is a strong net exporter of technology, leading the world in the number of patents, licenses, fees, and other transactions As of 1989, the United States had a net surplus of $1 3 billion in its technological balance of payments (National Academy of Sciences, 1992) [1]

Yet, when it comes to manufacturing technologies, data suggest that U S firms may lag behind some foreign competitors in the rate of adoption and the intensity of utilization of new technologies Daniel F Burton, the executive vice president of the Council on Competitiveness, believes U S industrial policy often favors research and development over demonstration and adoption More specifically, Burton argues that U S industrial policy treats technology transfer as an incidental dividend of government research and development (R&D)[2], and not as the primary objective In contrast, German and Japanese policies are designed to promote the application and diffusion of new technology (National Academy of Sciences, 1992)

Public support of pre-commercial R&D in Japan and the European Community (EC) may be higher than in the United States For example, through efforts like the MITI and Key Technologies programs, Japan has promoted partnerships among business, universities, and government "downstream" from basic research Manufacturing extension services, capital subsidies, accelerated depreciation, and direct subsidies have been used to promote technology development and diffusion Similarly, the EC has promoted collaborative R&D under the Framework Program The Framework Program is scheduled to allocate $8 4 billion between 1990 and 1994

Nevertheless, not all collective research efforts in Japan and Europe, particularly those subsidized by the central government, have been successful Despite years of effort, Japan has failed to gain a major foothold in the U S -dominated pharmaceutical industry Similarly, Europe's heavily subsidized electronics industry has failed to close the gap with the United States Therefore, "heavy-handed industrial policy," where the government picks technological winners and losers, is not the answer (Cohen and Noll, 1991, National Academy of Sciences, 1992)

An argument can be made for public support of pre-commercial R&D when private industry, acting in response to market incentives, underinvests in socially desirable projects (e g , Alston, 1992, Arrow, 1962, Cohen and Noll, 1991) Private sector underinvestment can occur due to the following types of market failure

(1) Appropriability A firm cannot appropriate all of the benefits from its R&D investments because others can "free-ride" on the public goods produced as a result of its initial R&D,

(2) Externalities An individual's production or consumption activities affect another person's production or consumption and those impacts are not compensated through a market transaction,

(3) Public sector benefits The benefits of the R&D are localized in the public sector, and

(4) Risk aversion and financial market failures A firm may value near-term payoffs more highly than society, thus leading to an underinvestment in activities that take a relatively long time to pay off, and/or a firm may be overly risk averse as compared with the best interests of society

Appropriability

Appropriability becomes an issue when R&D involves the promise of useful new knowledge that is generic, with wide applications across economic activities Generally, private goods can be sold commercially and the benefits from their sale are captured by those who own the associated property rights or patents In agriculture, this includes

[1]Sources are listed in the references section at the end of this article

[2]R&D in this paper refers primarily to commercial projects There are generally four stages in commercial R&D (Cohen and Noll 1991)

RESEARCH The first stage determines whether the basic ideas are technically sound This exploratory research either "expands the base of fundamental knowledge or applies the existing base to some new set of problems,"

DEVELOPMENT The second stage consists of "designing, building, and testing components and even small-scale versions of new technology" These types of activities are built on a firmer scientific base than research, and so the uncertainty is usually less,

DEMONSTRATION This category refers to "the construction of an operating example of the new technology to prove its technical and commercial feasibility" Demonstration projects are usually the most expensive and they are unlikely to be attempted unless the uncertainties surrounding its performance are considerably less than those associated with the previous two stages, and

ADOPTION The fourth category is when a private and/or public organization use the new technology hybrid seeds, which must be purchased each time a crop is planted However, even the patent system is often ineffective in protecting property rights over information (Hay and Morris, 1979)

Nonetheless, appropriability is most often an issue with collective goods By definition, collective goods do not lend themselves to profitable merchandising, even though there may be significant gains to society Agricultural examples of collective goods include improved self-pollinated plants such as any new variety of wheat that, once released and sown, can be retained and used as seed for planting in subsequent years Because private firms cannot capture all the benefits of producing collective goods, neither a socially optimal level of R&D nor a socially optimal amount of the goods will be produced

Government support of R&D in collective goods in agriculture is extensive In wheat, this includes basic research in seed genetics, applied research in the production of better varieties, demonstration projects to examine production in different climates, and adoption information provided by the agricultural extension service

The problem of market failure is likely to be smaller for relatively applied/pre-commercial R&D than for basic R&D (Evenson and Huffman, 1989), however, pre-commercial R&D can exhibit appropriability problems (National Academy of Sciences, 1992) For example, "learning by doing" and other forms of imitation may drive the price of a product down, perhaps leaving an operating margin insufficient to recover the costs of the original R&D (Cohen and Noll, 1991, Frisvold, 1991) Additionally, much of the benefit of R&D is often passed on to customers and does not enter into the profitability calculation of the firm (Mansfield, 1980, Scherer, 1982) For these reasons, neoclassical economic theory does not weaken the case for Federal support of pre-commercial R&D, but it does require evidence of appropriability problems or some other form of market failure (Alston, 1992)

