Learning Selection Revisited

Boru Douthwaite, *Martin Gummert*

Abstract

Ten years ago we developed the learning selection model to describe the development and early adoption of agricultural equipment in Southeast Asia. In this paper, we update the innovation histories of the three main technologies upon which the model was based. We find that the evolutionary algorithm based on interactive experiential learning remains valid. However, in the case of the most successful technology – the flatbed dryer in Vietnam – the R&D team did not withdraw once a critical mass of manufacturers and users were familiar with the technology, as the model says should happen. Rather the R&D team continued to champion the technology. In the process they developed new dryer designs, and major improvements to the original design. They achieved far greater impact than any other team. They were successful largely because they were able to work with the same networks of partners, in the same innovation trajectory, for 25 years. Replicating the success of the flat-bed dryer in Vietnam requires researchers to be embedded in networks that allow them to make the major modifications while local users, manufacturers and promoters take care of local adaptations and 'bug fixes'. This structure is similar to that enjoyed by plant breeders in the CGIAR System and by many researchers in the private sector. It is a way of putting the dictate to 'act local, think global' into practice. However, current trends in international research towards 'projectization' on one hand, and the production of international public goods (IPGs) on the other is increasingly leading to conditions of 'eternal boiling' which make the structure very difficult to maintain. Researchers do not stay working for long enough with the same partners because the funding keeps changing, nor do they work locally enough, nor long enough because of the expectation that they should generate new IPGs from scratch every one or two project cycles.

Introduction

Ten years ago the two authors – Boru and Martin – worked together on a German-Government-funded Postharvest Technologies Project that developed and promoted rice harvesting and drying technology in Southeast Asia. Martin led the project which was based at the International Rice Research Institute (IRRI), the Philippines.

Boru subsequently based his PhD thesis on the work. The main output of the thesis was a model – called the *learning selection model* – that describes how successful grassroots innovation processes begin. One of the thesis' main findings was that the most successful rice harvesters and dryers where the ones that had been most modified by local manufacturers and users. This ran contrary to the then dominant view that agricultural engineers, given their professional training, could and should design machines that worked without subsequent tinkering. The learning selection model described an evolutionary-like process in which scientists and engineers (the R&D team) work with interested manufacturers and farmers (the key stakeholders) to modify a technology, select what works, and spread the results. Boru subsequently wrote a book called

‘Enabling Innovation’ in which he found that the model helped explain other grassroots innovation processes such as the development of Linux and the Danish wind turbine industry (Douthwaite, 2002).

Ten years after the data was collected, Martin is working again at IRRI on postharvest technologies. Using his contacts and his own experience we revisit the three main machinery cases upon which the learning selection model was based. Our objective is to examine whether what has happened to flat-bed drying, low cost drying and stripper harvesting since 1997 can add to our understanding of how to enable grassroots innovation processes. First we begin by describing the learning selection model and a learning-selection-style innovation process.

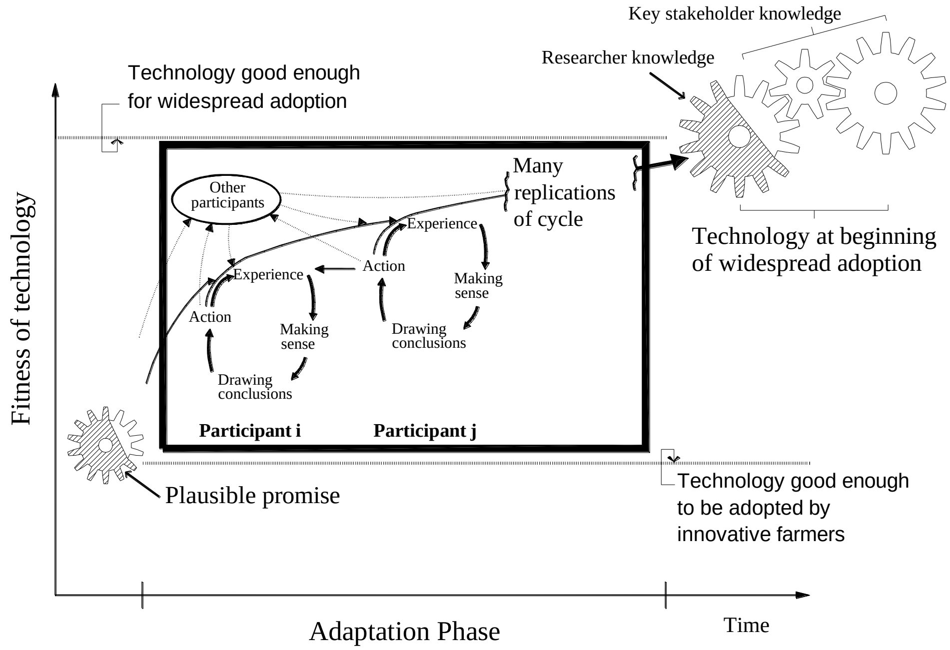
The learning selection model

As the name suggests, the learning selection model is based on an analogy with natural selection, which is the algorithm that drives biological evolution. Natural selection consists of three mechanisms. These are:

