3 Linkages Among Measurable Criteria and Sensitivity Analysis for Research Priority Setting: Learning from the Experiences of ICRISAT

Cynthia S. Bantilan
International Crops Research Institute for the Semi-Arid Tropics,
Patancheru, India

1. Introduction

The research priority-setting exercise conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in the early 1990s was driven by a determination to build an objective and transparent basis for its medium term plan (MTP) for 1994-1998 (ICRISAT, 1992). Like other members of the Consultative Group on International Agricultural Research (CGIAR), it faced the challenge of a changing external environment where funds for research were declining, and therefore, a pursuit of a focused research agenda was imperative. This change motivated stronger accountability and a search for an objective research priority setting and resource allocation process. Significantly, it prompted awareness among scientists and research managers about the impact and payoff of research.

The ICRISAT developed a structured priority-setting strategy which aimed at reflecting its multiple research objectives. The determination of the priority research portfolio was built on an analytical priority-setting methodology where a composite index is derived from a set of measures established for each of the following criteria: economic efficiency or total welfare gain, equity or distribution of the total welfare gain, sustainability and internationality.

This paper first discusses the priority-setting criteria and their linkages. This is followed by a discussion on database development and prioritised research portfolio. The strengths and weaknesses of database are examined by assessing consistency in parameters used for priority setting across research programmes. The next section demonstrates usefulness of impact assessment data in priority-setting analysis. The paper finally summarises important implications for future research priority-setting framework.

2. Objectives and Measurable Criteria

The CGIAR mission statement reads: "Through international and related activities, and in partnership with national research systems, to contribute to sustainable improvements in ways that enhance nutrition and wellbeing, especially for low income people" (TAG Secretariat, 1992). This mission statement defines mandate of the CGIAR institutions. ICRISAT's geographic regional mandate is the semi-arid tropics, where the world's poorest and hungriest people live. The global crop mandate includes six food crops-sorghum, pearl millet, finger millet, groundnut, pigeonpea and chickpea-mainly grown by poor people in a harsh and undependable environment of the world.

The above mandate of the ICRISAT may be translated into a set of objectives which may be used as a set of criteria for priority setting, namely, improvement in economic welfare, equity, internationality and sustainability. The measurements used for each criterion (Kelly et a/., 1995 and Bantilan, 1994) are discussed below.

Welfare gains: Two measures are commonly used in the estimation of welfare gains from research. The first measure is to estimate the value of expected change in output due to research. The second measure is to estimate research benefits and their distributional consequences by applying the principle of economic surplus. Both the approaches use basic concepts of demand and supply to represent the production and consumption environment, but substantial differences may occur between these measures. Under uncertain demand and supply conditions, the first measure may substantially overestimate research benefits. Therefore, a good understanding of underlying production and consumption environments is important in choosing the appropriate measure and in interpreting the estimates (Davis and Turnbull, 1992).

In the ICRISAT MTP, the first measure was used due to data limitations. The expected annual value of yield gains which would be achieved should the research be successful was calculated for each research theme by using yield loss data and anticipated percentage yield improvement from research within the targeted research domain(s). This value was discounted according to probabilities of success, ceiling rates of adoption and time value (discounted cash flow) relating to expected research and adoption lags to generate the present value of benefits. An aggregation of all net present values over a specified time horizon for which benefits continue to accrue, provides the total benefits in net present value (NPV) terms.

Research costs were estimated for human capital cost, operational costs and value of capital items required. For each theme, the discounted value of principal scientists' cost and operational and capital costs were calculated for each year of the projected research time frame. The sum of these annual figures provides the total ICRISAT cost in present value terms.

Having computed the present value of total costs and total benefits, with adoption levels and probability of success taken into account, the net benefit-cost ratio was obtained by dividing the net benefits (total discounted benefits less the discounted costs) by the discounted cost. The internal rate of return was also calculated. The net benefit-cost ratio (NBCR) and internal rate of return (IRR) represent the efficiency of research investments.

Equity: The equity criteria represent the distributive effects of research investments. This measure should reflect the share of various sections of society (e.g., poor and non-poor; male and female; or urban and rural) in the total welfare gains. A distributional indicator may be obtained from the economic surplus measure cited above. This requires estimates of elasticities or the degree of responsiveness to prices of each specific sector benefiting from research. As elasticities are not readily available for some crops or for specific sector, analysts usually take a range of reasonable values based on characteristic of the crop and market structure. Alternatively, some proxy variables are identified to represent the distribution of welfare gains.

