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Putting Research into Use: A Market Failure Approach

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Abstract

This paper explores innovation and technology development aid targeted at the African rural poor but often failing to deliver benefit. Using five cases of UK bilateral aid (current and historic) it suggests the prime importance of securing continuous knowledge interaction across the whole of the relevant value chain, combined with the need for institutional reform of science policy in this field. The paper's approach emphasises the underlying problem as an inherent tendency to failure in knowledge markets combined with often unsuitable institutional contexts.

Keywords: Innovation, development, agriculture, science, policy, aid

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RIU DISCUSSION PAPER SERIES

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1 Introduction

An increasingly important set of issues concerns how best to connect scientific research carried out in advanced research institutes (and usually funded by donors) with technology development aid to poor countries. This is so especially in relation to aid targeted at the rural poor. Very often considerable sums of money are spent but impact on welfare is hard to demonstrate. This paper suggests ways of thinking about this issue analytically in terms of a "market for knowledge" and how such a market is failing to allocate resources optimally. However, a knowledge market is different from a normal factor or product market in at least one important respect; that is the production value of knowledge is dependent on context. It will have a "value" in terms of cost of production (a supply price) but how that knowledge is valued in use is an entirely different matter since this will depend on the specific context[i]. And that varies over time and space. In industrial development this asymmetry between demand and supply is normally managed by the industrial firm whose investment activities throw up knowledge problems that can be managed either by the firm's R&D department or by recourse to external supplies of knowledge from the wider science system[ii].

But in the case of development aid such a bridge between demand and supply is usually much more difficult to establish. Indeed very often "knowledge" is largely supply driven and frequently bears little direct relationship to development problems. This paper explores the issue from the standpoint of rural technology development in African less developed countries. It will begin (section 2) by setting out the market failure issue in general terms providing a brief historical backdrop and setting out why this appears to be a structural problem of science policy often involving considerable economic costs. It will then go on to illustrate an alternative model using five case studies of technology development. These suggest a model of technology development that is more evolutionary in focus. Instead of the traditional disconnected approach with different organisations specialising in their own activities the cases suggest a "seeding" approach somewhat akin to that of open systems behaviour. A central role in this is complementary private sector development involving "below the pyramid" entrepreneurship and dynamical linkages of the kind first suggested by Hirschman in the early 1960s[iii].

The five project cases, which cover a mixture of crop and livestock interventions designed to alleviate rural poverty, are summarised in Section 3. They are/were all assisted by British overseas aid. The first two draw from events some 40 or so years ago and focus on technology interventions that appeared at the time to have had some initial (albeit temporary) success. The other three are contemporary projects funded as part of the UK Department of International Development (DFID) *Research into Use (RIU) Programme*. The RIU has now been operational for five years and has been designed as an innovative mechanism to capitalise productively on some of its previously funded research (over the period 1995-2005)[iv] in the renewable natural resources sector (RNRRS). These latter cases have been drawn from a range of projects specifically targeting private sector activity. Data on these have been gathered from a series of interviews and meetings with project staff over the period 2010/11. The cases are public/private partnerships designed to mobilise private sector resources that will ensure continuity once public funding has ceased. As such they demonstrate an approach to agricultural extension that is quite different from standard approaches that rely heavily upon a strict division of labour between the research function and the application function

2 Science Policy

“Market failures” occur where markets fail to allocate resources optimally; that is resources could be re-allocated to produce greater benefit at lower cost. Of course this issue is a generic one that transcends technology development for poor countries but perhaps it should be seen as an extreme example in the case of rural technology development aimed at the poor. The problem of science policy in relation to poor developing countries is a difficult one. For a variety of reasons many of these countries are locked into patterns of production which not only do not provide adequate levels of consumption for their citizens but also do not contain within themselves the means for escape. There are two aspects here. One is that the economic system finds it hard to react to changing demand conditions through a smooth re-allocation of resources. There is, therefore, a strong propensity for bottlenecks to arise and tendencies towards stagnation to develop. Secondly, the economic system does not possess the means to advance technically and hence the rate of growth suffers. Both aspects are interrelated since an adequate technological infrastructure is an important ingredient in economic transformation and since the possibilities for economic progress act as a spur to technological change.

These features may readily be seen (by contrast, as it were) with reference to the integrated economic systems of the industrialised countries where there generally exists a complex scientific system whose services may be drawn upon fairly readily by productive units. Typical components of such a system are the R & D departments of firms, specialist engineering and consultancy firms and the network of institutions in the public 'research' sector which possess a wide range of scientific and technological facilities of relevance to the business of economic production. Moreover such an integrated scientific system is the product of historic evolution in which a complex network of links between science and production gradually developed in an organic fashion. In contrast, for many developing countries the very absence of such a set of systemic links is at one and the same time both a feature of underdevelopment and (arguably) an obstacle to its removal.

