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On Reconciling the Multiple Objectives of Agricultural RD&E¹

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Abstract

International agricultural research institutions are now expected to deliver on a range of Sustainable Development Goals (SDGs) in addition to their traditional goal of developing technologies that increase the incomes of farm families and alleviate poverty. There has been concern that pursuit of these other objectives may have a high opportunity cost in terms of a slower rate of poverty alleviation. Here we argue that many of the SDGs can be thought of as capital stocks which are jointly related in production and consumption. There are opportunities for research institutions to exploit this jointness. Well-designed projects to deliver new technology lead to the alleviation of poverty (if the technology is widely adopted) but also have the potential to enhance a range of capacities in scientists and farm families and in environmental health. The risk of projects that do not have a technology focus is that the incentives for farm families to change behaviour may be weak and hence gains in SDGs may be small. One implication is that assessing the economic impact of new technologies remains important. While changes in SDGs should be at least qualitatively described, a finding of robust economic impact based on evidence of adoption, gives confidence of gains in other jointly supplied SDGs.

Keywords: Agricultural RD&E, Sustainable Development Goals, Productivity, Impact Assessment

Introduction

Agricultural productivity improves when greater output can be produced from fewer inputs – ‘two blades of grass where one grew before’, as Jonathan Swift put it. Governments investing in agricultural RD&E with the explicit purpose of improving productivity led to the widespread alleviation of the poverty of farm families in developing countries². Building the capacity of scientists in developing countries was a valuable spillover with a potential for future productivity gains. In the 2020 World Bank report *Harvesting Prosperity*, Fuglie et al. (2020, p.3) cited research showing that in poor countries an increase in agricultural productivity had twice as much impact on poverty reduction as a comparable productivity increase in other sectors of their economies.

¹ The work reported here was partly funded by the Crawford Fund.

² Gains in agricultural productivity was a source of cheap food for non-farm families and provided a pool of labour to other sectors of these economies.

In earlier decades, improving agricultural productivity was a major focus of international agricultural research institutions. The focus of agricultural RD&E has broadened in recent years with the share of public funds directed to productivity gains likely declining – at least in OECD countries if evidence from the United States (Pardey et al., 2013) and the Consultative Group on International Agricultural Research system (CGIAR) (Alston et al., 2021b) is common to these countries. Initially concern grew about the environmental impacts of more intensive agriculture and of new technologies. Some agricultural RD&E investments pursued productivity subject to a constraint that adverse environmental impacts be minimised. Some pursued positive environmental outcomes with minimal regard to productivity.

The goals in international research agencies such as the CGIAR system and the Australian Centre for International Agricultural Research (ACIAR) are much broader now than in past decades, encompassing not only goals of poverty alleviation and environmental protection but also various forms of capacity building in communities as well as in scientific institutions. The ACIAR (for example ACIAR, 2020) has six strategic objectives which contribute to twelve of the United Nation's seventeen 2030 Sustainable Development Goals (SDGs):

- Food security and poverty reduction;
- Natural resources and climate change;
- Human health and nutrition;
- Gender equity and women's empowerment;
- Inclusive value chains; and
- Capacity building.

The outcomes from the pursuit of these SDGs can be thought of as increases in the stocks of human, scientific and environmental capital.

In the past, some economists (e.g., Alston, Norton and Pardey, 1995, p.81) have expressed concern that pursuing multiple objectives might slow the rate of productivity growth – at least in the short term. They have argued that, ideally, other policy instruments ought to be used to pursue these other objectives leaving agricultural RD&E to focus on enhancing agricultural productivity. It might be thought that simultaneously pursuing this range of objectives necessarily involves trade-offs. The argument might be that a single-minded pursuit of productivity inevitably involves sacrificing the rate at which these other objectives (capital stocks) can be achieved, and/or that pursuing these other objectives necessarily slows the rate of productivity growth and the alleviation of poverty.