Externalities

Firms may also underinvest in pre-commercial R&D due to an environmental externality The crucial feature of an externality is that there are goods or services that people care about which are not sold in markets (Varian, 1987, Baumol and Oates, 1988) For instance, there is no market for pesticide leachate, nor is there a market for environmentally sound farming practices It is this lack of a definable market that requires government action

In the case of a negative externality, the price system works too well (Kneese and Shultzie, 1975) Profit-motivated firms produce to that point where their marginal costs of production (private marginal costs) intersect demand With a negative externality, private marginal costs do not incorporate all of the consumer costs associated with the disposal and use of a particular product (that is, social marginal costs) As a result, private marginal costs are less than social marginal costs, leading to overproduction from a societal perspective In turn, this overproduction generates a deadweight welfare loss for society

From an economic standpoint, the goal of regulation is to raise private marginal costs so they equal social marginal costs In a world of perfect information, regulators could use almost any policy tool to ensure this outcome Often, in reality, the best that can be done is to achieve a politically determined level of environmental quality at the least cost (Anderson, 1977) This objective can be reached with environmental taxes Alternatively, if policy-makers are reluctant to increase taxes, government support of R&D may prevent an environmental externality from acting as a barrier to entry for products that are more "environmentally friendly"

For illustrative purposes, consider biodegradable plastics Between 1960 and 1990 annual growth in plastic production averaged 10 percent, far greater than the annual growth in the overall economy (EPA, 1990) Unfortunately, increased plastic use has also resulted in increased plastic wastes In a 1990 report, EPA was primarily concerned with the impact of plastic waste on solid waste management and on the marine environment Plastics currently account for approximately 8 percent by weight and 20 percent by volume of the municipal solid waste stream (National Technical Information Center, 1992)

In addition, plastic waste in the marine environment often poses risks to marine life, human life, and aesthetic appearance The Marpol Treaty, signed in 1987 by 29 countries including the United States, prohibits the discharge of all plastic wastes at sea beginning in 1988 for commercial vessels and in 1994 for government ships In an effort to adhere to the treaty, the U S Army—in conjunction with the USDA and private companies—has implemented a large-scale effort to develop biodegradable polymers to replace petroleum-based plastics for all food uses

Many of these polymers are being made from corn, wheat, and potato starch The advantage of starch-based polymers is that they are fully degradable, but their cost is generally greater than the cost of petroleum-based plastics (U S Army/USDA, 1992) For that reason, there is little incentive for firms to manufacture starch-based polymers However, if the social marginal cost of starch-based polymers were lower than the social marginal cost of petroleum-based plastics, then the Government could improve resource allocation by subsidizing the production of starch-based polymers or taxing the production of petroleum-based plastics Alternatively, the Government may prefer to support R&D to reduce the private costs of starch-based polymer production

Public Sector Benefits

Firms may underinvest in pre-commercial R&D because the benefits are localized in the public sector A technological breakthrough in the production, for example, of starch-based polymers would increase market demand for corn or wheat and reduce program payments with a minimal, yet, positive effect on total farm income (Leblanc and Reilly, 1988, Beach and Price, 1993)

Consider the generic commodity program shown in fig 1 Initially, the target price is set at F, output is q, and government payments equal area FACP Next, suppose there is a technological breakthrough in the production of starch-based polymers This would shift the demand for program crops from D to D' In this case, the demand shift has no effect on output, but it does reduce government payments to FABP' Because total returns to producers are unchanged, farmers have little incentive to fund this type of demand-creating research (Frisvold, 1991) In comparison, the Government has a significant incentive, since demand-creating R&D would reduce the costs of farm income support programs

Similarly, innovations in the use and development of new crops, which are economically viable alternatives to program crops, could also reduce the costs of farm income support programs Consider the effect of a new crop on the commodity program shown in fig 2 As in fig 1, the initial target price is set at F, output is q, and government payments equal area FACP The development of economically viable new crops which compete for program acres, excluding those acres in the conservation reserve program, would shift the supply curve for wheat or corn from S to S' In this case, the quantity produced of program crops decreases from q to q', reducing government payments to FGHP'

Risk Aversion and Financial Market Failures

Private firms may underinvest in pre-commercial R&D because the private discount rate may be too high relative to the social discount rate, leading to an underinvestment in activities that take a relatively long time to pay off A related argument is that risk-averse firms may reduce R&D below the optimum social level (Arrow, 1962) This may happen because firms cannot transfer all of their R&D risks to shareholders, or because shareholders may not be persuaded to buy additional shares, or because all the incentives to the firm would be removed if all risks were shifted to