- **Novelty generation.** As a result of random genetic mutations and sexual recombination of differing genetic material, differences between individual members of a species crop up from time to time.
- **Selection.** This is the mechanism which retains random changes that turn out to be beneficial to the species because they enable those possessing the trait to achieve better survival and breeding rates. It also rejects detrimental changes.
- **Diffusion and promulgation.** These are the mechanisms by which the beneficial differences are spread to other territories.

The learning selection model is depicted graphically in Figure 1. It shows a technology, shown as a cogwheel, beginning as a ‘plausible promise’ that motivates the key stakeholders to co-develop it. The technology then increases in fitness by gaining knowledge and becoming ‘meshed in’ to existing systems through the adaptation and learning that takes place. Here, fitness is taken in the biological sense to mean improvements in the likelihood that the technology will be adopted and promulgated. The ‘meshing in’ of the technology, or its ‘social construction’ as it might also be termed, is represented by the move from a single cogwheel to three inter-locked ones. The increase in knowledge is represented by the increase in size of the cogwheel(s).

Figure 1: The Learning Selection Model



Learning selection is shown inside the black box in Figure 1 and is responsible for the evolution. Learning selection is a process built on Kolb's (1984) 4-stage experiential learning cycle, and is perhaps best explained using an example.

- **Experience.** Suppose a farmer finds that the rice miller pays her a low price for the grain dried in her dryer because some of it is not properly dried.
- **Making Sense**. She reflects and makes sense of the experience. She realizes that uneven drying is losing her money and that it might be sensible to try and improve the dryer's performance.
- **Drawing Conclusions.** She then develops personal explanations of what happened from her own or others previous experience or theories. She hypothezises that if she reduces the amount of paddy she loads into the dryer then drying will be more uniform.
- **Action**. She then decides to test her hypothesis, and in so doing generates a novelty.

Testing the novelty begins another learning cycle. Her selection decision to adopt or reject the novelty will depend on whether the rice miller now pays her more for her product. The miller will make this price decision after going through his own learning cycle when he tests a sample of her rice for milling quality. If the farmer is participant *i* in Figure 1 then the miller represents participant *j*.

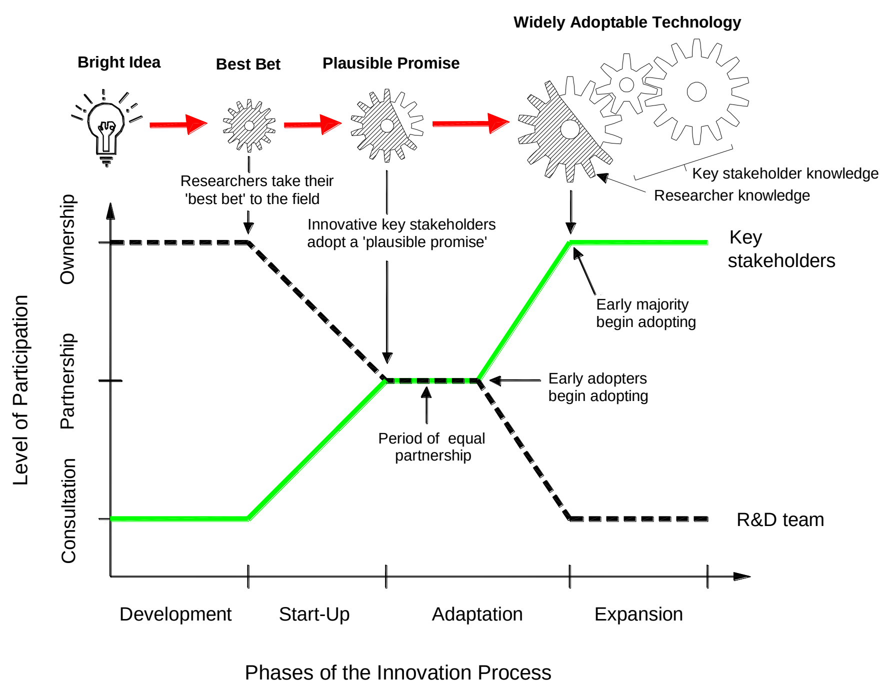
So far the third component of the evolutionary system—the promulgation and diffusion mechanism—is missing. In the example, promulgation of the novelty occurs when the farmer tells people in her social network, represented in Figure 1 by the 'other participants' box, about the benefits of her novelty and they choose to experiment with it themselves.