Historically the role of science in poor countries has been viewed very much from a modernising standpoint. Since industrial advance was associated with investment in science and technology in rich countries, it was felt that the quicker the developing countries built up their own corresponding capacities the better. This could be done by establishing science curricula in schools, opening universities and technical colleges with substantial science departments, establishing a network of institutions connected with research and scientific services and taking full advantage of foreign aid and technical assistance. Although there might be teething problems, there was general optimism about the long-run advantages that science and technology would bring. For industrial development foreign direct investment was also to be encouraged since it could provide developing countries with direct access to best practice technologies as they were being currently utilised in the rich countries.

However, in development agriculture this modernisation agenda has proved hard to achieve with livelihood standards continuing to decline despite growing investment in relevant science. In an early article Biggs and Clay (1981) pointed out that one reason for this is the relative alienation of institutional science where the "pursuit of knowledge" conventionally takes place under conditions of controlled experimentation i.e. on experimental stations where results can be reached which are independent of widely varied contexts. Conversely, one cannot achieve replicable and publishable results by 'experimenting' directly with subsistence agriculture.

In recent years this 'top down' approach to agricultural technology development has been confronted by an alternative model of technology transfer in which relations between science and production are viewed in a decentralised holistic way[v]. Here the focus is directly on the specific context as the locus of developmental attention with scientific inputs considered as only one resource along with many others necessary to enhance livelihoods, including for example the 'informal' knowledge possessed by the farmers themselves, as well as material inputs (seed, fertilisers etc.) and credit provided by central agencies. There have been a number of examples of this approach. As outlined above we shall use five cases, three of which are part of the current DFID Research into Use (RIU) portfolio and two from an earlier period. One of the latter concerns livestock disease control in East Africa and the other examines a DFID (then ODA) watershed development project in South Asia. The two earlier ones appear to illustrate examples of an effective knowledge market being created which subsequently failed for institutional reasons. The three recent cases represent attempts to develop new types of institutional structures which could promise relevant success. Our discussion and conclusions outline policy lessons that follow.

3 Project Cases

3(a) Livestock Disease Control [ILRAD]

An important disease that has affected African smallholder farmers for well over a century is that of Theileriosis or East Coast Fever (ECF). It is caused by a parasite spread by a vector [the brown-eared tick] and leads to debilitation and death of cattle. Demand for a solution to the problem of ECF had been expressed by scientists from the colonial era who were in constant touch with district veterinary officers (DVOs) in the field. Rather like the original American land grant system, colonial agricultural systems had a far-reaching extension service staffed with professional expatriate staff. DVOs and researchers would often have been together at university and at induction courses and so had close relationships. Demand for a vaccine for ECF was met by a lengthy research project started in colonial Kenya and completed in post colonial Kenya by British researchers (funded by ODA-then ODM) who developed the 'infect and treat' method (ITM). ITM simply involves infecting cattle with infected salivary glands of ticks (raised in a laboratory) and then treating the cattle with a simple antibiotic as they become infected. This confers immunity to subsequent tick-borne infections in the field.

However, in the early 1980s the post-colonial researchers who had worked on ITM were absorbed into a new international research centre called the International Laboratory for Research on Animal Diseases (ILRAD) and became 'international scientists' - unfortunately losing their ties with the field as structural adjustment policies began to impinge on extension services in the post-colonial era. The two-way process had been lost. Researchers in ILRAD then became ever more estranged from farmers and pursued high-tech solutions rather than trying to improve their ITM technology. The high tech solution for ECF was that of using modern molecular biology to develop a laboratory-based vaccine. Eventually these attempts were discontinued as it became apparent that the biology of the parasite was too complex to admit of any easy solution but this has only recently happened (2006). There is now an attempt to return to the ITM approach using private sector resources.[vi]

3(b) Indore Project

In this case a watershed of 2,000-3,000 ha. in Madhya Pradesh in India was made the focus of concern. Scientists were brought on secondment from a national university (located some distance away) and were charged with a directly productive function - that of increasing yields per hectare over the whole cultivable rain-fed area, with particular attention being given to the smaller farmer. A research station was established and the project was funded over six years. In this way scientists were forced into a position of having to pool their various specialist types of knowledge within a given productive context and were not able to leave technology transfer to a public bureaucracy. More specifically the elements of this approach were:

i. The existing technology[vii] was surveyed for the area and the key deficiencies isolated and defined, particularly those affecting the smaller farmer.
ii. On the basis of this diagnosis and other inputs, an optimum package was decided upon i.e. crop types, agronomic practices, soil/water improvements, fertilizer inputs etc.
iii. The scientists then worked with the farmers (in an interdisciplinary way) in a phased programme of implementation, feeding scientific problems back to the research station where necessary, and seeking assistance from government agencies where the obstacles were of a more practical nature (e.g. finance, seed availability).
iv. Farmers were encouraged to use their own investment resources but were guaranteed against financial loss in the first few years.
v. There was constant monitoring of technical and social transformation so as to change strategies where necessary.
vi. There was the expectation that imitation outside the project area would begin to occur through a process of technological diffusion (though one operating through a causal mechanism of differential *incomes* rather than differential *prices*).