Two proxy variables were chosen for the ICRISAT research priority-setting exercise: (a) number of poor people; and (b) number of female illiterates. The first proxy counts the total number of poor people in the primary domain(s) for which research is targeted. The second proxy represents the number of female illiterates in the targeted research domain.

Internationality: The "internationality" criteria aim to capture the international public good dimension or research spillover benefits from an international agricultural research institution. The "internationality" of a research theme is considered significant when research is weighted towards projects of greater international impact, leaving purely national projects to the national agricultural research system (NARS). The Simposon index of diversity was used to measure the "internationality" of research theme.

$$I_i = 1 - \Sigma_J \{S_{ij}/100\}^2$$

where S_{ij} represents the share of total gains resulting from research theme i in country j. In this case, a higher factor indicates greater internationality. The index was chosen on the basis of its simplicity and ready availability of data on total yield gain for each research theme from the ICRISAT MTP database.

Data sets enabling estimation of actual international benefits and welfare spillovers have recently become available from various sources (Evenson, 1994; Maredia et al., 1994; Brennan, 1989). A systematic information system has been established to support research priority setting at the international level based on the welfare model where estimates of research spillovers across agroecological environments and across countries are established (Ryan and Davis, 1990). The database is available and the approach may be readily adapted to enhance the existing measure of internationality.

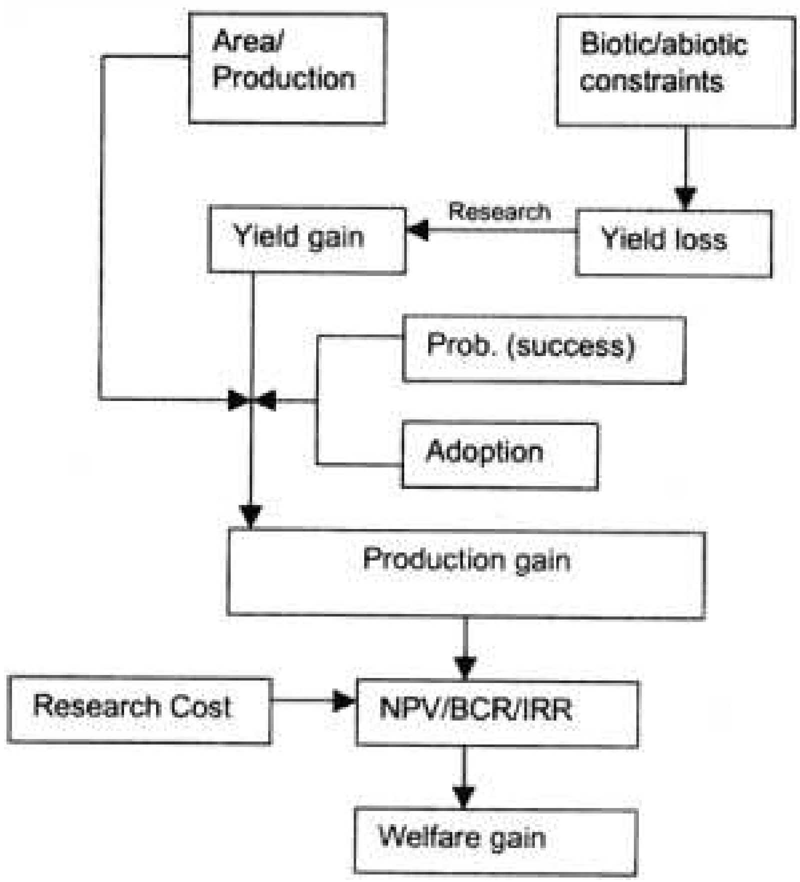
Environmental sustainability: Environmental sustainability scores were elicited from a multidisciplinary expert group among the ICRISAT scientists. The group was asked to assign ratings for each research theme that will indicate research theme's potential contribution to sustainable agriculture. The assignment of ratings is a way of delineating among alternative research options which are those likely to sustain the improved productivity of resource base (rating of 3) and which are likely not (rating of 1). It also identified those researches whose primary focus is to enhance the resource base (rating of 5).