The farmer, the miller and the people they are connected to through their social networks will be going through their own learning cycles creating the conditions for the recombination of differing observations and experiences that can lead to novelties that have 'hybrid vigour.' In the process the technology evolves and with it the participants' opinions and knowledge of it and the way they organize themselves to use and promote the technology.

The research found that the learning selection model is most useful when key stakeholder 'learning by using' and 'learning by doing' are important in the early adoption phase, which is the case for technologies that begin a new innovation trajectory. The learning selection process works best when users are able to modify the technology, and if there are ways of evaluating changes.

The machinery cases suggested a normative view of how an R&D team can involve key stakeholders and put their joint creativities to work (Figure 2) in a territory. The innovation process begins with a bright idea. The bright idea can come from something that has worked elsewhere or it could be something new. Either way, in the territory in question the idea is developed by individuals or small teams of researchers. Mokyr (1990: 9) believes it has to be this way because the process of inventing 'plausible promises' is by its nature something that 'occurs at the level of the individual.' He says creating a plausible promise is 'an attack by an individual on a constraint that everyone else has taken for granted'. It is not something that lends itself to a broad consensus approach. While the R&D team may ask the key stakeholders—the people who will ultimately take ownership of their idea, replicate it and make it work—for some advice, they are driving the process.

Figure 2: Stages and participation in a learning selection innovation process in which a new technology is developed and adopted in a territory



At some point the R&D team crystallizes the knowledge they have generated into a prototype: their 'best-bet' of what the key stakeholders want. Then, in what marks the beginning of the start-up phase, they begin to demonstrate their best-bet to the key stakeholders. It may take several prototype iterations before the R&D team has received and incorporated sufficient feedback for at least a few innovators to adopt it.

It is this adoption, based on the belief that the new technology makes a "plausible promise' of bringing benefit, which marks the beginning of the adaptation phase. It also marks the beginning of a period of co-development and learning selection in which the technology evolves and its fitness improves, as shown in Figure 1.

Learning selection works when people make changes to a technology and then select and promulgate the ones that they find beneficial. This improves the fitness of the technology—its suitability to the environment in which it is used—and hence its market appeal. At a certain point the attributes of the technology are good enough for the second category of adopters, Rogers' (2003) early adopters[1], to start to show an interest. This marks the point at which the key stakeholders begin to take over ownership of the technology.

However, the analogy between natural selection and learning selection is not perfect. One important difference is that natural selection is blind and learning selection is not—genetic mutations occur at random but technology and system change can be directed, particularly by those with power. Hence, learning selection does not necessarily happen. It only comes about if the key stakeholders are sufficiently motivated to adopt and modify a technology and if they can carry out sensible learning selection on it. When they first start they often do not properly understand the technology to carry out learning selection by themselves. Consequently, at least one stakeholder, often from the R&D team, must champion it and fill knowledge gaps until the other stakeholders have learned enough to take over. This take-over marks the end of the early adoption process and is the point at which market selection begins to work.

The take-over also marks the beginning of the expansion phase when the technology becomes mainstream. As this happens, the people adopting the technology change from hackers (innovators) and early adopters to people who want the technology to work reliably and profitably. Increasingly the market becomes the main selection mechanism. Manufacturers and researchers are able to gather and codify more and more information that can be used to build predictive models. This allows them to move from 'learning by using' which requires adopters to be co-developers, to 'learning by modelling', where learning comes from virtual tests carried out on computer rather than field experience. In so doing, the learning selection model of the innovation process becomes less relevant and the conventional assumption that manufacturers or R&D departments can and do develop finished technology begins to fit better.

Based on the learning selection model and the case studies, Douthwaite (2002) derived a ten point guide to fostering a grass-roots-based innovation process:

1. **Start with a plausible promise.** Begin an innovation process with a 'plausible promise'; something that convinces potential stakeholders that it can evolve into something that they really want.
2. **Find a product champion.** The next step is to identify the innovation or product champion. He or she needs to be highly motivated and have the knowledge and resources to sort problems out.
3. **Keep it simple.** A plausible promise should be simple, flexible enough to allow revision, and robust enough to work well even when not perfectly optimized.
4. **Work with innovative and motivated partners.** Participants in an incipient innovation process should select themselves through the amount of resources they are prepared to commit, in particular their time.
5. **Work in a pilot site or sites where the need for the innovation is great.** Early adopters will be influenced by their environment. Their motivation levels will be sustained for longer if they live or operate in an environment where the innovation promises to provide great benefit.
6. **Set up open and unbiased selection mechanisms.** During early adoption, the technology should evolve and become 'fitter' through repeated learning selection cycles. This requires setting up efficient and unbiased ways of selecting what works and abandoning what does not.