Figure 1

A Generic Farm Commodity Program

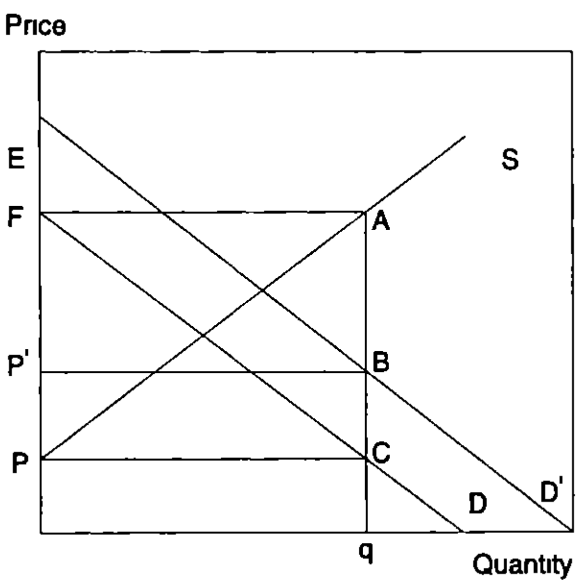
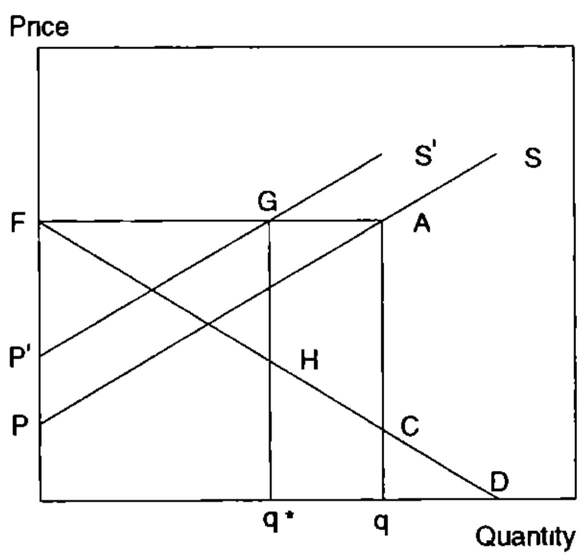


Figure 2

Introduction of a New Crop Given a Generic Farm Program



shareholders—that is, moral hazard While the effect of risk in R&D investment is mitigated by a firm's ability to finance investments out of retained earnings, the extent of the risk effect is an empirical consideration Neither of these reasons have been substantiated empirically

Furthermore, U S government policies tend to support investments with high short-term payoffs relative to the economies of Japan and Germany (Harrison, 1992) Some argue that the problem of "short-termism" in the United States is a result of too little government support, whereas others argue that the problem is too much government intervention (anonymous, 1992) Regardless, both sides agree that short-termism cannot be averted by letting the government pick technological winners and losers

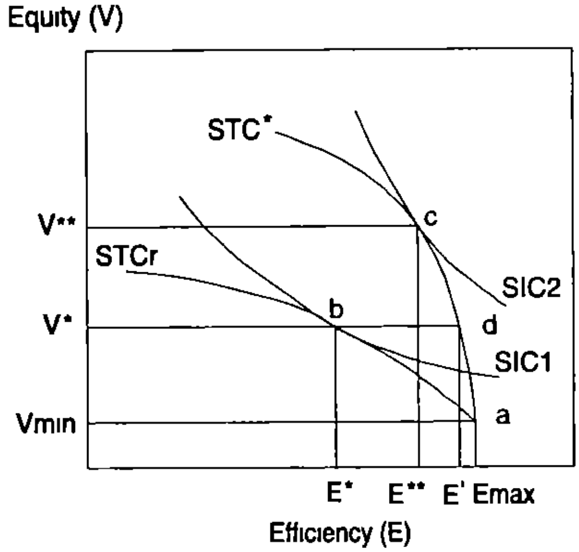
Setting Research Priority

In the economics literature, substantial progress has been made in analyzing the *ex post* benefits of R&D However, more work needs to be done to develop a logical, comprehensive system to evaluate the *ex ante* benefits from R&D Norton, Pardey, and Alston (1992) believe that three issues have proven particularly troublesome in *ex ante* priority setting specifying the weights given multiple objectives, measuring research performance against those objectives, and combining the weights with measures of performance

The desire to prioritize all research programs, even when their impacts are difficult to quantify, often leads to a simple weighting across rankings of crude indicators As a result, program directors, policymakers, and the like are frequently confronted with a set of multiple and poorly identified objectives This makes it difficult to derive rigorous performance measures, and hence place weights on the indicators at hand In addition, economists have not solved many of the measurement problems, and many of the solutions they have suggested are data- and time-intensive Perhaps a more fundamental problem is that the comparative advantage of sponsored research relative to other policy instruments has not been examined, nor have economists examined the possibility of combining sponsored research with some other policy instrument to enhance social, economic, and other societal objectives