The results[viii] of the project were actually quite impressive. Improvements took place in the use of fertiliser; there was an introduction of winter wheat and therefore annual double cropping; co-operative land management was begun with the start of bunding (which stopped erosion) and the introduction of the gabion filter to control run off; incomes improved rapidly and there were improvements in income distribution. Essentially, therefore, this project represented a different model of agricultural extension, one in which the transfer of technology was attempted in a decentralized, interactive manner with potentially much less involvement of a bureaucratic hierarchy and with the concentration of resources into a geographical area within which similar techno-economic problems would be faced. Farmers were provided with very little in the way of a direct subsidy. On the other hand they were guaranteed against losses and the expectation of the model was that improved practices would be taken in neighbouring areas through a process of emulation and diffusion, the technology being modified to meet changing conditions as required. However, the project was a time-limited one that ended in 1980 with the cessation of donor funding, the closing down of the field station and the return of the scientists to their home university.

3(c) Farm Input Promotions [FIPS-Africa]

FIPS-Africa is a not-for-profit company based in Nairobi, Kenya[ix]. It is largely donor-funded but generates also a small part of its own income. Its mission is to improve the agricultural productivity and livelihoods of small-scale farmers in SSA. Here marginal farmers produce very little on small farms (<1 ha), working on impoverished soils, using local varieties susceptible to disease (including Maize Streak Virus and Cassava Mosaic Virus), and drought. Improved crop varieties are available at the local research stations but farmers are generally unable to access them. Farmers often grow crops which are poorly suited to their environment, e.g. maize, which is often grown where it does not receive sufficient water or soil fertility. Poor farmers are unable to afford most farm inputs (in the standard retailed quantities), which in turn constrains the extent to which they are marketed in marginal areas.

To address this issue FIPS-Africa has developed and implemented an innovative methodology to improve small farmers' access to the appropriate farm inputs, and information on best use. Its aim is to reach as many farmers as possible as quickly and cost-effectively as possible. To this end, it works closely with scientists in the national agricultural research centres and private sector seed and fertilizer companies. Close links with the private sector ensure continued supply of farm inputs after funding has ceased. Essentially FIPS operates the following activities:

(i) *Input supply*; This involves working with private sector input suppliers and retailers, the research community and private extension providers to promote the sale of small packs of affordable non-subsidised farm inputs, to develop the supply chain, and to make sure that appropriate inputs are accessible to farmers. FIPS-Africa's small packs are very cheap (e.g. tomato seed for 1KES) and are affordable to even very poor farmers enabling them to experiment with very limited risk.

(ii) *Technical advice*; FIPS-Africa develops networks of village-based agricultural advisers in target districts. These advisers are recruited from a variety of backgrounds but all have demonstrated the capacity to build trust relations with local farming communities. Each adviser works in 5 villages with a target of 1000 farmers/year, although some go well beyond this. FIPS-Africa offers a range of services including: conducting demonstrations, selling small packs of seed and fertilizer, holding field days, establishing bulking sites of cassava and sweet potato varieties, establishing tree nurseries and vaccinating local poultry against Newcastle disease. Advisers sell farmers a range of seed varieties e.g. new varieties of maize, phaseolus beans, cowpea, cassava, sweet potato, cowpea, pigeon pea, pumpkin, tomato and lablab. They also sell improved fertilizers in small packs, teach farmers how to make compost, how to space seed and place fertilizer correctly, how to identify and break soil hard pans and how to harvest rainfall.

(iii) *Business development;* FIPS-Africa encourages its advisers to generate income from selling fertilizers and seeds, directly to farmers. Advisers also generate income from vaccinating local poultry. This motivates staff to reach more farmers, and provides an exit strategy for staff after cessation of donor funding. In addition FIPS-Africa works closely with two firms in the private mining sector to supply small affordable packs of fertilise input thus creating jobs in the formal sector. The intention is to formalise this relationship so as to enable FIPS-Africa to benefit financially.

