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**“MAKING SCIENCE AND TECHNOLOGY
WORK FOR THE POOR”**

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**MAKING SCIENCE AND TECHNOLOGY
WORK FOR THE POOR**

Lecture 3

**Development Strategies
For Africa**

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I. Introduction

One of the enduring themes in development economics is the theme of “moving the technological frontier” vs. “moving producers from below the frontier toward the frontier”. This theme implies some degree of location specificity of the technological frontier.

Moving the technological frontier requires R&D by private firms or by public agencies; R&D requires high levels of skills. Moving the frontier also requires sustained organizational support over many years.

Moving producers from below the frontier toward the frontier is generally regarded to be less demanding of skills. It is also regarded to be less demanding in terms of long term support. Agricultural extension programs are a case in point. These programs typically do not rely on research skills in the applied agricultural sciences. In many cases, they attempt to rely on “local” change agents, often with little training in science or engineering. Early experience with extension programs in Africa (1960-1985) was disappointing in terms of growth or cost reduction. In spite of ratios of extension staff to farmers on the order of twice those observed in Asia, only modest growth could be associated with extension programs. After 1985, two major extension system reforms took place. The first was the Training and Visit” (T&V) reform where added discipline in terms of regular training of extension staff by “subject matter specialists” (who generally were not scientists) and regular visits to farmers took place. The second reform is the Farmers Field School Movement, currently in vogue.

In addition the extension-technology transfer field has seen heavy participation by Non-Government Organizations (NGOs). As I noted in Lecture 1, NGOs generally do not do research; i.e., they did not produce a single Green Revolution Modern Variety (MV). But many are convinced that MVs are not needed (and many are openly hostile to technology). The argument is that farmers are not planting the “right” MVs and using the “right” practices. Farmers need “advice, not new technology” by this argument.

In Lecture 2, an analysis of Innovation Capital (i.e., moving the frontier) and Imitation Capital (moving farmers toward the frontier) was made for agriculture. The conclusion from that analysis was broadly consistent with the analysis of T.W. Schultz in his 1964 book, Transforming Traditional Agriculture. In this book, Schultz argued that “traditional agriculture” was “poor but efficient” and equivalently “efficient but poor”. This argument rested on two propositions:

- a. That the technological frontier has a high degree of location specificity, and

- b. That farmers experiencing few technological improvements had time to experiment with alternative practices and adopted those best suited to their circumstances.

The Lecture 2 evidence supported Schultz. Location specific technology meant that there was little scope for importing Modern Varieties to replace traditional varieties. As an example, the French agricultural system did not produce a single (France-crossed) MV for African countries over the past three or four decades. Nor did the US, UK, German or Japanese programs produce MVs for Africa.

The IARCs did produce MVs adopted in several countries and they produced parental material that was widely used. But location specificity was important. Lecture 1 also showed how the incorporation of host plant resistance traits (to diseases and insect pests) and host plant tolerance traits (to abiotic stresses) in MVs were necessary to expand the MV margin.

Lecture 2 also noted that when farmers are constrained to traditional crop varieties in economies dominated by traditional technology and without competitive industries, mass poverty is the result. Traditional agricultural families might have earned two dollars per day per capita at 1960 prices. At 2000 prices, they probably can't earn one dollar per day per capita.

Finally, Lecture 2 provided some evidence that extension – technology transfer programs cannot “jump start” an economy onto a growth path. Extension – technology transfer programs are effective only after the technology frontier has been moved, and that can only effectively be achieved by developing MVs.