In figure 3 we consider some of these tradeoffs The economics literature has traditionally used a social welfare function (SWF) to specify preferences among multiple social objectives Fig 3 examines the simplest case of multiple objectives—the case of two objectives Following Norton,

Figure 3
Economic Efficiency with Two Social Objectives



Pardey, and Alston (1992) we examine the tradeoff between economic efficiency (E) and equity (V)

Let curve STCr represent the best possible combinations of economic efficiency and equity that can be achieved by varying the mix of a research portfolio only If the research portfolio were chosen to maximize economic efficiency (Emax) then point (a) would be the result Next, let curve SIC1 represent policymakers' willingness to substitute equity for economic efficiency The highest level of social welfare through changes in the research portfolio, given policymakers' willingness to substitute equity for efficiency, occurs at (b) where SIC1 is tangent to STCr

Last, let STC* represent those combinations of economic efficiency and equity that are possible by adding a second policy instrument, such as a tax, to the mix of the research portfolio In this case the optimal outcome is point (c) where the production frontier STC* is tangent to the relevant indifference curve SIC2 Clearly, (c) represents higher levels of both equity (V**) and efficiency (E**), than point (b) This occurs because the research-policy approach combines research and nonresearch instruments in a more efficient way than pursuing the equity objective through research alone

It is possible to reach STC* with a smaller loss in economic efficiency, yet retain the efficiency level of the research approach (V*) Point (d) represents an intermediate solution between the free market outcome (a) and the combined research/tax program outcome (c) The efficiency loss from the combined program is (E**), and it is (Emax - E') at point (d) This gives a net gain in efficiency of (E' - E**), with a loss in equity of (V** - V*)

Fig 3 demonstrates the need for economic analysis in identifying the tradeoffs involved in using research policy as an instrument of social policy While economics alone cannot indicate the least-cost way of achieving non-efficiency objectives, evaluating past investments, assessing alternatives, and setting priorities for future investments are economic problems Therefore, economists must work with those scientists and engineers doing pre-commercial R&D to help insure the most efficient use of our limited resources (Alston, 1992)

Scoring Models

Multiple and poorly identified objectives, measurement errors, and other associated problems can hamper policymakers' search for practical evaluation procedures For that reason, peer review systems can be a cost-effective alternative to the overly quantitative priority-setting procedures suggested by some economists Peer review systems are especially attractive in evaluating different projects and determining their contribution to the overall program

Scoring models are often used to organize peer review discussions, reduce subjectivity, and bring the objectives of the program to the forefront Strengths of scoring models include (Shumway, 1973, Shumway and McCracken, 1975)

- a basic simplicity and favorable error characteristics (in a statistical sense) as compared to other more sophisticated decision models,
- the identification of a small number of criteria which, when properly related, will help evaluators choose between alternative projects,
- the development of a discrete scale for each criterion with sufficient range for all relevant alternatives and only enough intervals to discriminate between those that differ significantly,
- the formation of a set of both qualitative and quantitative criteria provided that each is independent of the others,
- the incorporation of decision criteria to reject automatically, or segregate for separate evaluation, a project which falls outside the acceptable range, and
- the relative score of each criterion can double as an information system, thus permitting evaluators to identify areas of relative weakness and encouraging researchers to consider alternative approaches

On the other hand, scoring models are not very useful in determining the distributional effect of "aggregate research" Scoring models are also unable to quantify public sector/private sector interaction and spillover effects Lastly, scoring models do not provide estimates of the marginal rate and average rate of returns to research (Norton and Davis, 1981) Nevertheless, under a program like the AARC Center, a scoring model may be the most cost efficient approach to evaluate project proposals [3]

Traditional Economic Welfare Analysis

As suggested above, a scoring model is ill-prepared to answer the more difficult question of the likely effect of pre-commercial R&D on the size and distribution of national income From a theoretical perspective, the positive economic aspects of this question can be addressed by using economic welfare analysis As suggested by Harberger (1971, p 785), there are three basic postulates that should be accepted as providing a conventional framework for welfare analysis

(1) the competitive demand price for a given unit measures the value of that unit to the demander,

(2) the competitive supply price for a given unit measures the value of that unit to the supplier, and

(3) the net benefits or costs of a given project, program, or policy accruing to each affected individual should be added without regard to that individual's economic or social status

For example, consider the effect of a technological breakthrough in the use of agricultural products as materials in manufacturing Given the initial demand and supply curves, total surplus can be measured as the sum of consumer and producer surplus (Harberger, 1971) A breakthrough in the use of agricultural materials in manufacturing would shift the demand for agricultural products

