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The Economics of New Technology Adaptation and Adoption

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Adaptation is a critical aspect of applied agricultural research but is one that should be better understood. Accordingly, its dimensions are explored here through analogies with the adaptive behaviour of a person seeking a change in employment. A similar process is then used to illustrate the sequential phases of the adoption of a new technique by a farmer - in this case through analogy with the purchase of an automobile. Although adaptation and adoption are quite different phases of the implementation of new technology, their economics are closely interrelated, since an *ex ante* investigation of the economics of adoption is a necessary consideration in the *ex ante* appraisal of a process of adaptive research.

1. Introduction

Our language is rich in words that sound similar but are really quite different. *Metaphoric* and *metamorphic* epitomise such a pair. For the present essay, the Conference Organisers have chosen to have discussion of another interesting pair — *adaptation* (and its cousin *adaption*) and *adoption* which, while being linked by both alliteration and consonance, pertain to somewhat distinct processes and phenomena. Interesting overlaps do, in fact, occur between the two (e.g. Saruwatari and Cruz 1985) but it is contended here that they can nevertheless be considered separately — a contention challenged by Gordon MacAulay in his discussion of this paper at the Conference, but one borne out at least by the AGRICOLA keyword database, which in 1979-91 featured 8923 entries under Adaptation, 263 under Adaption (together 'A1'), 3807 under Adoption ('A2') yet only 45 in the A1.A2 intersection.

Whilst on semantic matters, it should be clarified that this piece relates generally to agricultural development in less-developed countries (LDCs). The concept of 'new technology' in the title is taken to pertain to any set of techniques that might be considered novel in various contexts, such as their non-standard association together or perhaps merely their novelty to a particular person, who might be

someone working in research, extension, farming or processing. The word 'economics' is presumably intended to inspire some ends-means considerations in the discussion of these topics, which are often addressed without direct reference to economic perspectives. As with any economic investigation this, in turn, obliges consideration of all the elements that contribute to an economic assessment and these range, at least, from the sociological to the technological.

Whatever may be our personal circumstances, changes in technology touch every facet of our lives (e.g. Rosenberg 1971, 1976, 1982). Accordingly, this means that, in considering the problems of changing technology that are peculiar to agriculture, we can usefully draw on experiences beyond the agricultural sector to help guide a search for essential features and instructive insight (cf. Evenson and Ranis 1990). This thought has led to the central thrust of this essay, namely, the exploitation of analogy in a search for fresh understanding. The discipline of agricultural economics, hybrid that it clearly is, draws routinely on analogy from its several parent disciplines, including those of the agricultural sciences and the science of economics. It may not then be too surprising to find this agricultural economist groping for helpful analogies.

Two particular analogies are proffered here, one for each of the topics of adaptation and adoption. Through these it is intended to highlight aspects of the phenomena as they relate to LDC farming, that otherwise may be obscured by the complexities of the reality within which adaptation and adoption are played out. In this way, constructive checklists of the features of each phenomenon can be put together and considered for relevance in agricultural development work (cf. Arnon 1989).

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2. Adaptation

The essential notion in adaptation is making something suitable for a designated purpose, or fitting something in where it was not before. This invokes thoughts of processes of change that lead to the modification of things to fit varied circumstances different from whence they came. As such, adaptation indeed plays important roles for anyone who lives in other than a small, static, closed economy. Adaptation certainly plays crucial roles in agricultural research and, since research is vital in technological change in agriculture and such change is imperative in the economic development of many nations, adaptation thus warrants the attention given to it in this Conference.

The analogy chosen to highlight features of adaptation is that of a person contemplating a change in employment. The reason for the choice of this particular analogy is to be found in the author's contemporary anguish over switching employment from his long-home university to an international development bank.

2.1 Recognising the Challenges and Differences

A person contemplating change, whether it be in employment or in agricultural technique, must reflect on the adequacy of the existing arrangements and the utility that these arrangements bring to all concerned. The latter typically extends beyond the immediate decision maker to other members of the household, and even further. Such introspection is seldom easy. Much information may be needed, and judgment may be required about the prospects for change (for better or worse) from the present situation. Such prospects often depend on the uncertain and usually unpredictable actions of others, including politicians and bureaucrats, on the state of the economy, and on other matters 'closer to home'.