In this paper we make several points:

- The efficacy of RD&E in enhancing productivity growth and alleviating poverty depends on the prevailing levels of these stocks of human, scientific and environmental capital;
- These capital stocks are inter-related;
- New profitable production technologies may serve as a vehicle to induce gains in these other capital stocks; and
- Research outputs that do not deliver incentives for changed behaviour by farm families may result in minimal gains in these capital stocks.

In brief, research programs can be devised in a way that new technologies profitable for farmers to adopt, not only alleviate poverty but also provide a vehicle for gains in other SDGs. The relationship may not be

symmetric. Investing in other millennial goals without attention to the critically important incentives for change by farm families may result in minimal progress towards the SDGs and no alleviation of poverty.

The Pathway from RD&E to Outcomes is Long and Complex

The way research delivers on poverty alleviation and other objectives is complex and long-term in nature (Mullen et al., 2015). Annual investments in research and extension can build up stocks of knowledge of various types:

- New knowledge or new technologies available to farmers;
- Human scientific capacity, enhanced through training, mentoring and learning by doing;
- Other knowledge not immediately reflected in new technologies;
- Knowledge held by policymakers; and
- Knowledge held by research managers.

These stocks of knowledge provide flows of services, which result in new technologies becoming available to farmers. If these new technologies lower costs, increase yields or improve quality, farmers have an incentive to adopt them, thus enhancing their productivity, increasing their income and alleviating poverty³.

The extent of adoption and subsequent gains in productivity depend on many other factors, such as:

- The financial resources available to farm families;
- The health of natural resources (soil, water and air);
- The health and nutritional status of families;
- The participation of women in farm family operations and decision-making;
- The efficiency of value chains before and after the farm gate; and
- The technical capacities of farmers and the scientists that work with them.

These factors correspond to the above-mentioned SDGs. What is important is that these factors can be regarded as stocks of human and environmental capital which influence the outcomes of investments in research and extension. Low levels of these stocks will likely constrain the adoption of new technologies⁴.

The extent of productivity gains and alleviation of poverty depends on the level of these stocks. Agricultural RD&E can increase some or all of these stocks through various feedback processes. These feedback processes can be represented by adapting a model developed by Mullen, Gray and de Meyer (2015)⁵. The joint changes in these stocks might be represented heuristically in a production function as:

$$\left(IK_t, IC_t, INR_t, IZ_t \right) = i(R_t, \dots, R_{t-L_R}, E_t, \dots, E_{t-L_E}, K_t, C_t, NR_t, Z_t)$$

³ Some new technologies in the value chain may lower off-farm costs and increase demand at the farm gate, leading to poverty alleviation.

⁴ Political stability, an objective of Australia's overseas aid program, can also have large impacts on the rate of economic development and poverty alleviation and the returns to international agricultural RD&E.

⁵ An adaption of a research production function from Alston et al. (1995).

Where R_t and E_t are lagged series of research and extension investments⁶ likely to include a range of capacity building activities; K_t is the stock of knowledge or new technologies available to farmers; C_t is the stock of human scientific capacity in the form of scientific capacity and knowledge held by scientists, science managers and policy makers; NR_t is the stock of natural resources; and Z_t is the stock of human capital held by farmers and their families in the form of technical skills, and capacities to engage in farm and household decision making. The 'l' notation on the left-hand side of this relationship denotes an increment in time t to these four capital stocks.

The relationship says that as a result of past investments in research and extension (or project activities more generally) there will be increments to these four capital stocks in time t and the size of these increments will depend not only on the level of investments in research and extension but on the existing size of the capital stocks. This equation is a general form of a multi-output, multi-input production relationship where complex product transformation and input substitution possibilities are deliberately left implicit.

How these four capital stocks grow can be represented as follows using K_t as an example:

$$K_t = K_{t-1} + IK_t - DK_t$$

Where DK_t is the depreciation of the knowledge stock in the present period, perhaps because a technology becomes obsolete and is disadopted, and recalling that IK_t from RD&E depends on the other capital stocks. Similar relationships hold for the other three capital stocks⁷.