[3]Scoring models can incorporate efficiency criteria by including factors related to both the execution of a research project and the selection of a project mix In fact these factors should be included because, as Cohen and Noll (1991) observe, "whatever the objectives of the decisionmakers are, efficiency is almost always going to be a useful instrument for achieving them "

outward As a result, producers would necessarily gain because they would sell more goods at a higher price In comparison, the net welfare effect on consumers may be positive or negative depending on the elasticity of supply and demand, and on the nature of the research-induced demand shift

Because many of the projects being considered by the AARC Center involve new markets or at least new market niches for existing products, the data necessary to make economic surplus calculations are not available [4] Therefore, as mentioned above, a scoring model may be the most cost efficient approach to evaluate project proposals for the Center Still, it is misleading to cast scoring methods as an alternative to economic surplus (Norton, Pardey, and Alston, 1992) Clearly, economic welfare is one of their most (if not the most) important objectives The bottom line is that when economic surplus measures are available they should be incorporated as data in any scoring method procedure In contrast, when economic surplus measures are not available, then one should recognize that economic surplus is implicit in all scoring approaches For that reason, scoring models should not be regarded as an alternative to economic surplus, but, rather, scoring models complement more complex evaluation procedures based on *ex ante* estimates of economic surplus

Review of Selected Research Programs with Similar Objectives

If programs were economically rational and designed with a single objective, then from an economic standpoint, the only data needed to evaluate a particular set of projects would be measures of

- the size of the relevant market,
- the percentage shift of supply or demand,
- the probability of success,
- the time path of adoption of results,
- the time path of costs, and
- the discount rate (Alston, 1992)

None of the programs reviewed here has a single, simple objective

The biofuels program at USDA's Office of Energy (OE) is quite close The stated goal of the biofuels program is to develop technologies to produce commercially competitive liquid fuels from biomass as an alternative to petroleum based fuels This single goal with closely related objectives allows OE to use a simple formula to rank alternative projects

$$Net\ ranking = P * NB * e^{-rt}$$

where P is the probability of success, NB is the total net benefit discounted to the first year of commercial operation, t is the number of years to adoption, and r is the discount rate (Kuhn and Rendleman, 1992) This equation can also be used to obtain an ordinal ranking of projects, rather than a cardinal ranking It is particularly useful to compare tradeoffs However, when multiple objectives are specified, as in the AARC legislation, using simple formulas to rank proposals is often misleading

The Advanced Technology Program (ATP) is a new effort, administered by the National Institute of Standards and Technology of the Department of Commerce and designed to assist businesses in carrying out research and development of precompetitive, generic technologies Like the AARC Center, the ATP faces multiple objectives in a complex dynamic environment To circumvent many of the difficulties associated with multiple objectives, the ATP uses a peer review system based upon a multi-stage scoring method to evaluate and select projects to fund The evaluation criteria and sub-criteria are shown in table 1

Under the ATP, the Department of Commerce has stated a bias for projects with high risk and potentially high payoffs They are able to take these risks given a comparatively large budget Since 1990, 38 projects were funded at over $100 million (Technology Access Report, 1992) Also, legislation was introduced last year to elevate funding for the ATP to a total of $1 4 billion for 1994-1998 In comparison, a $4 million annual budget and a goal to be self-funding prevents the AARC Center from financing too many high-risk projects

An alternative evaluation scheme proposed by Fernandez-Cornejo is closer to the economic fundamentals necessary for the AARC Center to be self-sufficient (See table 2) [5] This scheme promotes a diversified portfolio of projects by limiting the size of each project to less than 25 percent of the total budget This method also emphasizes the need to avoid duplication and capitalize on each partici-

[4]As a reviewer observed, traditional welfare analysis may not be very helpful given the dynamic nature of technical change and the deviations from perfect competition (Nelson, 1982) created by the patent system and exclusive licensing agreements between public and private agents

[5]The evaluation procedure written by Fernandez-Cornejo was submitted as a proposal to the Research and Technology Division of the Economic Research Service and does not represent USDA official policy or views

Table 1—ATP Evaluation Criteria

Criteria	Sub-Criteria
Scientific and Technical Merit	• Quality and degree of innovation of the proposed technical program • Appropriateness of the technical risk and feasibility of the project • Coherency of technical plan and clarity of vision of technical objectives • Adequacy of systems-integration and multi-disciplinary planning including integration of appropriate downstream or upstream production, manufacturing, quality assurance, and customer service requirements
Potential Broad-based Benefits	• Potential broad impact on U S technology and knowledge base • Potential to improve U S economic growth and the productivity of a broad spectrum of industrial sectors or business • Timeliness of the proposal (i e , the potential project results will not occur too late to be competitively useful)
Technology Transfer Benefits	• Evidence that if the project is successful, the participants will pursue further development of the technology toward commercial application • Project plan adequately addresses technology transfer requirements to assure prompt and widespread use and protection of results by participants and as appropriate, other U S business
Experience and Qualifications	• Adequacy of staffing, facilities, equipment, and other resources to accomplish the proposed program objectives • Quality and appropriateness of the full-time technical staff to carry out the proposed work program and to identify and overcome technical barriers to meeting project objectives
Level of Commitment and Organizational Structure	• Level of commitment as demonstrated by contribution of personnel, equipment, facilities, and matching funds • Evidence of strong commitment to complete and, if appropriate, provide support for continuation beyond the period of federal funding • Potential return to the U S government