A logical and important first step in this 'recognition phase' is to explore other options that are realistically relevant to the situation at hand. Naturally, the experience of the person, including both formal and informal education, will influence both the understanding of alternative options and the

way in which further information about them is gathered. If, as Schultz (1975) argues, the essence of human capital is the ability to deal with disequilibria, nowhere does this come more to the fore than in the way in which new prospects are assessed, including those relating to employment.

Whatever may be the educational/experiential background, analysis of new prospects must involve access to different types of information sources. There may well be professional journals targeted on particular aspects of 'the new', and there may be opportunities to discover relevant information in more diffused and opportunistic sources, such as newspapers, radio and television.

The final phase of the recognition process consists of an *ex ante* analysis or synthetic overview of all the various informative materials that have been assembled. Naturally, there are specialised tools available for assisting in this process, most notably modern decision analysis (Anderson, Dillon and Hardaker 1977) featuring such aids as decision trees (Raiffa 1968), which lay out sequences of possible actions and possible events in a structured and helpful way.

All these steps for the would-be job-changer have direct counterparts in the assessment of new technology. There are parallels in the way that applied science and social science investigators go about characterising an environment to identify productive new agricultural technologies and, as will be seen later, in the way farmers consider the adoption of changed practices. Grappling with such characterisation may sometimes be described as dealing with locational specificity (Menz and Knipscheer 1981; Dillon and Anderson 1990, p. 170). From other disciplinary perspectives, particularly those involving the adaptation of germplasm, the work might be depicted as comprehending the nature of genotype-environment interactions and exploiting the opportunities they present (Arnold and Innes 1976; Simmonds 1981; Anderson, Herdt and Scobie 1988, p. 15). These may vary greatly over short distances in what may seem rather similar cropping ecologies, as witnessed by the plethora of locally-tuned maize hybrids in the United States Cornbelt. Contrariwise, one of the ironies of the early phases of the Green Revolution is that most of the initial

gains were predicated on the widespread adoption of a few broadly-adapted photoperiod-insensitive semi-dwarf modern cultivars of rice and wheat.

One noteworthy aspect is the way of dealing with variability in cultivar performance that may change systematically with different plant (Arnold and Austin 1989) and animal (Anderson 1988) materials in different agricultural environments. For instance, molecular biologists, plant breeders and agronomists are comparable to job seekers who include in their *ex ante* assessments deliberate accounting for the risks perceived to be involved. These scientists properly seek to discover — increasingly, it is comforting to note — how different genes, materials and methods perform under the much less than ideal circumstances that will occur more or less frequently, but especially more so, in farming situations of uncontrolled water regimes (Anderson and Hazell 1989). Such risk assessment has not always been given due recognition in the work of plant improvement programs but, with the failures of many supposedly improved technologies in less than the most favourable mega-environments, this aspect is now receiving more attention (Anderson 1991). Whether such special attention to work pertaining to ‘marginal lands’ is really appropriate, is a key research policy question that concerned analysts are striving, so far unsatisfactorily, to answer (Graham-Tomasi 1991, Pardey, Roseboom and Anderson 1991, Anderson and Jodha 1993).

2.2 Understanding the Adapted Modifications

Taking first the employment analogy, the new recruit should ideally enter a process of systematic exposure to the culture of a new environment. Many organisations arrange for formal training to assist new recruits to comprehend better their new working circumstances. Such ‘training’ can be interpreted, in part at least, as deliberate behaviour modification, with the general purpose of easing the fit of the new, whilst creating minimal disruption to the existing structures and procedures.

The counterpart of this phase in adaptive agricultural research is to take the new materials that were judged *ex ante* to be promising, and to integrate them into the new environment through such ac-

tivities as cross-breeding in plant and animal improvement programs. The circumstances under which the products are examined and selected in formal experimental designs should be deliberately varied, and the performance of new elements in the target environments should be tested, especially in what has often been called farming systems research (Lagemann 1982). Such activities may be described as applied and adaptive research and are often conducted ‘on-farm’ (Byerlee and Collinson 1980). Determining a good balance between applied and adaptive research and more ‘upstream’ research that may, importantly, contribute to expanding the frontier of agricultural production, is another key research policy issue that, regrettably but understandably, is subject more to anecdote and prejudice than to the results of careful analysis.

2.3 Checking that the Modifications Proposed Really Do Work Well

Organisations have many different ways of dealing with ‘the new’, several of which can be characterised as risk-averse behaviour on the part of the employer. A period of probationary service is often required of new recruits during which time the employer is relatively free not to make “permanent” the intended longer term employment arrangement. The idea is that management should carefully assess performance in the new environment. This will involve the assessment of ability to perform new tasks in the working environment and to conform with its culture (Hunt 1971). Employers differ greatly in the way they choose to use such screening methods and thus in the care with which they assess recruits.