Lecture 2 also addressed the question, “Can industrial growth transform traditional agriculture?” The answer to this question was that this has not happened in practice. No country achieved industrial competitiveness (i.e., the capacity to export significant manufactured goods in international markets) without first having achieved agricultural transformation. Some 15 to 20 developing countries (many in Africa) are dominated by traditional agriculture and traditional industry. Another 20 or so (also mostly in Africa) have modernizing agriculture (a partial Green Revolution) but have not yet achieved international industrial competitiveness. The 50-plus countries achieving both modernizing agriculture and industrial competitiveness have high economic growth rates and achieve poverty reduction rapidly. Few of these are in Africa (Figure 2.3, Lecture 2)

One of the least understood development phenomena is the failure of many countries to achieve industrial competitiveness, even though they have very low wages. Most development economists do not consider industrial production to be location specific and hence do not push

for R&D in producing firms (and the Intellectual Property System to support R&D). Yet as noted in Lecture 2, many important markets for agricultural machinery do have location specificity (e.g., cassava processing equipment or tropical fruit processing equipment). And with low wages, the demand for machines is very limited.

There is a growing recognition that one of the mechanisms for “buying into” industrial efficiency is through “exploiting” multi-national corporations (MNCs). It is sometimes said that there are three classes of developing countries:

1. Those without the institutions to attract MNC investments (i.e., corruption, legal systems, etc.)
2. Those with the institutions and with MNC presence, but a political concern that they are “being exploited by MNCs”.
3. Those with the institutions to attract MNCs and organized programs to “exploit MNCs” to fullest advantage.

The first group of countries is generally stuck with inefficient industries. The second group is modernizing slowly. The third group is achieving rapid economic growth. Institutions do matter for both agriculture and industry and for services as well. But public policy is critical. For many African countries it is critical that the agricultural frontier be moved forward. For countries where agricultural transformation is taking place, the achievement of industrial competitiveness is critical – and this requires engineering and science skills and a policy environment to create a demand for those skills. Similar skill requirements exist in the service sector.

I. African Needs

Lectures 1 and 2 put forward several important conclusions regarding investments and policies required to engineer an escape from mass poverty.

1. Institutions matter. The high “transaction costs” associated with modern input markets in Africa reduced the impact of the Green Revolution.
2. Traditional agriculture, with a reliance on traditional farmer-selected crop varieties and low productivity livestock system means mass poverty in today’s globalized world.
3. Industrial growth and industrial competitiveness does not in practice “transform” traditional agriculture. Industrial growth does not precede agricultural growth.

4. Extension programs, while effective in some countries and periods, do not transform traditional agriculture. Traditional technology is highly specific to agro-ecological conditions (AEC). Modern varieties (MVs) are highly specific as well and it is seldom the case that MVs can be used in a location for which they were not targeted.
5. Mechanization gains are effectively not available to farmers in poor countries.
6. Gains from fertilizer use are limited by the genetic technology of traditional varieties.
7. Population expansion-induced cultivated land requires fertilizer and soil management practices to maintain fertility.
8. Agricultural development does not take place during periods of civil conflict.

The implied “route” to change for low wage mass poverty countries is:

First, Crop Genetic Improvement must be achieved. Lecture 1 discussed the complexities associated with producing MVs for small AEZs and for marginal AEZs. Africa has MV systems that have delivered to some AEZs for some crops. Africa is poorly situated for MV development because of small and challenging AEZs. It also suffers from a “small country” problem, where it is difficult to build an effective low cost NARS CGI program.

Second, as farmers have an opportunity to evaluate the new varieties, they will have increased demand for extension and advisory services. The new varieties can create a state of disequilibrium in a traditional economy. The existence of this disequilibrium can then set in motion other types of disequilibria. The Green Revolution in India clearly created increased rural non-farm employment opportunities.

As economic forces respond to the introduction of technology, new economic opportunities are created. These include animal breeding improvements.

But producing MVs for African conditions is demanding. It requires specialized skills. PhDs in plant breeding, agronomy, plant physiology, genetics and entomology are required for an effective CGI team.

II. Building Innovation Capital

Many Sub-Saharan African NARS programs have experienced long periods with very modest accomplishments in terms of developing technology (varieties, practices) that farmers actually adopt. They have generally been less productive than their Asian or Latin American counterparts. There are several possible explanations, including:

1. Poor management.
2. Insufficient recognition of the need to invent location-specific technology.
3. High transactions costs, which serve as a barrier to innovation (the commercialization of an invention).
4. Poor integration with extension programs.