pant's comparative advantage With tighter budgets at all levels of government, public agricultural research systems must avoid duplication whenever possible and ensure that a proposed project, if worthwhile, cannot be more efficiently carried out in other parts of government Lastly, by multiplying the scores of each factor together, this method achieves balance among criteria and reinforces the argument that one criterion is of little value unless accompanied by relatively high scores on all other criteria[6] However, for this method to be useful for the AARC Center it needs a more specific technical evaluation

The Technical Advisory Committee to the Consultative Group for International Agricultural Research (CGIAR) proposed a modified scoring method to allocate the $250 million CGIAR annually provides to support agricultural research relevant to developing countries TAC's scoring method uses a spreadsheet format to force relative adjustments across priorities The economic logic of the approach is that, other things equal, the greatest returns to research should result from allocating resources to those commodities of highest value Nevertheless, as mentioned above, economic efficiency criteria may not reflect concerns about income distribution, equity, externalities, long-run resource degradation, and other similar concerns To overcome these problems TAC suggested a modified baseline in which the value of production and the number of poor and usable land areas were equally weighted and indexed In TAC's view the composite baseline represents a better beginning point for its analysis given CGIAR's mission (McCalla and Ryan, 1992)

The advantages of the spreadsheet scoring model are its transparency to both scientists and decisionmakers and its structure, which allow multiple decision variables to be accommodated The disadvantages include a difficulty in arriving at a consistent pattern of research at disaggregated levels and an untractable system when resource constraints are introduced Additionally, TAC's spreadsheet model is extremely sensitive to changes in the selected weights (McCalla and Ryan, 1992)

The Proposed Method to Evaluate AARC Center Proposals

As stated earlier, the legislation establishing the AARC Center provides a peer review process, to

[6]Our multiplicative scoring model is consistent with an underlying multiplicative research production function (such as the Cobb Douglas or translog functions) However given the subjectiveness of each factor considered (inputs in the research production function) it was decided to use a simple weighing procedure with no interaction terms

Table 2—Evaluation of Cooperative Agreements

Factor	Value
Contribution of project objectives to Agency's mission	0,1,2,3,4,5 (low - high)
Contribution of methodology to achieve project objectives	0,1,2,3,4,5 (low - high)
Likelihood that methodology will be carried out as planned	Continuous variable ranging from 0 (unlikely - data will not support methodology, model is not well grounded, research is totally unknown) - to 1 (certain - data is available and will support methodology, model is well grounded, researcher is well known)
Overlap, duplication, complementarities with other projects	0 duplicates other projects 1 moderate overlap 2 small overlap 3 no overlap 4 small complementarities with other projects 5 important complementarities with other projects
Cooperative venture or is agency financing the project	Continuous variable ranging from 0 (agency solely financing) to 1 (cooperative venture, clearly specified in the proposal)
Comparative advantage	0 agency has a large comparative advantage 1 agency has a moderate comparative advantage 2 cooperator and agency have similar comparative advantage 3 cooperator has a moderate comparative advantage 4 Cooperator has a large comparative advantage
Cost	0 budget is over 25% of total allotment for all agency projects 1 cost seems too high/low 2 cost seems right

help ensure the technical, scientific, and economic feasibility of each funded project and to help insure that the best interests of society are duly represented From an economic perspective, the peer review process needs to establish that

1) each funded project meets a minimum level of technical or scientific merit, and
2) each funded project demonstrates that the private sector, acting in response to market incentives, would underinvest in the research, development, and/or commercialization of the project

Recall that private sector underinvestment, from a national viewpoint, can occur due to (a) appropriability problems, (b) externalities, (c) benefits which are localized in the public sector, and (d) financial market/risk considerations Because there is mixed theoretical and empirical support for (d), we encourage the AARC Center to give priority to those proposals which fall in one or more of the first three categories

We propose a three-phase scoring method designed to help guide the evaluation of proposals submitted to the AARC Center The first phase involves an initial screening of pre-proposals to insure compliance with the basic program[7] The principal investigators of those pre-proposals which meet the basic requirements, as set up in the request for pre-proposals, are asked to prepare a more complete proposal in phase 2