The FIPS-Africa programme has been operational for some 6 years and has now grown in scale in Kenya and into Tanzania[x] (with plans for movement into Rwanda and Uganda). There are now 15 regional advisers who have themselves recruited around 10 extension workers each to cope with increased demand. Both advisers and workers operate as independent businesses. FIPS-Africa supplies resources in the form of seeds, materials and technology but these resources have to be repaid, similarly with the farmers in a cascading outreach. In this way the project creates income, output and employment in poor rural areas (including youth employment). It also creates a spirit of independence among all actors.

3(d) Stamp out Sleeping Sickness(SOS)[xi]

Sleeping sickness is used to describe two quite distinct diseases caused by different sub-species of *Trypanosomabrucei*: *Trypanosoma brucei gambiense* and *T. Brucei rhodesiense* are both human infective; the third sub-species, of *Trypanosomabrucei*, *T. Brucei*, is morphologically indistinguishable from the others, infects a range of mammalian species both domestic and wild, but is not human infective. *T. B. Gambiense* and *T. B. Rhodesiense* are invariably fatal in humans if left untreated. These two diseases have distinct clinical pictures and their discrete geographical distribution across Africa serves to emphasise these differences; understanding these biological, clinical and epidemiological differences has been crucial in devising effective methods of disease control and in defining health policy in relation to sleeping sickness. One of the main factors stimulating current remedial measures is the fear that spread of the two strains is threatening poor populations in Uganda. Cross impact of the two parasites could lead to major problems in diagnosis and treatment of the disease.

The Stamp out Sleeping Sickness (SOS) project has now been operational for some 3 years. It is currently being run through a loose consortium based at the Faculty of Veterinary Medicine (FVM) at Makerere University, Uganda. Stakeholder interests include cattle owners, district veterinary officers, universities (mainly Edinburgh and Makerere), the corporate sector, local private sector companies, donors, and national regulatory authorities. The component being funded by DFID through RIU is an attempt to develop long-term sustainability through a public/private partnership designed to create small veterinary businesses, the argument being that unless steps are taken in this direction veterinary care will continue to remain within the province of charities such as NGOs and the "corporate social responsibility (CSR) activities of international private companies. As such it will remain a "dependent" activity reliant on outside inputs and in this sense not integrated into national capacity building. The challenge is really one of how to bring this new sustainability about.

The FVM is attempting to do this by creating a new *Institute for Strategic Animal Resource Services (AFRISA)* linked to (but financially independent of) the University of Makerere. Part of this new institute programme is a body designed for in-training community service delivery. The University sees this as a generic mechanism for equipping graduates for a labour market that is no longer satisfied by the supply of traditional university degree-holders. Instead the demand is for graduates that not only possess saleable business skills but are also capable of actually generating their own jobs virtually from scratch. Under this programme (which is still at a formative stage) veterinary students spend the final year of an undergraduate degree entirely in economic production activity producing at the end a project report that is assessed as a key component of the final degree. In the SOS case and in co-operation with a private veterinary company, final year undergraduates participate in block treatment of cattle and ancillary spraying activities. A small number of these undergraduates have set up as small "agrovet" businesses under the supervision of the private veterinary company. Phase 2 of SOS activity began operations in January 2010.

3(e) Real IPM-Biological Control Agents (BCAs)

The Real IPM Company established in 2004 is based on an old coffee farm near Thika, Kenya[xii].Real IPM's income comes from: training, consultancy and BCAs. Almost 80% of its income comes from the sale of BCAs to Kenya's export horticulture industry. The company has two categories of BCAs (i) predatory mites e.g. small spiders; and (ii) beneficial microbes (bacteria or fungi). It breeds and produces 10 to 20 million predatory mites per week[xiii]. It had a turnover of Ksh 71 million in 2009 and now employs over 80 permanent staff. In Kenya about 50% of flowers are treated with bio pesticides and about 50% of this is supplied by Real IPM. Ten years ago bio pesticides were hardly used but are now increasingly in demand due to retailer standards and international regulatory pressures. The 2008 recession spurred Real IPM to consider alternative markets to export horticulture. With export horticulture dominating its sources of income it identified the millions of smallholder farmers in Kenya as an alternative market However, without donor support, Real IPM was unwilling to enter this little understood market (there are no BCAs registered for use on domestic cereal crops in Kenya). The registration procedure was supported by the Agriculture Enterprise Challenge Fund (AECF) which provided a grant and a refundable loan

The project is promoting two products, a pack of the biological control agent and a pack containing soluble nutrients which are to be used in seed priming. Seed priming, to get early, uniform and more vigorous crop establishment, is a technology that was developed under the DFID RNRRS Plant Sciences Programme, particularly through research led by the University of Bangor. The striga control agent *Fusarium Oxysporum* (Foxy 2) was developed by the University of Hohenheim and is currently produced by an overseas firm. The parasitic weed Striga, often appearing on infertile or degraded soils, is a pest of a number of crops, particularly cereals. A number of methods for its management are being investigated – host plant resistance, development of IR maize (enabling the application of post emergence herbicide), push/pull and other systems of boosting soil fertility[xiv]. All approaches have advantages and disadvantages but the adoption of a Striga control strategy is likely to depend upon farmer awareness of the problem.