Linkages among the measurable criteria and database for research evaluation

Figure 3.1 presents the relationship among the measurable criteria, viz. welfare gains, distribution of welfare gains (equity), internationality (research spillover effects) and sustainability. This figure shows the variables which underlie the measure of welfare gain. These are: (a) crop area and production; (b) yield losses due to biotic and abiotic constraints; and (c) expected yield gain due to research. The figure illustrates that the realisation of the expected production gain is subject to two conditions: (i) the probability that the research succeeds, and (ii) the resulting technology is adopted in farmers' fields. The resulting welfare gain due to research over a time horizon may be expressed in net present value (NPV) terms and measures of research efficiency (NBCR and IRR).

The link between total welfare gains and the distribution of these gains (equity) is demonstrated in Figure 3.2. The number of poor people and female illiterates serve as proxy variables to measure the distributional effects or equity. This is of interest as the ICRISAT targets the harsh and undependable environment of the semi-arid tropics to improve the welfare of poor people living in these areas.

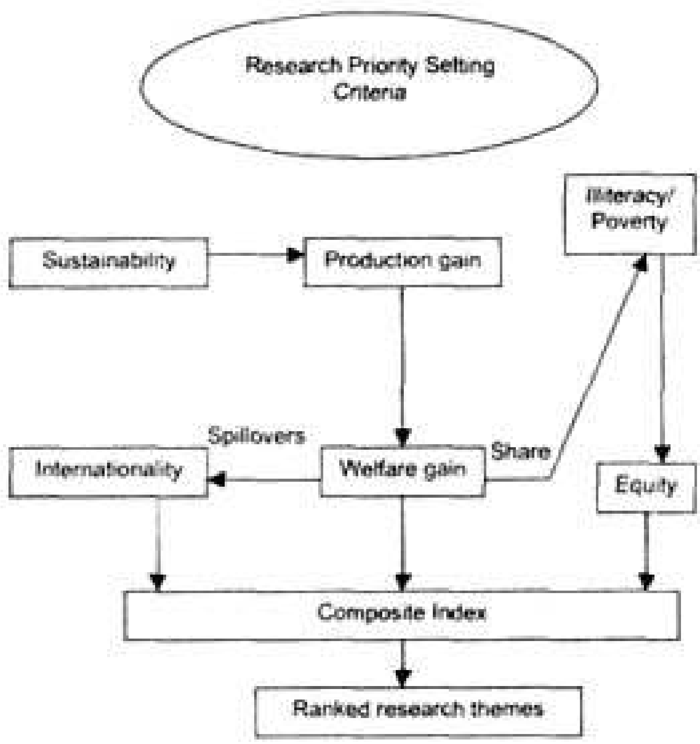
Figure 3.1: Basic parameters for measurement of welfare gains



The important link between environmental effects of technology and the level of production gains from research which ultimately determine the actual magnitude of total welfare gains over a specified time horizon is also shown. The score defined to measure environmental sustainability reflects the extent to which production gains are expected to be maintained over time as the use of the technology affects the natural resource base. The concept is illustrated by considering two alternative scenarios: (a) welfare gains are expected to be maintained over some period as the technology does not have adverse environmental effects or even enhances the resource base; and (b) welfare gains are not sustainable over time due to adverse effects of the technology on the resource base. Situation (a) illustrates cases where improved productivity is sustained over time so that welfare gains from research which accrue to society are maintained over time. Situation (b) presents the case where the improved productivity is not sustainable so that the benefits eventually decline with the deterioration in quality of the resource base. In this case, research-induced technological change, in fact, deteriorates the resource base, generating negative externalities, which neutralise or overweight the productivity gains.

A composite index, a weighted average of the four measures, is computed as a summary measure for setting priorities among alternative research options. The simulations discussed in this paper are derived using this index and linkages among the underlying variables.