In phase 2, experts would evaluate each proposal for scientific/technical merit and for evidence of private-sector underinvestment Review panelists (Panel I) would be selected from among recognized specialists who are uniquely qualified by training and experience in their fields Panel I would be comprised of experts from universities, government, and nonprofit research organizations

Each member of Panel I would review in depth at least three proposals Each proposal would be reviewed by three reviewers and scored according to the four categories and nine criteria listed in table 3 The score provides a relative ranking among projects and enables panel members to decide which rating fits the project The total score is obtained by calculating the geometric sum of the scores of all nine criteria Thus, a balance between criteria is established In addition, the method

[7]In the future, Phase 1 could also include a screen to divide the projects by subject and by size of request This can be used to promote diversity and reduce the risk of funding only large/small projects or the risks of funding projects in one subject area

Table 3—Phase 2 Evaluation Criteria

Technical Review Criteria	Description	Score
A Assessment of Technology		
Scientific and Technical Merit	• Quality and degree of innovation of the proposed technical program • Coherency of technical plan and clarity of vision of technical objectives	3 high merit 2 intermediate merit 1 low merit 0 no merit
Adequacy of Approach and Excellence of Research Procedure	• Research plan is scientifically feasible • Proposed methods and equipment are appropriate and sufficient to accomplish the objectives	3 highly adequate 2 adequate 1 slightly adequate 0 inadequate
Overlap, duplication, complementarities with other projects	• Proposed research does not substantially duplicate any ongoing or previous research but rather is complementary to other research • Proposed research would enhance benefits of total portfolio	5 important complementaries 4 small complementarities 3 no overlap 2 small overlap 1 moderate overlap 0 complete overlap
B Assessment of Project		
Capability of Key Personnel	• Identified personnel have the necessary background and skills to successfully complete the project	3 highly capable 2 capable 1 questionable capabilities 0 incapable
Project Design	• Project has been conceived and organized in a manner appropriate for achieving the desired results	3 excellent design 2 good design 1 adequate design 0 poor design
C Evidence of Market Failure	• Private firms cannot appropriate all the benefits of R&D • Evidence of externalities • R&D benefits are localized in the public sector	1 evidence of market failure 0 no evidence of market failure
D Feasibility and Efficiency		
Probability of Success	• Objectives can be accomplished • High Probability of success in light of past accomplishments and performance	3 high probability 2 intermediate probability 1 low probability 0 zero probability
Efficiency of execution	• Project is likely to be executed efficiently, within the stated time period and budget	1 efficiently executed 0 5 medium efficiency 0 inefficiently executed
Comparative Advantage	• Principal Investigator (PI) has a comparative advantage in carrying out the pre-commercial R&D • Proposed R&D is not likely to be completed as successfully and efficiently at a USDA research facility	4 PI clear comparative advantage (ca) 3 PI moderate ca 2 PI and USDA similar ca 1 USDA moderate ca 0 USDA clear ca
Cost	• Project promotes a diversified portfolio of AARC funded activities	2 cost seems right 1 cost seems too high/low 0 budget is over 25% of total budget for all projects

reinforces the assumption that a high score on any one criterion is of little value unless it is accompanied by relatively high scores on all other criteria (See footnote 2) The score sheet also provides additional information on areas of relative strength and weakness of each project

Next, each member of Panel I would lead a discussion of one proposal to the rest of the panel The other two panel members who have read the proposal would be asked to support or challenge the statements of the lead reviewer Each panel member would write an evaluation of the proposals he/she has read The lead reviewer would write a summary of the discussion that led to the rating by the full panel Projects would be rated by a consensus of the full panel, as

- recommended highly,
- recommended with comments the project will be approved after some identified changes,
- recommended conditionally the project has met some but not all of the criteria, leaving some serious deficiencies which must be corrected before approval can be granted, or
- rejected

Panel II should be comprised of reviewers with expertise in business planning, finance, and technology transfer The makeup of Panel II should be similar to the AARC Board

Only those principal investigators with proposals that were "recommended highly" or "recommended" in phase 2 should be evaluated in phase 3 Each member of Panel II would read all proposals and review in depth at least three proposals As in phase 2, each member would discuss in depth at least one proposal in front of the full panel, while the other two panel members who have scored the proposal are asked to support or challenge the statements of the lead reviewer The lead reviewer would summarize the discussion of the full panel

Phase 3 criteria are displayed in table 4 The highest ranked proposals from phase 3 would be designated as semifinalists and their ranking would be submitted to the board

Last, the principal investigators from those institutions which are designated as semifinalists in phase 3 would then be asked to make an oral presentation to the Board Because all the pro-