Again, conceptually, these capital stocks are elements in production functions related to the SDGs. So, for example, the production function for final agricultural output can be represented as:

$$Q_t/X_t = f(K_t, C_t, NR_t, Z_t, W_t, A_t, J_t)$$

where current agricultural output (supply), Q_t , depends on a flow of conventional inputs, X_t . The left-hand side is a measure of total factor productivity. A gain in productivity results in a gain in profitability provided the terms of trade (prices of outputs relative to the prices of inputs) remains unchanged (O'Donnell, 2010). Productivity depends on the capital stocks from above, uncontrolled factors such as weather and pests, W_t , a flow of services from publicly provided infrastructure in the form of education, transport and communications for example, A_t , and the farm policy setting, J_t . Note that Q_t and X_t are vectors of multiple outputs and inputs at time t . Similar relationships can be conceived for say the supply of environmental and human health outputs.

The key is that research institutions can contribute to the SDGs through a variety of activities because of the inherent jointness in the pursuit of these goals. However, it is difficult to measure and value changes in some of the SDGs. This makes it difficult to determine the efficacy of investments in achieving individual SDGs. No logic nor accounting system can disentangle this inherent jointness making unique attribution impossible. Regardless, unless project activities lead to incentives that are clear and sufficient (monetary or otherwise) for farm families to change their behaviour, the returns to these activities may be poor. It seems likely that monetary incentives are more easily perceived than non-monetary incentives and hence more likely to induce changes in behaviour.

⁶ Not all of which are direct investments in agricultural productivity.

⁷ This representation is perhaps too simplistic in not explicitly reflecting the jointness between the four stocks.

Investing in agricultural RD&E to develop new technologies that are profitable for farm families to adopt leads to increased incomes and reduced poverty. In the course of developing these technologies and promoting their adoption, a range of other capacities related to the SDGs are likely to be enhanced. Mullen et al. (2022) reviewed some ACIAR projects where productivity-focussed RD&E contributed to critical environmental outcomes. It seems unlikely that activities focussed on other SDG objectives would have delivered similar outcomes.

For example, in India, the favoured rice-wheat rotation required the burning of rice stubble, creating a serious air pollution problem. Applying an obvious policy response, the Indian government prohibited stubble burning but did not enforce the ban, probably in consideration of the burden this would impose on farmers⁸ in terms of reduced productivity and incomes. A series of research projects partly funded by ACIAR developed the 'Happy Seeder'. As an alternative to stubble burning, this tractor-powered machine cuts and lifts the rice stubble, sows wheat into the bare soil, and deposits the stubble over the sown area as mulch (Millham et al., 2014, p. iii). Several analyses (referred to in Mullen et al. (2022)) found the technology to be profitable for farmers; however the rate of adoption has been slow in part because of the capital costs of the technology and in part because some of the benefits, in terms of improved soil fertility and reduced irrigation needs, accrue over a number of years and are not immediately apparent to some farmers. Governments have subsidised the investment in Happy Seeders to farmers and cooperatives and the adoption of Happy Seeders is advancing with gains in air quality, soil fertility and water use. These ACIAR projects also delivered significant gains in human and scientific capacity as evidenced by graduate students trained and scientific papers published.

Another example related to environmental outcomes is from China, which has 400m ha of temperate grasslands much of which is heavily degraded from overstocking (Kemp, 2020). This degradation has led to severe dust storms and poor air quality across large areas including Beijing. An obvious policy response is to remove livestock from the rangelands and governments experimented in a limited way with this option which imposed severe costs on already poor farmers despite government subsidies. ACIAR co-funded a series of projects, aimed at developing sustainable livestock grazing systems on temperate grasslands in China. The key result of this research is that grassland herders can increase incomes and reduce grassland degradation by reducing their stocking rate.

The extent to which herders have reduced stocking rates in many places across the grasslands is not known at this stage. However, studies in Siziwang found that average stocking rate was about 0.8 sheep equivalents/ha and as low as 0.5 sheep equivalents/ha for some – a reduction of about 50 per cent. Presumably, herders would not have adopted this technology if it had significantly reduced their incomes.