Figure 3.2: Linkages among four priority setting criteria

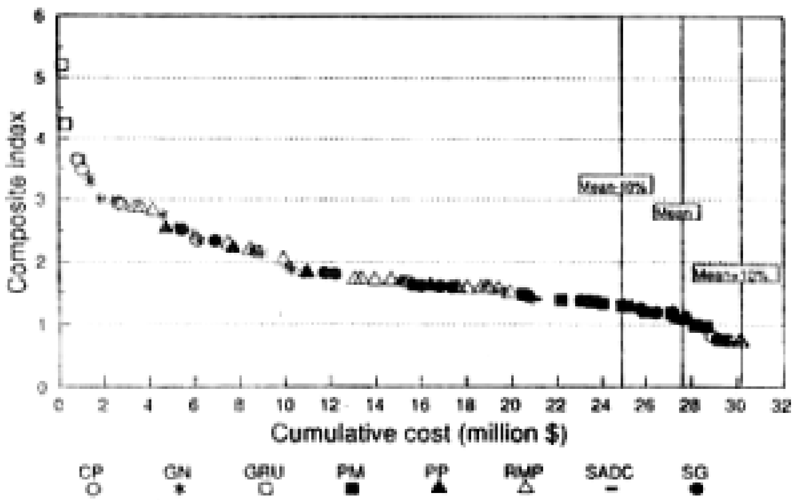


3. Structured Database and Research Portfolio

Systematic calculation of measures of the four criteria identified requires a structured database. The database developed from the medium-term planning process of the ICRISAT contains comprehensive information for each of the 110 themes (For details of prioritised research themes, see chapter 7 in this volume). The data variables include research objectives, target research domain, estimated yield losses, expected yield gains, probability of success, adoption rate and ceiling level, research and adoption lags, expected output, and manpower and capital requirements. This database serves as a benchmark or reference for research evaluation of future projects relating to the 110 research themes included in the 1994-1998 portfolio.

The prioritised research portfolio for the MTP 1994-98, representing the situation where efficiency, equity, sustainability and internationality are given equal weights, is taken as benchmark for this analysis. Figure 3.3 depicts the composite index-cumulative cost mapping of the 92 research themes slated for core funding in order of their priorities. The distinct mark assigned to each commodity or unit clearly shows the commodity/unit level distribution of priorities. The budget cut-offs indicated on the right hand side of these composite index-cumulative cost mapping explicitly show the number of themes affected in alternative budget scenarios. The figure clearly indicates that research themes relating to genetic resources (GRU) and groundnut (GN) are high priority themes, as they do not drop out in any of funding schemes. Resource management (RMP), chickpea (CP) and sorghum (SG) research themes lose at most only three themes each in a constrained funding situation; while a significant number of pigeon pea (PP) and pearl millet (PM) themes are expected to be dropped out in a constrained funding situation.

Figure 3.3: Cumulative cost vs composite index (based on benchmark for all themes)



Lack of consistency or bias?

This section examines the apparent lack of consistency in the data used to compute the composite index across research programmes. The generation of the data was a year-long iterative elicitation process where every scientist from all programmes of the institute was involved. To minimise the differences in judgement across programmes, the ICRISAT conducted a peer review of each programme (cereals, legumes, resource management and genetic resources) estimates; and the judgements are taken as the best available from the institute during that time.

The estimates of measurable criteria used in computation of the composite index (Table 3.1) were examined to identify the factors which account for priority ranking of themes. If lack of consistency is perceived in the elicited values underlying the priority rankings, then clarification of this issue may be attained by undertaking a comparative analysis of the MTP data provided by researchers across disciplines and programmes. Scrutiny of the efficiency parameters (area, expected yield improvement, probability of success, adoption ceiling and research cost) is facilitated by a comparison with their averages. This comparison aids examination of the comparability of estimates across disciplines and programmes and consistency with available secondary data.

As seen from Table 3.1, differences (among groups) in the estimates of probability of success, adoption ceiling and adoption lags are small. Estimates for the probability of success show that, on average, scientists from five research groups expect about 50 per cent likelihood of achieving research success. This means that the significant differences of the economic value of success (EVS) and net benefit-cost ratio (NBCR) among crops/groups are unlikely to be attributable to this variable. Similarly, comparative levels of the adoption ceiling for all groups are expected in the range of 30 per cent to 40 per cent. Pearl millet, pigeon pea and chickpea were above the average level of 34 per cent, while sorghum, groundnut and resource management fell below the average. The narrow range of the expected ceiling levels of adoption indicates the consistent conservative estimates that scientists were willing to provide with respect to the extent to which improved research outputs are expected to be adopted by farmers.