[1] Rogers (2003) five types of adopter (i) innovators, (ii) early adopters, (iii) early majority, (iv) late majority, and (vi) laggards.

7. **Don't release the innovation too widely too soon.** When people show enthusiasm for a prototype it is very tempting to release it as widely as possible but this should be resisted. The technology will always be less perfect than one initially thinks.
8. **Don't patent anything unless it is to prevent someone else privatizing the technology.** In learning selection, people co-operate with each other because they believe that all will gain if they do. The process is, therefore, seriously damaged if one person or group tries to gain intellectual property rights over what is emerging. Patents are monopolies that immediately reduce the novelty generation rate and thus slow down future development and the flow of ideas.
9. **Realize that culture makes a difference.** Culture can influence the degree to which knowledge is guarded within a particular group, or spread around.
10. **Know when to let go.** Product champions need to become personally involved and emotionally attached to their projects to do their jobs properly. This makes it easy for them to go on flogging dead horses long after it has become clear to everyone else that the technology is not going to succeed. Equally, project champions can continue trying to nurture their babies long after they have grown up and market selection has begun. It is, therefore, a good idea to put a time limit on the product champion's activities.

Findings

We now look at the three technologies in turn to see how their development in the last 10 years supports or challenges the understanding of how successful grassroots innovation unfolds provided by the learning selection model in general and the 10 point guide in particular.

Flatbed Dryer

In the flatbed dryer, a fan blows hot air through a bed of rice. In 1997, flatbed dryers in the Philippines and Vietnam typically had a capacity of 4 to 6 tonnes and could dry one batch in 7 to 8 hours. About 1500 dryers had been installed in Vietnam, made by a large number of small-scale manufactures. In contrast, less than 100 dryers have been sold in the Philippines, largely through the promotional efforts of the Philippine Rice Research Institute (PhilRice).

Vietnam

There are now approximately 6200 flatbed dryers installed in Vietnam. A major factor in the four-fold increase was the strong championing of flatbed drying by Dr. Phan Hieu Hien, who had designed and installed the first flatbed dryers in Vietnam in 1983. Since 1983 the pattern has been that Hien and his Nong Lam University (NLU) team release a new design of dryer which is copied, modified and improved by local workshops and the users. NLU monitors these modifications and comes up with major design changes and improvements. This cycle has repeated for nearly 25 years.

In 1998 Hien led a DANIDA-funded project that provided financing for about 2000 dryers. The project was able to link technical expertise in NLU with extension services and credit. In 2001, NLU, in response to user requests, increased the capacity of the dryer to 8-10 tonnes by increasing the size of the drying bin and fitting a higher capacity blower. In 2004 they further modified the dryer so that the airflow is reversed half-way through the drying process, thus reducing moisture variation in the dried rice and allowing for shorter drying times. NLU took the lead role in developing efficient dryer fans continued to focus on dryer fan design because poor performance fans had nearly killed-off flatbed drying in the late 1980s. NLU transferred design and fabrication technology to 15 manufacturers in the Mekong Delta, 7 of whom have built fan test ducts according to JIS (Japanese Industrial Standard B 8330-1962). NLU developed simple blower testing equipment including a pitot tube and airflow meter and a solar collector for supplementary heating. IRRI played a role in some of the improvements made, including the introduction of an automatic rice hull furnace.

On the demand side, adoption and adaptation of dryers was driven by increasing quality consciousness of the export-oriented rice sector. The main constraint was a lack of support to manufacturers from the extension service in provinces where the technology was new, and lack of financing to purchase dryers.

The Philippines

The number of flatbed driers used in the Philippines has increased from 100 to 200 in the last 10 years, mainly due to the efforts of PhilRice engineers who have provided technical assistance to interested farmers and cooperatives. Some modifications have been made to the design, but fewer than in Vietnam. In early 2007, the Secretary of the Department of Agriculture was impressed when he saw a PhilRice-designed flatbed dryer working in a farmers' cooperative and initiated a program to install roughly 1000 units nationwide, following the PhilRice design, but to be implemented by the Bureau of Postharvest Research and Extension (BPRE). Similar machinery programs in the past have failed because farmers groups were supplied with poor quality equipment due to lack of technical support from the implementing agency. There is a risk that this will be repeated given that BPRE will implement the program, not PhilRice who have more experience with flatbed drying in the Philippines.