A final example relates to the objective of gender equity. Women are often responsible for some (or all) farm activities. The development of technologies that recognise the key role of women in farming and empowers and develops capacities in these women not only leads to poverty alleviation in the short term; the management skills gained give farm families greater resilience to cope with change in the future (Pamphilon and Mikhailovich, 2017).

While investments that focus narrowly on, say, environmental outcomes or on the empowerment of women, might lead to later gains in the alleviation of poverty via the relationship described above, the

⁸ Millham et al. (2014) argued that subsidized prices for water and electricity encouraged the widespread adoption of the rice-wheat rotation and if these subsidies were removed the Happy Seeder became even more attractive.

pathway to impact is less direct and more uncertain than investing in the development of technology and creating direct and tangible incentives for adoption.

A straw person counter argument might help make this point. Suppose that a research project achieves a better understanding of, and improves the measurement of, climate change in a particular environment but does not provide farmers with an incentive to change their farm management. While expanding scientific knowledge, and possibly leading to a change in public policy, the project results will have minimal impact on other capital stocks, including the poverty level.

The challenge is to design research programs for delivering technology that farmers will adopt; programs that increase farm income and alleviate poverty, while also adding to other capital stocks, such as natural resources or human health or women's empowerment⁹.

Producers, processors and consumers in the agribusiness value chain all share the benefits of new technology¹⁰. In developing countries, many semi-subsistence farm families benefit as both producers and consumers, and initially they capture most of the benefits of new technology. Such technologies, if profitable for farmers, are a highly effective way of alleviating poverty throughout the economy.

The Challenge for Impact Assessment

Given the role of profitable technologies as vehicles for attaining a range of sustainable development goals, it remains important to estimate the economic impacts of the technologies based on a plausible causal pathway from project activities through to changed behaviours or final outcomes. Investments that deliver economic benefits to farmers are also likely to enhance other SDGs because of the jointness of capital stocks described above. If technologies are not adopted, there can be little confidence in gains in the other SDGs.

While it is important to demonstrate economic impact, it is also critical to describe in qualitative terms the joint outcomes related to other SDGs (as well as other economic impacts not quantified) that can be plausibly attributed to project activities. Often the limited resources for specific impact assessments result in this qualitative component being 'underdone'. However, analyses by Gordon and Chadwick (2007), and Mullen et al. (2015), suggest that capacity building activities potentially deliver large returns.

Enthusiasm for assessing the impact of their investments by the managers of agricultural RD&E funds has waxed and waned across institutions. This ambivalence arises from a poor understanding of what constitutes sound practice in impact assessment and of the role impact assessment might play within a research institution. Another source of ambivalence is that some (perhaps many) impact assessments have had a narrow focus on subsets of economic impacts (ignoring qualitative outcomes) and have not been rigorous and transparent¹¹.

One role for impact assessment is to demonstrate that scarce resources have been used efficiently. There is a large domestic and international literature reporting high rates of return to agricultural RD&E. These studies are *ex post* in nature and are most credible when based on historical evidence of adoption. In a

⁹ Noting that other policy tools can be used to enhance these capital stocks.

¹⁰ For a deeper understanding of how marketing chain operators share the various benefits of new technologies, see Mullen et al. (1989).

¹¹ Lindner et al. (2013) set out a process for assessing the credibility of impact assessments.

recent empirical study, Alston et al. (2021a,b) assessed the returns to CGIAR investments in agricultural RD&E and to investments in national agricultural research systems (NARS) in partner countries. They estimated a rate of return of 10:1. The Australian experience is reviewed in Mullen et al. (2022) and the findings are consistent with the international literature¹². The consensus is that the rate of return to public agricultural research is high which indicates that under-investment remains chronic.