The variables of area, expected yield gains and research cost varied substantially across groups. The area estimates indicate that resource management, sorghum and groundnut are research themes that target the largest area, each covering more than 8 million ha globally, followed by pearl millet and chickpea covering 6-7 million ha each. The area given are based on researchers' target domains and are approximated based on existing crop area data or estimates of pest or disease (or other biotic/abiotic constraints) endemic areas. This comparative standing of the crop domains are confirmed by published data on global crop area (FAO, 1994). Expected yield gains and research costs are estimated more subjectively, and thus, require clearer justification. The yield gains expected by scientists indicate that a higher yield gain is expected from resource management than genetic enhancement research. The comparative standing of expected yield gains among mandate crops (i.e. higher for pearl millet and pigeon pea than groundnut, sorghum and chickpea), has a bearing on the claims with respect to genetic enhancement in these crops, and the difficulties of overcoming the major constraints facing production of some crops.

An examination of relative magnitude of research costs brings out that: (a) in spite of average to below average values for CP themes with respect to yield improvement, probability of success and adoption ceiling, significantly low research cost gave an NBCR that is three times the average NBCR across the groups; (b) small area coverage of the pigeon pea themes is similarly offset by the relatively low research cost estimate for this crop; (c) the GN themes fared better than the PM themes even as pearl millet promised a significantly higher expected yield gains, probability of success and adoption ceiling levels because the projected cost of GN research was almost half that of the projected cost of PM research; and (d) low NBCR rates for SG and RMP groups were primarily due to high projected research cost. Having been estimated subjectively, research cost variable requires a closer re-examination of estimates and a clearer justification for the extreme values.

An example of the required scrutiny is given for the case of chickpea. The data behind the estimates of the chickpea themes were re-examined by the legumes programme, and the original judgements on benefit-cost ratios were scrutinised. Much work has already been done on the themes relating to chickpea and therefore, probabilities of success were high, and on-going incremental costs were low. Two factors are identified to account for the above observation. These are: (1) number of scientists required to achieve the research objectives and hence the cost of research; and (2) market price. Technical information on research theme and output price differences account for the higher NBCR valuation for the chickpea themes.

Table 3.1 further illustrates relative position of commodity groups/research units ranked by the composite index and the five indices on which it is based (net benefit-cost ratio, poverty, gender, internationality and sustainability). The composite index explains the following priority ranking by commodity group/research units: (1) GRU; (2) GN; (3) CP; (4) RMP; (5) SG; (6) PP; and (7) PM. The relative positions of the commodity/unit groups with respect to the five measurable criteria explicitly clarify the basis of the priorities set in the MTP research portfolio. For example, the GRU group of themes stands out with clear advantage in all respects, i.e. NBCR, poverty, gender, internationality and sustainability. In spite of its low NBCR, groundnut-is ranked second as it gains advantage over the other five groups with respect to poverty, gender, internationality and sustainability.

Table 3.1: Value of parameters used in the composite index for priority ranking, ICRISAT MTP 1994-98

Parameter		Commodity group							Average
		GRU	GN	CP	RMP	SG	PP	PM	
1.	Efficiency								
	Area (m ha)	ne	8.0	6.2	12.3	11.5	2.5	6.9	8.2
	Yield improvement (%)	ne	7.2	6.1	12.8	6.0	9.3	10.0	8.2
	Prob. of success (%)	72	46	54	47	67	50	51	53
	Adoption ceiling (%)	ne	30	36	30	32	36	42	34
	Adoption lag (year)	6	5	6	4	7	5	6	6
	Economic value of success (m $)	54.2	119	122	438	117	116	58	146
	Research cost first year (m $)	0.14	0.27	0.22	0.37	0.42	0.22	0.52	0.33
	Net benefit-cost ratio	59.4	9.9	49.6	12.4	11.1	15.9	8.1	17.7
2.	Poverty (number of poor people, million)	397	188	77	86	77	101	36	111
3.	Gender (number of female illiterates, million)	378	205	120	93	84	149	62	129
4.	Internationality	1.0	0.67	0.36	0.51	0.69	0.15	0.46	0.53
5.	Sustainability	4.0	3.4	2.7	3.2	2.6	3.5	2.6	3.1
6.	Composite index	4.36	2.19	2.14	1.64	1.59	1.53	1.19	1.84

Shifts in priority sequence with changes in the weighting system

The final ICRISAT MTP research portfolio for 1994-1998 was derived by assuming that the four research priority criteria (NBCR, equity, internationality and sustainability) are equally important. This section examines the implications of deviations from this assumption on the research priority ranks. Clearly, the weighting system is a policy decision. Making transparent and explicit to research decision makers the actual trade-offs involved with respect to various weighing decisions is important.