The counterparts here concerning changing agricultural technique usually feature a program of on-farm testing of promising materials, together with some fine-tuning of the new technology to fit better the circumstances found on farms or fields of different types (Byerlee, Collinson *et al.* 1980, Tripp and Woolley 1989). Often, too, the fine-tuning process will involve important modifications made by farmers themselves as they struggle to apply the new methods on their own fields (Biggs 1980, Byerlee and Hesse de Polanco 1986, Chambers and Jiggins 1987). It is usually necessary to conduct such on-farm work over several seasons to

confront a range of climatic and disease challenges, and in this way to assess the robustness of the potentially adapted new technology (Dillon and Anderson 1984).

2.4 Economics of Adaptation

The process of adaptation described above has costs and benefits that differ in their ease of estimation. It is usually somewhat easier to assess the costs of the work involved in adaptation. The cost side of the employment-seeking analogy can be established fairly well, and so too the budgeting implications of a program of adaptive agricultural research. All is not so straightforward on the benefit side, however, as there are several separate considerations. The first relates to the physical aspects of the new situation. In the agricultural counterpart, it will be necessary to describe fairly accurately the physical yield and other technical performance characteristics as a first step in quantifying any benefits. This is a demanding task in the case of variable production environments. The next stage, however, is still more challenging, namely, the estimation of the financial benefits involved in the modified situation. Since benefits of either new employment or new agricultural techniques are earned over time, there is a need to deal with the temporal dimension, usually by discounting.

Whilst these difficulties may be fairly formidable, they are nowhere near as great as those involved in the next step of processing the net benefits into personal value or utility terms. This means, minimally, allowing for the risk aversion of the decision makers involved. This is usually best handled through a (concave) utility function, as are also, in principle, any non-pecuniary dimensions of the decision (Anderson and Dillon 1992, Feder 1980). In other words, the formal methods of decision analysis, already alluded to, provide a framework for such demanding analytic work. The fact that such decision-theoretic frameworks appear to be so seldom used in assessment of job-choice decisions is indicative of the practical difficulty of charting all the elements (Keeney and Raiffa 1976, MacCrimmon and Wehrung 1986).

These several difficulties carry over directly to the

case of assessing the value of adaptation in an agricultural context. For an individual farmer, even considering the simplest case of a new and presumably well-adapted technology involves all these previously-mentioned difficulties and more (Anderson 1985) — including, notwithstanding the approach here adopted and the data indicating vast historical precedent (first paragraph of text), everything to be mentioned below relating to the benefits and costs of adoption of the technique itself. Thus much of the subsequent consideration of *adoption* is also naturally subsumed within a comprehensive assessment of work on *adaptation*. One cannot really make an appraisal of the social benefits of a set of research activities in technology adaptation without due assessment of who is going to adopt and of the extent of adoption, gauged across different categories of farm size, geographical location of operations, and so on. Sometimes such investigations, one ambitious example of which is described (warts and nearly all) by Anderson, Herdt and Scobie (1988), are described as ‘impact studies’. While logically an *ex post* activity, the term is sometimes unfortunately also used for *ex ante* work (Anderson and Herdt 1990, Anderson 1992a). The raising of the adaptation/adoption links thus makes this an appropriate stage to consider the second topic of this essay, namely, adoption.

3. Adoption

The main idea in adoption work is that something is taken from somewhere or someone else, or that a choice is made to do this. The word ‘taken’ may perhaps be used too literally in this dictionary-style definition, since most agricultural adoption phenomena involve the outlay of scarce resources. Thus it is more ‘buying’ than ‘taking’ that is usually involved, although when taking, borrowing, or even stealing are possible, they offer clear economic advantage.

Such may be the case also for the further analogy chosen to illustrate this topic, which is a decision faced by many people several times during their lives, namely, the purchase of a replacement motor vehicle. Because of its familiarity, it is believed that the several stages involved in deciding about a new vehicle are well and widely understood, perhaps more so than are the analogous steps that a

farmer goes through in deciding whether or not to adopt a new farming technique. By exploring the analogy with a vehicle purchase, it is intended to place the multi-stage nature of decision making that necessarily surrounds a choice of new farming technique in a familiar setting. Such a setting is relatively free of the jargon of rural sociology and other disciplines that have contributed to the vast literature on adoption of new agricultural technologies (reviewed, e.g., by Feder, Just and Zilberman 1985).