Indonesia

The flatbed dryer first reached Sumatra, Indonesia, in 1982/83 when 500 units of various sizes were distributed to village cooperatives in South Sumatra through a presidential grant. The project was terminated because of unsatisfactory results. In 2004, the South Sumatra Forest Fire Management Project (SSFFMP) financed one flat bed dryer with 3.3t capacity, designed by the Indonesian Centre for Rice Research (ICRR). The dryer was installed with a farmers group (UPJA) in the tidal swampy areas of South Sumatra. Local manufacturers copied the dryer and increased the drying bin capacity to 8-10t, but using the same blower and furnace with the result that drying time increased from 8h to 24h. Unlike in Vietnam, manufacturers have not yet received the technical support they need to match the fan and dryer design to the dryer capacity. Nevertheless, local manufacturers have installed about 40 units, and adoption is increasing. Sales are driven by difficulties in drying and selling wet paddy. The main constraint to a more rapid increase in sales is the quality and performance of the dryer itself. Manufacturers lack technical assistance that would help them improve quality, unless there is a well-funded project like the SSFFM Project. The national extension system, that could provide technical support, has been decentralized to the sub-district level so that extension workers are unable to source specialist technical information, such as data on dryer fan design, and often do not have resources to go to the field. As a result there is no continuous upgrading and improvement of the design, as in Vietnam.

Other Countries

In 2004 IRRI organized a dryer manufacturing training course held at NLU in Vietnam. As a result, versions of the NLU dryer have been installed in Myanmar, Laos and Cambodia. A Myanmar manufacturer and the head of the Myanmar Rice and Paddy Traders Association (MRPTA) participated and MRPTA subsequently installed 24 dryers. They were successful in part because they remained faithful to that design, rather than immediately trying to develop their own 'improvements', as many engineers tend to do. This is perhaps because, being millers and traders, they wanted something that worked quickly to improve the poor quality of milled rice. The installation was championed by the Executive Secretary of MRPTA, a former medical doctor, whose own family owns a rice mill. The main constraint to further adoption is the limited capacity the MRPTA has to install dryers and train users.

A Lao participant also attended the 2004 dryer training course in Vietnam and in 2005 installed a 4t dryer, with a bamboo rather than perforated screen floor to the drying bin. In 2006/07 he developed an even smaller 1t dryer with a metal bin and using 2 small-capacity blowers (developed for the low-cost dryer). In 2007 he reported that the 4t dryer was better suited to Lao conditions and replaced the bamboo floor with perforated steel sheet, thus reverting to the original Vietnamese design.

An IRRI project installed one dryer in Cambodia in 2007 at a farmers group. The national counterpart from the public sector tried to build the blower to save money, but it fell apart after 2 hours of operation. In collaboration with a manufacturer, who also attended the training in Vietnam, the project replaced the faulty blower and furnace and conducted a series of confidence building activities including training and demonstrations to restore the reputation of the technology. The dryer is now being used by farmers groups and is frequently being visited by rice millers, who want to invest in drying technology.

Low-cost Dryer

The low-cost dryer, also called the SRR dryer, was first developed by Hien and the NLU team in 1994. They sold 670 dryers to farmers from 1995 to 1997. The original design used low-temperature, could dry 1t in 48 hours without mixing, and appealed to farmers who needed to dry their paddy before selling it. NLU shipped low-cost dryers to the Philippines, Bangladesh, Myanmar and Indonesia for evaluation.

Vietnam

Sales increased to about 1000 a year by 2000 but dropped since then to a few hundred a year in 2007. The fall is due in part to the success of the flatbed dryer in that rice traders and millers have become increasingly willing to buy wet paddy at a good price, so farmers themselves do not need to invest in their own dryer.

The NLU team developed a second model with a faster drying time by increasing the temperature of the blown air and reducing the grain bulk depth. However, this required the use of two bins, instead of one, and manual mixing of the grain. Hence it costs more and requires more labour to operate it.

Other countries

In the Philippines a low-cost dryer was tested and modified by the Bureau of Postharvest Research and Extension (BPRE), loaned to a farmer but found to be too loud by his neighbours. The project was dropped. In Indonesia a dryer was tested by the ATIAMI project in West Sumatra and South Sulawesi, but with no adoption. One constraint was that using the dryer meant farmers had to upgrade their electricity supply to a more expensive category. In Cambodia, the Cambodia IRRI Australia Project (CIAP) and the Support Programme for the Agricultural Sector in Cambodia (PRASAC) project tested them but also with no adoption. Cambodia still does not have a proper power grid. Electricity is still mostly supplied by old United Nations Transitional Authority in Cambodia (UNTAC) generators and where available is too expensive. Most villages do not have electricity at all.