Almost all of the farmers in Western Kenya save their cereal seed from year to year (overall in Kenya the figure is 70%). The potential for crop devastation from striga makes farmers risk adverse and this deters them from investing in their crop, e.g. in fertiliser. 91% of farmers registered by Real IPM have a mobile phone although 100% have said they had access to one. Illiteracy is high and the project has learnt that farmers are therefore less likely to respond to text messages than calls. Variations in the weather have made it hard to follow a season and this means that Real IPM field staff have to be alert to the weather in terms of getting plots established.

In January 2010 the name “Stop Striga” was agreed and registered and the pack designed. The initial procedure was for the seed to be primed by soaking it overnight in a soluble solution and then Foxy 2 is applied just before planting. For the first planting (early season 2010), 77 farmers (target was 50) were selected and trained in seed priming with a phosphate solution. They were given close support throughout the process. In the first planting of primed seed yield data were very unreliable because of inaccuracies in area planted and weight harvested. During this period the Real IPM team began to consider the marketability of the phosphate fertiliser component of the Stop Striga pack. The phosphate that it had been recommended, being laboratory grade, would put the price of a Stop Striga pack beyond the budget of most farmers. An investigation into alternatives took place. Single Super Phosphate (a common source of fertiliser) was found to burn the seed but by June a good and affordable alternative source had been identified; 6g of fertiliser (0.12KES/g) would be needed per packet that mixes with c. 2 Kg of seed. This product could be sold as a stand-alone product and the trade name Gro-Plus was agreed and a pack and instruction designed. Producing 25,000 packs was estimated to cost KES35 per packet; 50,000 would cost 25KES.

To date therefore, much of Real IPM’s work has been a marketing one, setting up a database of potential poor farmers. Using a combination of data mechanisms such as smart phone contact, text messages, interviews, barazas, churches, shows and field days the company is concentrating on reaching as wide a range of demand as is possible. For example, the IPM team have developed a database of the Nyanza administrative area with contact points at Province, District, Division, Location, Sub-Location and Chiefs, with their mobile numbers. The Provincial Commissioner and the Provincial Director of Agriculture were briefed on the project. The Provincial Commissioner has given permission for meetings to take place and this has cascaded down. Through this barazas have been called to identify the good farmers. Three quarters of chiefs contacted have called meetings for Real IPM (Nwakiri district). The barazas include men and women; the largest has had 500 people the smallest 40 and 100 is typical.

4 Discussion

Arguably each of these cases represents an attempt to reduce market failure in the supply of and demand for knowledge. In the livestock ECF disease case the “demand” for a solution had been met in the colonial period by means of a set of close networked relations involving scientists on the ground, farmers and DVOs. This achieved the development of a live vaccine in the 1970s that although needing more research, had begun to show considerable success. However, the approach was then abandoned in the face of a search for high-tech solutions within large international laboratories. Since the supply of relevant knowledge then effectively disappeared the market began to fail and is only now recovering 30 years or so on. In the Indore case a decision was made to put together a team of scientists on an experimental station who were then charged with development. The initiative worked well in a developmental sense but failed as soon as the project ended and scientists returned to their home university. While the project was on-going the knowledge market functioned well. When it ended it failed. The question then follows; what is it that brings about such market failures?

We believe that the problem is institutional in nature. In poor countries dominated by subsistence farming it has long been recognised that technological change requires public sector intervention in some form or other. As far as R & D is concerned the appropriate vehicle is held to be the publicly financed applied research institute set up to perform relevant research regarding particular forms of agricultural product[xv]. The expectation has always been that such bodies will produce ‘knowledge’ which will ultimately benefit the poor farmer. Here, a major problem has been one of ensuring that scientific advances made in research institutes are communicated to farmers in ways that ensure derived technological changes can be readily adopted. The traditional means of bringing this about has been the agricultural extension system. Agricultural ministries take on the responsibility of developing technology ‘packages’ based partly on research material produced by research institutes which are put together in a form which can be understood by subsistence farmers. The actual task of communicating these packages and the provision of relevant material input is given over to extension agents, normally secondary school or university graduates who are provided with a little extra training in agricultural development problems and who are normally given responsibility for a certain geographical area.