3.1 Establishing a Mind-Set for a Change

Times and needs change and a first step in deciding about changing vehicles is to recognise that the old one is depreciating, that new technological options are available, and that the repair and maintenance costs will be lower on the new than the old, at least in expected terms. A positive attitude towards change usually requires that the decision maker comes to realise a degree of dissatisfaction with the present, as was the case for the employment-change analogy. If the present is demonstrably unsatisfactory, such as featuring regular disappointments and breakdowns, the process will be energetically sparked. On the other hand, the realisation may come through hearing about new possibilities, perhaps through the advertising media or through observing what others are doing.

The agricultural counterparts of all this are readily apparent in observing farmers reflect on the satisfaction or otherwise that they perceive for their present techniques (Lindner, Pardey and Jarrett 1982). As well as the electronic media and the activities of input suppliers, they may also have the benefit of an extension service that purposely brings new things to their attention. Orchestrated field tours and farm visits may make farmers more aware of what others are doing. The important thing is that an attitude of enthusiasm for change is arrived at, which is a pre-condition for subsequent stages of the adoption process.

3.2 Learning the Particularities

Once one is 'in the market', the process of learning about the particular new possibilities develops. Most directly for the vehicle analogy is the test

drive, whereby someone actually gets into the new product and can assess its performance at first hand. In the counterpart on-farm situation, farmers may carefully observe what their neighbours are doing, and perhaps also indulge in pilot testing (partial adoption) to learn about the possibilities and how these might suit their own circumstances.

A related stage is deliberately to gather performance data on the new. In the vehicle case, there are many trade journals available and independent reviews by automotive writers and others to help the would-be buyer determine the suitability of the new product for their personal needs. Analogously, farmers engage in a process of seeking to discover other people's experience and views of a new technology. Sometimes such material is assembled in digested form in farm journals and specialised television and radio programs, for instance.

3.3 Implementing the New

Again, there are several sub-stages involved in the process of implementing a decision to adopt. First, consider the analogy of the vehicle purchase, since there the sub-stages are usually well structured and differentiated activities. Early on comes the arranging of finance for the purchase. Perhaps the transaction is being made out of current resources and, in such case, there may be no 'problem'. Perhaps more typically, a purchaser of a new vehicle will enter into a credit arrangement, quite likely using a scheme that is deliberately tailored to the automotive market.

It is often most convenient to arrange also for insurance of the vehicle at the same time as finance. In fact, most lenders will oblige the purchaser to hold a particular type of policy in order to protect the loan. The insurance industry has its own subtleties, not all of which are easy to comprehend, and it may prove difficult to gain perfect information about the market. Additionally, some purchase schemes involve contractual arrangements for repair and maintenance plans, which is really a specialised insurance scheme going beyond mere ownership. The actual purchase is the consummation of all this and features a handover of the keys, filling the tank and driving off with fingers and toes

crossed about after-sale service and the behaviour of other drivers.

What do these several stages tell us about the farmer adopter? Certainly it will be necessary for the farmer to plan carefully for the adjustments in resource use, including perhaps credit, with also possible links to crop insurance, and to consider carefully the risks (Feder 1980, Anderson and Hazell 1993) in the implementation of a new farming technique. Sometimes the adopter may prefer to take up just some elements of the package without going for the whole of the new technology, and in this way may be denied access to what may be subsidised rural credit and insurance schemes that are being advanced for the 'package' of new technology (Perrin *et al.* 1976, Biggs 1980). This may be because the individual's farm circumstances are such as not to warrant the full package. In this case, especially given individuals' differences in perception of, and aversion to, risk (Anderson and Hamal 1983, Szmedra, Wetzstein and McClendon 1990) such choice might well be perfectly rational, and would be seen as such if the farm circumstances were fully comprehended by outside observers (Jansen, Walker and Barker 1990).

3.4 Economics of Adoption

As for the case of adaptation, all the above steps have their costs and ultimately, perhaps, benefits. As noted in the discussion of the economic evaluation of adaptation, the evaluation of adoption involves many closely related steps, including documentation of experience with performance and satisfaction with 'the new', including the maintenance and safety features observed as it is used, whether it be a motor vehicle or an agricultural technique.

Any full-fledged economic investigation of adoption of a particular new agricultural technique is, as has been noted, a necessary step in the corresponding evaluation of the adaptive R&D process that may have contributed to its articulation. It is in this sense particularly that the two major concepts in the title of this essay are so linked, notwithstanding their intrinsic differences.