Stripper harvester

The first stripper harvester was built at IRRI in 1990. By 1997, 139 units of a much-modified version had been built and sold in the Philippines and units had been shipped to farmers and manufacturers in 14 countries. Sales in the Philippines peaked in 1995.

Philippines

In the Philippines, sales of the stripper harvester have fallen to zero. According to Dr. Lito Bautista, an engineer at PhilRice, this was due to the poor performance of the machine in soft wet fields, and high losses. In 1998 PhilRice attempted to build a small stripper combine harvester, which was never finished. A few farmers who bought machines are still using them on their own fields, although they have stopped servicing other farmers’ fields.

Indonesia

The only country where there is any reported uptake of stripper harvesting is Indonesia, where over 200 machines of various types have been sold.

The first prototype stripper harvesters were shipped to Indonesia in 1994 and 1995 by the IRRI Postharvest Technologies project. One machine went to the ATIAMI Project in West Sumatra and the ATIAMI Project carried out field demonstrations in Sumatra and South Sulawesi. The project lent a prototype Chandue Workshop for copying. No sales were made because almost immediately the manufacturer tried to develop a complicated track system for the stripper harvester, to overcome mobility problems, but got nowhere and gave up in 2001. Then, in 2005, Chandue Workshop began marketing six models of stripper harvester (Table 1) and produced 210 machines.

Table 1: Stripper harvester models built by the Chandue Workshop, South Sulawesi, Indonesia

Model number	*Description*
DP 4000	Very similar to the original IRRI design shipped to Indonesia
DP 5000	Also walk-behind, with 2 star-wheels
DP 6000	Walk-behind, 3 wheels, collection box in front
DP 7000	Operator sits on top, otherwise similar to original IRRI design
DP 8000	Operator sits on top, two engines, one driving each side, can turn on the spot, 8 ft width (i.e. width of one metal sheet)
DP 9000	Walk behind like the original IRRI design, but 8ft width, that is 2.4m wide rotor compared to 0.8m for the original

Figure 3: The DP 7000 Stripper Harvester
Note the prominent display of the patent number and the seat for the operator

In 2006, IRRI and the second author became aware that Chandue Workshop was suing a competing workshop owner, who is related to him, for patent infringement. Mr. Paisal, the owner of the Chandue Workshop, claimed he had invented the stripping mechanism. Despite IRRI going to some lengths to provide evidence that stripper harvesting was originally patented in the UK, Mr. Paisal continued to pursue his case and as of May 2007 it still had not been resolved. In the meantime the manufacturer being sued complained he had spent a lot of money fighting the court case against him.

There are several factors that might explain why stripper harvesters are being sold in South Sulawesi. Firstly, asynchronous planting means that there is harvesting all year so a mechanical harvester can be used nearly all the time, thus paying for itself quickly. Mechanical harvesting is needed because there is labour shortage and there are no competing harvesters on the market as yet. The ATIAMI project carried out a systematic assessment of 26 manufacturers and lent a prototype stripper harvester for copying to the most capable and interested. Finally, the manufacturer, Mr. Paisal, is an archetypal inventor / tinkerer who was clearly motivated to develop the technology for the sake of pursuing novelty.

Discussion

We begin this section by examining how the respective innovation histories of the past ten years confirm or contradict the learning selection model and the ten point guide to launching grass-roots innovation processes. We then examine the implications for science and technology policy.

Does the learning selection model hold up?

Of the three technologies – flatbed dryer, low-cost dryer and stripper harvester – the flatbed dryer is clearly the most successful. There are about 6000 units installed in Vietnam and the technology has been exported to five other Southeast Asian countries. Its success in Vietnam is in part due to its continuing development in response to changing market requirements. This confirms the basic evolutionary algorithm upon which the learning selection model is based.

The findings largely confirm and add insight to the ten-point guide to fostering a grass-roots innovation process. The low-cost dryer failed to prove itself a *plausible promise* in the Philippines, Cambodia and Indonesia for different reasons. As a result co-development of the technology with users did not start.

A *product champion* proved crucial to the success of the flat-bed dryer in Vietnam. The same R&D team championed the flat-bed drying for 25 years in which time they made major improvements to the technology and strove to maintain quality through, amongst other things, developing and providing blower test kits. They also linked to extension services and helped provide credit.