The general view now is that this model is fraught with difficulties for at least six reasons:

1. It is enormously expensive in its use of resources. Extension agents have to be trained in a range of appropriate skills and *enough* of them have to be so trained to allow for a reasonable amount of client coverage.
2. The sheer magnitude of the problem also defies description. Anderson (2008), for example, maintains that “one can assume based on earlier surveys that typical farmer-to-extension

agent ratios are in the range between 1,000 and 2,500 to 1"[xvi]. When account is taken of the relative lack of experience of extension personnel, time constraints, language difficulties and distrust of them as 'outsiders' on the part of farmers, it would not be surprising if contemporary evidence concluded that agricultural extension workers have so far had little substantial impact on productive practices in rural agriculture[xvii]. And indeed it does appear that in many parts of the world extension agencies are able to do little more than scratch the surface of the problem.

3. A third factor is the sheer complexity of agricultural technology. Since, as Biggs and Clay (1981) pointed out some time ago, this is essentially systemic and locationally specific the character of technical change is not something that isolated extension workers can handle. Yields per hectare (and hence rural livelihood improvements) will only rise to a new best-practice plateau where all the necessary elements in the technology are handled correctly. Simply to introduce changes in one or two components will not do the job – indeed it may actually reduce output and incomes with devastating effects on poor families.
4. A fourth factor is that of risk and uncertainty. The perceived risks to the farmer in changing established practices are very great simply because he is normally operating at or near subsistence level. This produces an inherent asymmetry. If a recommended change turns out to be successful, perceptions of risks with respect to any subsequent change are not likely to change significantly. If, however, it turns out to be unsuccessful, the farmer may take the view (not unreasonably) that henceforth representatives of agricultural extension systems are not to be trusted.
5. A fifth problem with this approach is that it tends to take little account of traditional 'informal' R & D which represents an important and continual source of technological change in subsistence agriculture. Institutionally it does not facilitate the integration of traditional knowledge into the technology packages of the extension agents. Nor in general are these agents in a position to carry out this sort of integration exercise themselves.
6. Finally note should be taken of the ways in which local political interests shape the orientation of agricultural development assistance in ways which benefit particular ethnic groups and particular classes of farmer (often the larger capitalist farmer).

Hence, the vertical, specialised system of agricultural extension is now increasingly seen as costly, clumsy and inefficient[xviii]. Nevertheless, there are two major reasons why it continues to be the dominant mode of rural technological change in many poor countries, and these relate to vested interests and perception of employment. Thus in most developing countries there is now a substantial public bureaucracy associated with the provision of extension services and ancillary activities. To close such a bureaucracy down or to alter radically its nature will in many cases be seen as threatening jobs and resisted accordingly. A second reason concerns the professionalization of agricultural science and the ways in which agricultural scientists view, and value, their work. Here 'good science', in the sense of the empirical pursuit of knowledge, can only really be practised under conditions of controlled experimentation i.e. on experimental stations where results can be reached which are independent of interfering factors. Conversely, one cannot achieve replicable and publishable results by experimenting directly with subsistence agriculture. Given the reward system associated with science as a profession, therefore, it would be very surprising indeed if agricultural scientists strayed much beyond the confines of their laboratories and trial plots.

Far simpler, is it not, to pass the job of transferring knowledge to another branch of the public services? And indeed this is standard practice, the justification being that the proper role for the agricultural scientist is that of the establishment of basic principles the detailed application of which is somebody else's concern. Furthermore academic alienation of this type tends to deepen since in the face of lack of demand for their services research institutions tend gradually to sink back into the role that they know best – that of the disinterested pursuit of knowledge – often encouraged by the organisations which provide them with their resources, the donor bodies and their advisory science councils which themselves are staffed by senior scientists brought up in the conventional tradition.[xix]

The three RIU cases represent a more recent approach to technology development. They are similar insofar as they improve knowledge market efficiency but differ in their business development focus. In the case of FIPS the creation of "bottom of the pyramid" demands from poor farmers appears to have spawned a positive feedback loop that is allowing welfare improvements that are self-sustaining. In the Real-IPM case a private sector organisation is carrying out the developmental research necessary to introduce an imaginative technology solution to a major problem impacting on poor farmers. In the AFRISA/SOS case (which is really the newest) the establishment of the 3V agrovet shops (under the supervision of a local drug firm) is expected to act as the seed corn of a new set of local entrepreneurs that will scale out on a business basis supported by the private and the university sectors.