The implications of the weighing system is examined by checking how the priority sequence shifts when the weights assigned to the priority setting criteria are changed. The composite indices were recalculated by assigning zero weight to one criteria at a time and equal weights to rest of the three criteria. The results indicate that there were no significant! changes in MTP priority ranking when each of the three criteria, viz. sustainability, internationality and equity is ignored in computing the composite index. The correlation coefficient between benchmark and revised composite indices was 0.95, 0.96 and 0.92, respectively. However, the priority sequence shifts substantially when zero weight is assigned to efficiency criteria (correlation coefficient 0.77). This means that the priority importation of each of the other three criteria is about the same, but the priorities implied by the efficiency criteria is different from the other three.

4. Conclusions and Implications for Future Priority-Setting Analysis

The ICRISAT developed a structured priority-setting strategy, which aimed at reflecting its multiple research objectives. The determination of the priority research portfolio was built on an analytical priority-setting methodology where a composite index is derived from a set of measures established for economic efficiency or total welfare gain, equity or distribution of the total welfare gain, sustainability and internationality. The strategy started with the development and extensive use of a rich data set pertaining to research objectives, estimated yield losses due to production constraints, expected yield gains achievable via research, probability of success, rates of adoption, adoption ceiling, research and adoption time lags for each of the 110 themes defined for the ICRISAT's research portfolio.

Five areas of consideration are important to improve the 1994-98 MTP criteria and measurements. The first is clarification of economic efficiency as a research objective. Reference to economic efficiency as a research objective raises the question of market failure and the implication that research is definitely correcting this market failure. Total welfare gains may present better criteria for priority setting as agricultural research is primarily an instrument to improve agricultural productivity. Thus, a measure is required to represent this, rather than representing the implied correction of market failures in agriculture. Measures of improvement in productivity or total welfare gains in agriculture, in terms of net present value or internal rate of return are suggested to be readily calculated using the data available from the 1994-98 MTP round.

The second area suggested for consideration relates to the two measures on which calculation of welfare gains from research have usually been based. The first measure estimates the expected change in output due to research and values of this change in terms of the current or expected commodity price. The second measure estimates research benefits by applying the principle of economic surplus to obtain the size and distributional consequence of improved technologies derived from agricultural research. While both approaches utilise the same basic concepts of demand and supply, a good understanding of the underlying production and consumption environment is called for in the process of choosing on appropriate measure. Substantial differences may occur between these measures and under uncertain demand and supply conditions, consideration of stability of estimates favour the use of the second measure.

The third area that needs further examination is the equity measure, representing distributive effects of research investments. This measure should reflect the share of the total welfare gains among various sectors of society, e.g., poor and non-poor; male and female; or urban and rural. The proxy variables chosen for the ICRISAT research priority-setting exercise are: (a) number of poor people, and (b) number of female illiterates. An analysis that can provide a convincing case that these proxy variables are in fact reflecting distributive effects is to take the welfare gain estimates and show that shares of these are distributed based on these two proxies.

The fourth aspect that may be improved is the measure for the internationality criteria. The Simpson index of diversity, by the definition used to measure internationality, applies on the share of production gains due to research accruing to different countries around the world. In this case, the share of total yield gain realised in a country is directly proportional to the production share of that country relative to total world production. An improvement of this measure is estimation of actual welfare spillovers which have been illustrated in the recent literature (Ryan and Davis, 1990). In these recent developments, research spillovers take into account the applicability of research related technologies beyond regions where the research was originally targeted. The international public good dimension of research is captured by taking into account the applicability of research across production environments and the production proportions of the defined production environments for each of the countries.

Improvement in the consideration of sustainability as criteria for research priority setting may be achieved by taking the conceptual scenarios of sustainable productivity effects explicitly in the measurement of welfare gains, where the ratings serve as a modifier of the computed welfare gain rather than as a separate independent criteria. An explicit identification of the overestimation or underestimation of welfare gains depending on whether or not and how these welfare gains are sustained over time may bring better consistency in the information generated to support research priority-setting decisions.

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