Table 4—Phase 3 Evaluation Criteria

Criteria	Description	Score
A Economic Impact		
Market/Market Share	• Product/service has the potential to significantly affect the market • Product/service can gain a significant market share	3 high market impact 2 intermediate market impact 1 low market impact 0 no market impact
Commercialization Plan	• Timeliness of the proposal (i e , the potential project results will not occur too late to be competitively useful) • Project plan is adequate to transfer technology from the laboratory to the plant floor or marketplace • Project adequately addresses technology transfer requirements to assure prompt and widespread use	3 excellent plan 2 good plan 1 poor plan 0 inadequate plan
Job Creation	• If successful, the project will create a significant number of geographically dispersed jobs (direct and indirect), relative to the project estimated revenues	1 significant creation 0 5 small creation 0 negligible creation
B Level of Commitment		
Evidence of Commitment	• Evidence of strong commitment to complete and, if appropriate, provide support for continuation beyond the period of federal funding	3 strong evidence 2 evidence 1 little evidence 0 no evidence
Project Budget and Level of Private Sector Funding	• Level of commitment as demonstrated by contribution of personnel, equipment, facilities, and matching funds • Overall financial support is appropriate for the tasks presented and demonstrates an understanding of the issues and problems likely to be encountered • Proposal shows an awareness of anticipated financing needed to bring the product to market	2 adequate funding 1 moderate funding 0 inadequate funding
Management	• Appropriate management structure is identified to facilitate business growth	3 excellent structure 2 good structure 1 poor structure 0 inadequate structure

posals that are designated as "semifinalists" in phase 3 meet all technical and economic criteria, the final decision would be based upon

- the availability of funds, and
- an appropriate distribution of funds among technologies and their applications (this will insure a diversified portfolio of funded projects)

Conclusion

An argument can be made for government support of research and development (R&D) when private industry, acting in response to market incentives, underinvests in socially desirable projects Private sector underinvestment, from a national viewpoint, can occur due to appropriability problems, externalities, benefits localized in the public sector, and financial market/risk considerations

The AARC Center was mandated by Congress to support pre-commercial R&D in new industrial uses of agricultural commodities To help ensure success, Congress also provided for a peer review process to evaluate AARC Center proposals In turn, peer review needs to establish that (a) each funded project meets a minimum level of technical/scientific merit, and (b) each funded project is based on evidence that the private sector, acting in response to market incentives, would underinvest in the research, development, and commercialization of projects that are socially desirable

Scoring models are often used to organize peer review discussions and bring the objectives of the program to the forefront This paper develops a three-phase scoring model to evaluate the proposals for the AARC Center The first phase involves an initial screening of pre-proposals to ensure compliance with the basic program Those pre-proposals that met the basic requirements are contacted for a more complete proposal in phase 2 In phase 2 scientific, technical, and economic experts (Panel I) would evaluate each proposal for scientific/technical merit and for evidence of private-sector underinvestment Only those pre-proposals that are "recommended highly" or "recommended with comments" would be evaluated in Phase 3

Phase 3 reviewers (Panel II) should have a demonstrated expertise in business planning, finance, and/or technology transfer The highest ranked proposals in Phase 3 are designated as semifinalists and their ranking submitted to the Board The principal investigators of those proposals would then be asked to make an oral presentation to the AARC Board Funding decisions would then be made by the Board

Appendix: The Alternative Agricultural Research Center

Title XVI, subtitle G, of the 1990 Farm Bill provides government support for the AARC Center The stated purpose of the AARC is

- to develop and produce marketable products other than food, feed, or traditional forest or fiber products,
- to commercialize new nonfood, nonfeed, uses , and
- to direct research and commercialization efforts toward agricultural commodities that can be raised by family-sized agricultural producers

The AARC Center is led by a Board of nine members, appointed by the Secretary of Agriculture The Board consists of one USDA representative, one leading scientist, a producer of agricultural commodities, a person engaged in the commercialization of an industrial product from an agricultural material, two nominations by the Director of the National Science Foundation of persons with expertise in processing and/or applied research relating to the commercialization of industrial products from agricultural materials, and two nominations by the Secretary of Commerce of persons who have demonstrated expertise in financial and management matters [8] The AARC Board's responsibilities include

- establishing policy and program direction,
- determining high priority areas to receive assistance,
- issuing requests for proposals, and
- making final decisions on whether and how to provide financial assistance (AARC Center Program Pamphlet)

The AARC Center may provide financial assistance in the form of loans, interest subsidy payments, venture capital, and repayable grants that are

[8] Issues such as trade-offs in the composition of the Board, i e , the value of having the industry's input and experience versus the cost of having a possible shift in the direction of research as discussed by Ulrich, Furtan, and Schmitz (1986) are beyond the scope of this paper

matched by private or local public funds The AARC Board may also

"establish one or more temporary committees with agricultural, scientific, technical, or other expertise, whose duties shall be to provide information, analysis, and recommendations, on scientific, technological, policy, and other matters (section 1658, subtitle G of section XVI of the 1990 Farm Bill)

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