There are two further points to be made here. First, analyses of the rate of return to investment in RD&E typically focus on quantifying a subset of economic gains from productivity improvements. At best, other welfare enhancing outcomes related to the SDGs are described qualitatively. Hence, estimated rates of return are likely to underestimate total welfare gains, sometimes by a substantial margin.

Second, the traditional explanation for the persistence of high rates of return to RD&E generating productivity gains is that the new knowledge underlying the new technologies has the characteristics of public goods – non-rival in consumption and non-exclusive.

The outcomes from the pursuit of most, if not all, the SDGs also have the characteristics of public goods – global public goods in some cases – and, hence, it is also highly likely that investment in the SDGs is less than optimal from society's viewpoint. For example, there are spillovers/externalities associated with poor human and environmental health outcomes that necessitate a public response. Potentially, these issues are threats to world security requiring a global public response. There are also the moral/ethical arguments shared by many as to why rich countries should help poor countries. Education has also been seen to have public good traits, so capacity building is likely to fit in the category of a public good, as does empowerment of women via capacity building.

Ex ante impact assessment can contribute information that informs resource allocation and priority setting. The potential contribution of *ex ante* impact assessment is greatest when it is part of the process of developing a research proposal. It can lead to improved project design and a clear focus on project outcomes as alternative pathways to outcomes are explored and scientists gain greater understanding of how their activities are linked to final outcomes.

Conducting *ex ante* assessments on project proposals that are already finalised is a pointless exercise: a mere nod towards proper assessment that meets some bureaucratic dictate¹³. The opportunity for improved design has been missed and these analyses, where only some impacts are quantified, are unlikely to play a significant role in research allocation and priority setting.

The *ex-ante* nature of these assessments does not absolve the analyst from basing assumptions and projections on whatever empirical evidence is available. This evidence might come in the form of research results and farm level trials, the experience of similar technologies, a careful consideration of the target population and the resources available to promote adoption, all informed by the experience and judgement of scientists and farmers. Projections about adoption are also influenced by the nature of the technology. Higher rates of adoption are likely to be achieved by embodied technology such as new plant varieties whereas information-based technologies that require greater management skills such as

¹² One wonders about the influence of this body of work because public investment in agricultural RD&E both in Australia and in other OECD economies has declined over recent decades (Alston, Pardey and Rao, 2021b, p.4). Perhaps, the 'without' scenario would have been an even steeper decline in investment.

¹³ Unless capacities are developed in the project team that leads to a sharper focus on impact pathways during the project and in the development of later projects.

integrated pest management are likely to have lower levels of adoption. The ADOPT software developed by Kuehne et al. (2017) is a more formal approach to developing projections about the adoption and impact of technology.

Conclusions

Nowadays international agricultural research institutions are routinely expected to deliver on a range of SDGs in addition to their traditional goal of developing technologies that increase the incomes of farm families and alleviate poverty. There has been concern that pursuit of these other objectives may have a high opportunity cost in terms of a slower rate of poverty alleviation.

Here we have argued that many of the SDGs can be thought of as capital stocks which are jointly related in production and consumption. There are opportunities for research institutions to exploit this jointness. Well-designed projects to deliver new technology lead to the alleviation of poverty (if the technology is widely adopted) but also have the potential to enhance a range of capacities in scientists and farm families and in environmental health.

The risk with projects that do not have a technology focus is that the incentives for farm families to change behaviour may be blurred and weak and gains in achieving SDGs may be small.

An implication is that assessing the economic impact of new technologies remains important. While changes in SDGs ought to be qualitatively described, a finding of robust economic impact, based on evidence of adoption, increases confidence that gains in other jointly-supplied SDGs will be achieved.

Typically, analyses of returns to agricultural RD&E investments have only valued the economic impacts of productivity gains which means that the true rate of return to investments that deliver a range of SDG outcomes is higher, perhaps by a substantial margin, than the estimated rate of return. The outcomes from the pursuit of SDGs have the characteristics of public goods and, hence, are likely to suffer from inadequate public investment as evidenced by these high rates of return.

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