Interested and motivated individuals were crucial for the success of stripper harvester and flat-bed dyer in Indonesia, and the flat-bed dryer in Myanmar. In all three cases they were motivated by the need for the respective technologies in their areas and the fact they appeared to make a 'plausible promise' of meeting that need. The individual characteristics of the adopters themselves made a big difference. Some were motivated to make major changes before properly testing the original design and improving on that (e.g., flat-bed dryer in Laos; stripper harvester in Indonesia). This tendency appeared in engineers and manufacturer who wanted to make the design their own. While this reduced the 'fitness' of the technology and slowed progress, it also led to major innovations (e.g., stripper harvester in Indonesia).

Staff from the IRRI postharvest technologies project played an important role in helping *select beneficial modifications* and spread them. An important example of this was the training course they organized for manufacturers from different countries to learn how to build the Vietnamese design of the flat-bed dryer. The technical expertise required to both suggest and evaluate modifications was largely missing in the flat-bed dryer development in Indonesia, and was initially lacking in Laos. Perhaps closer contact between dryer researchers and innovating manufacturers and engineers may have helped them avoid early mistakes. The fact that certain types of people are more likely to behave in a certain way showed that at least professional *culture makes a difference*.

Politically-motivated government machinery supply programs still risk *promoting equipment too widely*.

The *patent* battle in Indonesia showed that patents taken out to stop others privatizing a technology must be taken out country by country to be effective. It also showed the serious damage that a struggle over intellectual property rights can do to an innovator's motivation and cash-flow.

The biggest insight from the findings is to the tenth point – *knowing when to let go*. According to the learning selection view of early innovation (Figure 2) the R&D team should withdraw after a couple of years of co-development to become 'consultants'. This clearly did not happen in Vietnam, and much of the success of the flatbed dryer in that country can be attributed to the fact that the R&D team have been involved for 25 years.

A software industry analogy can help understand what seems to have happened in the flatbed dryer innovation history in Vietnam. Some software companies work with three product states, the current version (e.g., version 3.1) on release which has known bugs, the next release (e.g. version 3.2) with bug fixes and minor new features, and the longer-term next version (version 4) with major new features. What we see in Vietnam is that once manufacturers become familiar in a territory with the flatbed dryer they were able to fix bugs and develop minor new features. They were not, however, able to develop major new improvements in response to likely market changes. This was carried out by the NLU team who developed major modifications such as reversible airflow, and spin-off new technologies like the low-cost dryer.

The learning selection view of innovation (Figure 2) was originally developed to show the production of international public goods, or IPGs. IPGs are 'research outputs of knowledge and technology ….. that are applicable internationally to address generic issues and challenges' (Harwood et al. 2005: 6). In Figure 2, researchers come up with a good idea, convince potential manufacturers and users in one or more pilot sites that it is a 'plausible promise', co-develop it with them for awhile before withdrawing to go on and seed the next innovation trajectory. The model assumes that from bright idea to co-development should be done within the time period of two project cycles – in other words about 6 years. The assumption is that once established in a pilot site and under the control of the key stakeholders (the people who manufacturer, promote and use the technology in the territory), the technology will become widely adopted and eventually spread to other territories in other countries, thus justifying the label of IPG. The researchers are not responsible for this 'extension'.

The flatbed dryer innovation history challenges this conceptualization. It suggests that to really make a difference, the R&D team should not jump ship, but seek to generate major novelties within the same innovation trajectory. It suggests that researchers should be embedded in networks that include key stakeholders (the people who make, promote and use technology).

Implications for Science and Technology Policy

The idea that more public sector research should be carried out within networks that link researchers to information about need, use and future trends has major implications for the CGIAR system. The previous Science Council Chairman said that CGIAR Centres should not undertake location-specific research because of the high opportunity costs involved (Ryan, 2006). But if CGIAR scientists are not involved in location-specific research then they may not be located within a network of individuals and organizations who are responding to a real need, in a real *locality*. The flat-bed dryer story shows that researchers can generate IPGs while carrying out location-specific research as they respond to needs that are not location-specific. It shows that within an existing innovation trajectory research can generate IPGs that begin new innovation trajectories (e.g., the low-cost dryer). Hence probably only a small percentage of research should be 'blue sky' i.e., research that attempts to establish new innovation trajectories without being embedded in an existing one.