4. Cautions

Before attempting to draw conclusions from the above, let me take advantage of the points made by my friend and erstwhile institutional colleague, Gordon MacAulay, in his discussion of my presentation. MacAulay considered that there may indeed be merit in the analytical approach of 'dividing and conquering' that is taken above. He was less enthusiastic, however, about the approach of using analogies. His concerns were several, including the inherent limitations of any particular analogy to capture the many subtleties of something potentially as complex as a new agricultural technology. His expressed preference was to seek analogies linked into the process-innovations and product-innovations literature and, in his judgment, an analogy based on the birth of a baby may have been a more fruitful one. More generally, he considered that a range of analogies would really be required to do full justice to the more complex topics. Space limitations discourage me from extending my range of analogies.

MacAulay implicitly argued that I have made insufficient use of my identified steps because there would be, in principle, opportunity to use such identified steps (a) in choosing research areas where high payoffs may be obtained, and (b) designing interventions that would have more rewarding or better outcomes in both adaptation and adoption. He speculated further that there may be implications for who should pay for different research and extension activities within the processes of adaptation and adoption. For instance, such work might help identify more precisely at which stage governments may justifiably be involved. Most substantively, MacAulay argued, convincingly I think, that the processes involved in both adaptation and adoption are intrinsically so interlinked that they cannot really be considered separately, as has been done above. He rightly saw a continuum of issues based on adaptation of existing techniques before adoption, adaptation during the process of adoption, and adaptation after adoption with the aim of dealing with difficulties in local application of a technique. In this regard, he cited the important case of international adaptation of technology, particularly through the transfer of people and knowledge from one country to another, such as docu-

mented by Hayami and Ruttan (1971, p. 175).

In raising, but not answering such questions and others, MacAulay implicitly made a case for further examination of the economics of both adaptation and adoption and for study of both the dynamics and separability of these processes. It was not my intention to imply that they were indeed sequential and I would be the first to agree that some aspects of adaptation and adoption must necessarily be simultaneous, at least for important subsets of agricultural technologies. He cited the work of Knudson (1991) as pertinent in indicating dynamism through changes in the parameters of such processes in response to other exogenous variables. All in all, it seems that we still have far to go in seeking comprehensive understanding of such phenomena. I agree with Gordon MacAulay on this point and thank him for his assistance in finalising this essay.

5. Conclusion

What then are the main messages from all my stepwise analogies? A central proposition is that farm-dependent information is critical both in the assessment of whether a technique is sufficiently adapted to farm circumstances, and of whether a farmer or farm household will sensibly choose to adopt such an 'improved' method or technique. A key characteristic of such data is that they are difficult to elicit, usually rather specific to particular farm and environmental circumstances, and generally not easy to incorporate into formal models. Such difficulties may explain why the processes of adaptation and adoption may well be 'under-studied' by most of the professionals involved, ranging from earthy agronomists to exotic anthropologists. The information sets are expensive to assemble and it is a continuing 'good question' as to just how many resources should be devoted to their collection and analysis, as opposed to standing back and letting the processes develop naturally, unimpeded by such comprehension. This is a second-round level of consideration that has too rarely been addressed, but the more I consider it, the more pessimistic have I become (Anderson 1992b). While unreasonable haste may be the direct road to error, the careful studious route may never reach its destination.

Thus a final common theme between the two big 'A's, which can surface by way of conclusion, is that both processes involve costs, risks, and uncertain benefits. It should not surprise that many instances reveal technological failures in the sense that, say, a program of adaptation does not succeed in making worthwhile technological progress, or that a program designed to foster the adoption of some technique thought to be useful fails because the benefits do not adequately compensate the costs and risks faced.

Only by looking at the elements that properly must be addressed in sequence in each process can such failures (or, indeed, successes) be adequately understood. A 'black-box' approach to studying adaptation and adoption can hardly be expected to be revealing, and failure to examine the components carefully will lead only to opaque and rather sterile findings, such as concluding that adaptive research either succeeded or failed in some instance, or that an improved technology was either adopted or not adopted under specified circumstances. To make both processes more economical in attaining greater expected social gain, we should look within their structure to the steps of decision and points of intervention, such as have been detailed herein by means of imperfect but hopefully revealing analogies. My analogies may require further adaptation but, if comprehension of change mechanisms in rural areas is assisted, the stepwise framework may warrant some cautious adoption.

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