Here we have something akin to a biological model of social development. Innovations are articulated in a practical context with a continuing set of problems (both productive and scientific) being thrown up as a result of experience. Some of these are dealt with at a common-sense level by local staff. Others require external help. Some of this might come from the facilitating body (FIPS or AFRISA, for example), others from private sector suppliers like the Real IPM. Yet others may need further scientific input from research stations or universities. But in all cases demand and supply pressures are integrated. In such a context the innovators can never 'get things right' simply because the set of 'right' conditions can never be independently defined. Also, since conditions are constantly changing, problems are dealt with *ad hoc* as they arise, the ultimate test being the extent to which technology and economic development is occurring.

In the Indore and ECF cases this clearly had begun to take place. Scientific and technological activities provided a continuous dynamic to economic production through a continuing series of linkage feedback. In the Indore case the plan was that these relations would continue to exist so long as they remained socially productive i.e. until research constraints of the area had been as fully resolved as they were likely to be, given the level of development of the basic scientific disciplines and the institutional character of agricultural production in that area. In the ECF case closely networked activities among researchers, officials and users contributed to the development of a successful live vaccine.

But in both cases a limit was reached. In Indore the scientific community appeared to feel constrained by being taken out of their professional comfort zone and asked to take on attributes of the entrepreneur and the manager. They were also being asked to relate to each other across disciplinary boundaries, including importantly those of the social sciences. No longer was it considered sufficient for these scientists to produce a 'shelf' of knowledge as his or her sole contribution while the application of this knowledge becomes the responsibility of some other person or group. On the contrary, the transfer of agricultural technology was seen to be akin to its industrial counterpart where successful innovations usually involve close interchange along the associated value chain[xx]. Unfortunately this new professional role was resisted strongly by the Indore scientists since they felt unable to fit their activities with university-oriented incentive structures. And despite the success of the project from a developmental standpoint there was subsequently little follow up on the part of either the donor or the university. The end of donor aid spelt the end of a promising and efficient knowledge market.

For ECF the successful start on a live vaccine was brought to a halt in rather a different way but perhaps with intriguing similarities. In this case the creation of an international research centre provided an opportunity for research on a molecular-based vaccine that might perhaps become a "silver bullet" that would eliminate ECF at a stroke. The live vaccine solution on the other hand would never, it was felt, be other than partially successful since it had begun to need further applied research on field based problems such as dealing with the cold chain necessary to preserve the vaccine in tropical conditions. Such problems did not lend themselves to sophisticated scientific solutions. Rather they involved "trial and error" applied research. Of course this is normal in industrial development and indeed defines the work of the applied engineer. But for agricultural science there was no such capacity. Nor apparently was there the will to create one. Instead the scientific community quickly discovered a mechanism (the large international research centre) to continue on a conventional scientific trajectory.

Here we believe, lies the heart of the problem. In industrial development the knowledge market operates fairly well because demand and supply are closely integrated. The industrial firm knows very well that unless teething problems are dealt with it will be unable to commercialise its innovations. Accordingly it pays close attention to solving the myriad of design and marketing issues that routinely plague any new type of technology development[xxi]. These are not "high science" activities but have usually significant technological content. They also require close interactions along relevant value chains that are normally operated through private sector activity. Conversely in both the ECF and Indore cases the role of the private sector was minimal. This meant that possibilities for using the technologies developed as the starting point for creating sustainable economic value chains either did not exist or were ignored. Conversely in all the RIU cases private sector value chain creation has been an integral part of the story. And it follows hypothetically that an effective and efficient technology (knowledge) market should include the private sector as an essential ingredient.

5 Conclusions

What does this imply for public policy for rural development in poor countries? Our own view is as follows. The need for economic progress is very pressing and there is arguably a strong case for concentrating the resources to which developing countries can get access (including those relating to science and technology) directly on this major goal. However, there is clearly a high level of market failure. And since a very large proportion of scientifically trained personnel are concentrated within the publicly-financed research and university system, this in itself implies the need for a revised role for such institutions. Viewed in this way the (modernising) comparison with scientific systems in rich countries is misconceived since in the latter parts of the world there is a flourishing private sector that can either solve its own knowledge problems or can easily have recourse to the wider science system. Conversely in poor African country agriculture there is no such sector. Demands need to be created in a different way. The organic approach of the three RIU cases seems a likely way forward but it will need public policy support at all levels.

The lead should perhaps be taken by aid donors since they are able to provide appropriate incentives and disincentives. Project technology development aid should therefore primarily be funded if its targets are able to move towards an efficient technology market where supply and demand become effectively connected; that is where the there is a minimum level of knowledge market failure. How this is done will be complex and difficult but there are inspirational models that can be helpful (Anderson (2008). The cases outlined above illustrate two important aspects of the way forward though others could be mentioned. Firstly it is necessary to ensure close integration of supply and demand; in the absence of this there is bound to be knowledge market failure. Secondly the central role of the private sector is crucial since allowing relevant entrepreneurship to take root decreases the need for central bureaucratic control. Very probably also such entrepreneurship should encompass the totality of value chains in the manner initially proposed by Albert Hirschman (1964). In neither the Indore nor the ECF case was this considered important. Indeed it may have been seen as threatening on the part of scientific establishments for old-fashioned resource allocation reasons.