In fact, the CGIAR's most successful research in terms of its impact—breeding of improved crop varieties—is carried out within established innovation trajectories. In the case of rice, the core 'IPG' was the idea of breeding semi-dwarf varieties that could yield more without the plants falling down. For the last 40 years IRRI has been breeding semi-dwarf varieties with resistance to different pests and adapted to different conditions within an evolving network of partners. Advanced research centres like IRRI are responsible for major modifications while bug fixes and minor modifications are dealt with locally.

The plant-breeding model is similar to that of much of the private sector. Here, researchers work to develop improvements to existing product lines and every now and then spin-off 'plausible promises' that seed new product lines. They are part of integrated network that identifies customer needs, provides feedback on performance under different conditions and predicts future trends.

'Projectization' of research together with the emphasis on production of IPGs makes it increasingly difficult for CG Centre scientists to embed themselves in this way. More often than not, a coalition of partners comes together to meet the donor's requirement, work together (or not) for 3 years to develop an IPG and then dissolve. If they are lucky they will get an extension. Project proposals are rarely evaluated on the track history of the network of people proposing them, and whether that network does link the researchers to the key stakeholders. Instead donors want to be associated with something new because history means they might have to share credit with a competing agency. We're setting up a straw man here, we realize, but it rings true to our own experiences.

Innovation systems behave as complex adaptive systems. If the networks are rigid and unchanging then they are unlikely to be innovative. Equally if networks are constantly forming and breaking up then the system is in a state of 'eternal boiling' and also will not be able to respond to a changing external environment. The twin trends towards working in projects and the necessity of producing IPGs creates conditions of 'eternal boiling'. So do funding decisions made for short-term political reasons rather than for the good of the technology. Under such conditions part of the role of a product champion can be understood as smoothing out turbulence by managing to keep working on coherent sets of ideas and technologies with a network of people over time and across institutional boundaries and jealousies.

A challenge in fostering innovation processes therefore is how to strike the correct balance between network rigidity and eternal boiling, between continuity and change. The innovation histories suggest that this is most likely to happen when researchers are embedded in a network that makes them aware of emerging needs and links them to potential users with whom they generate solutions. Public-private partnerships are one way of doing this. Hien and his team, while employed by a university, constructed dryers in family owned businesses, and then moved the production to a private arm of the NLU, which was specifically founded to generate profit by producing equipment. Dryers worked in Myanmar when public-sector funds were used to train people from the Myanmar Rice and Paddy Traders Association who wanted a working dryer and to generate profit. When the provision of machinery is driven by government-funded machinery programs it often fails because they are driven by short-term, political (rather than commercial) considerations.

Conclusions

Ten years ago we developed the learning selection model to describe the development and early adoption of agricultural equipment in Southeast Asia. The updated innovation histories of the three main technologies confirm the evolutionary algorithm upon which the model was based. However, in the case of the most successful technology – the flatbed dryer in Vietnam – the R&D team did not withdraw once a critical mass of manufacturers and users were familiar with the technology, as the model says should happen. Rather the R&D team continued to champion the technology. In the process they developed new dryer designs, and major improvements to the original design. They achieved far greater impact than any other team. They were successful largely because they were able to work with the same networks of partners, in the same innovation trajectory, for 25 years. This finding challenges the conventional wisdom in the CGIAR system that researchers should avoid carrying out adaptive location-specific research and rather develop so-called international public goods (IPGs) that have broad applicability. Rather it suggests a research-for-development approach that ensures researchers are solving real needs of real people in real localities, for extended periods of time. IPGs will be generated in the process, almost as a spin-off. Researchers do not need to be physically in each locality working with every farmer or manufacturer. Like the flat-bed dryer R&D team, they need to be embedded in networks through which they become aware of need, opportunity, how the technology is being promoted and used and what the market is likely to demand in the future. This structure is similar to that enjoyed by plant breeders in the CG System and by many researchers in the private sector. It is a way of putting the dictate to 'act local, think global' into practice.

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Biosketch of authors

Boru Douthwaite is a technology policy analyst working for the International Center for Tropical Agriculture (CIAT) in Cali, Colombia. His current research focuses on the development and use of Participatory Impact Pathways Analysis in complex projects and programs (see http://impactpathways.pbwiki.com). He previously worked as an agricultural engineer for eight years in the Philippines at the International Rice Research Institute.

Martin Gummert is postharvest development specialist working for the International Rice Research Institute (IRRI) in Los Baños, Philippines. His current research focuses on strengthening research extension linkages in the postharvest value chain with regional focus on the Greater Mekong Subregion and Indonesia. He has previously also worked as team leader of the Indonesian German Assistance to the Indonesian Agricultural Machinery Industry (ATIAMI) project and as a private consultant in information and communication technology and agricultural development.