To stress these points, however, is but one part of the story since the making of effective science and technology policy is something that can only be carried through effectively by those who have a deep knowledge of the relevant social, political and economic context. We suspect that a primary ingredient is a healthy scepticism about the benefits of Western science and technology *as currently deployed* combined with a willingness to take on board those aspects which appear to hold out most promise for long-run success. Whatever and however this is done, it is certain that the institutional context will be of fundamental importance. There ought, for example, to be no automatic presupposition that the institutional forms appropriate to, say, the USA in 1960 should have relevance to the development prospects of countries at quite different 'stages' who may wish to choose radically different paths for the future.[xxii]

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i For a detailed discussion of the knowledge market and related issues see Clark (2002)

ii See Bell (2006, 2007) for a detailed analysis of the complexity of these relations

iii See Hirschman (1964)

iv See http://www.researchintouse.com/about/index.html

v There are many sources here but perhaps Biggs (1990), Hall (2004, 2011) and/or Chambers and Ghildyal (1985) summarise the issues as well as any.

vi This 30+ year-old technology is now being heralded as a breakthrough by GALVMED and ILRI (see: www.scidev.net/.../cattle-disease-vaccine-launched-30-years-after-invention). See also ILRAD (1989-1994), Musisi et al (1999) and Clark et al (2007) for more detailed analysis of the ECF issue.

vii We are using the term "technology" as a shorthand for the range of technological capabilities and practices extant on that watershed in that period.

viii For details see Clark and Clay (1987)

ix See www.fipsafrica.org/index.php for more information on this case.

x Recently the technique has been expanded into Nigeria. See www.vanguardngr.com/2011/04

xi For more up to date detail on this case see Clark et al (2007), and www.stampoutsleepingsickness.com

xii See www.realipm.com for more details on this case

xiii One microbe (Metarhizium anisopliae, for the control of adult thrips) which it has commercialised had been heavily researched by ICIPE but never commercially applied. Now ICIPE gets 1% 'royalty' from Real IPM's sale of the fungi.

xiv See Khan et al (2008)

xv The original model for this was the Land Grant system which proved so successful in 19th century America, though its post-war transplantation to developing countries much later on has proved problematic. See, for example, Anderson (1991)

xvi See op cit p11. Anderson uses earlier surveys as sources for his estimate

xvii See, for example, Feder et al (2010) and Rohrbach (2010). Anderson (2010) also provides a useful outline of the demise of the World Bank T&V system after c.1995; see p12

xviii There are many sources going into these points in addition to those cited above. A good general source is the ODI AGREN occasional paper series (see for example Hall et al 2001). See also Leeuwis and van den Ban (2004) and World Bank Development Report (2008) which emphasises a switch to "agricultural services" involving private sector players. Indeed Adolph (2010) in a recent detailed analysis of the area argues that "Public sector advisory services have suffered from cut-backs and reform attempts that often left only rudimentary and poorly resourced services in place, which reach few farmers and do not generally provide up-to-date and relevant information„ (see p iv).

xix Although one seeks in vain for a rigorous conceptual discussion of the epistemological basis for agricultural science practices

xx See Bell (2007)

xxi See Bell (2006)

xxii It has been suggested recently that the stunning increase seen in Brazil's farm production "The Miracle Of The Cerrado" - can be mirrored in Africa (The Economist Aug 20th 2010) by the simple expedient of Africa's agricultural scientists all working together in a "systems approach". The transference of Brazilian systems to Africa sounds attractive at first sight but ignores the many differences between a country and a continent. Indeed, Brazilian agriculturalists tried a simple fix in the 1970's by adopting a "cutting edge" package from the US. Brazilian scientists now acknowledge that this "silver bullet" approach did not work and they had to develop their own package – a process that took over 30 years. The lesson from Brazil is that Africa will have to develop its own systems, country by country, to improve agricultural productivity and so reduce poverty. A similar point can be made about Collier's (2008) advocacy of policies supporting *inter alia* large scale commercial farming in poor countries which avoids the issue of how this is to be achieved within a reasonable time frame. It took Europe through enclosures and early industrialisation some 200 years. Stalin managed it in a decade and with appalling social costs in a highly centralised economic system. In Africa, however, while there is of course some large scale farming this impinges on a small minority of the population. The only way forward really is to work within existing economic structures and look for appropriate institutional change.