SSA NARS suffer from all of these problems. The second problem, insufficient recognition of the need to invent for the AEZ, is characteristic of the broader problem of trying to achieve something with lower skills than are actually needed. This is illustrated by the West African Rice Development Association (WARDA). WARDA initially was mandated to “screen and evaluate” MVs for potential adoption in West Africa. WARDA failed to discover appropriate MVs. After relocating in Bouake (from Liberia where it has been impossible to function for the past 20 years), it accepted a mandate to invent and innovate. WARDA was successful in its early years at Bouake and did produce MVs with potential for the regions. Tragically, civil war in The Ivory Coast has destroyed WARDA a second time.

But clearly IRRI, for all of its success in Asia, did not deliver for Africa. Nor did CIMMYT deliver maize varieties to Africa until it located breeders in Africa (20 years after making progress in Latin America). Similarly, ICRISAT did not assist Africa until it located programs in Africa. And none of the “screening and evaluation” programs in SSA has actually identified significant MV technology for SSA. There just isn’t a “low skill” option. SSA needs programs with the capacity to produce MVs for the AEZs in Africa. And this means building and strengthening CGI programs in SSA locations. How many? Southeast Asia built 100 effective CGI programs. South Asia built 200 effective CGI programs.

SSA has few effective CGI programs at present. This, as noted, is partly because IARC support has been quite weak in SSA. IITA has struggled relative to other major IARCs – CIMMYT, IRRI, ICRISAT and CIP. CIMMYT did deliver wheat MVs but not maize MVs to SSA. And it was delayed in developing programs for SSA. IRRI never did deliver to SSA and WARDA has made unfortunate location choices. ICRISAT was also late in developing SSA programs.

But part of the problem has been poor management and poor design. Some of the problem has been a small country problem where a country is not able to achieve the scale necessary for CGI effectiveness. The history of cooperative programs is not good in Africa.

Can Africa deal with its NARS-CGI problems with policy reform? Can NGOs contribute? Or does SSA have to put in place programs to train a new generation (or at least a partial generation) of scientists?

The answer to these questions is pretty clear. Reforms of existing programs will help but will not reenergize these programs. NGOs will not contribute. Most NGOs in Africa are hostile to technology (environmental NGOs) and many are hostile to farmers (see comments on USAID below). Most have commitments to international organizations rather than to SSA farmers. And NGOs do not have invention/innovation skills.

The Green Revolution in Asia and Latin America was supported by capacity (or capital) building programs. These programs took many forms. Some university-to-university programs were utilized in the 1950s and 1960s. A number of faculty development programs in universities were supported. These took the form of mentoring and supporting visiting faculty in “flagship” university programs where support for Ph.D. study abroad was given to key flagship faculty. Those supported returned to bring frontier applied science to their universities. The producers of the Green Revolution in Asia (China was a special case) and Latin America were either among those supported or were the students of those supported in these programs.

These programs were established in some African countries. And Africa does have flagship universities (in spite of extreme difficulties). But the political support for universities that was critical to the success of these programs was not given in Africa to the degree that it was given in Asia. (The development university movement of the 1980s failed because development universities were perceived to be second-class universities.)

By the 1980s, these capacity-capital building programs were de-emphasized with the result that Asian agricultural research programs had build capital, while few African countries achieved the required capital.

There were two reasons for the de-emphasis. The first was based on a failure to recognize the “public value” of training inventors/innovators. Studies of private values of schooling based on measures of the increased income associated with an added year of schooling do show highest percentage gains for an added year of primary schooling, next highest percentage gains for an added year of secondary schooling, and lowest percentage gains for a year of university schooling. These studies had a profound impact on foundations and aid agencies and gave them cause to de-emphasize the largely graduate program support for Invention/Innovation capital. Had these studies properly measured the public externality values of higher education (the price of buying your way into the growth process) they would not have terminated these programs. (See Part IV for an economic justification and public/private value calculations.)

The second reason for de-emphasis was “donor fatigue” and the general “unraveling” of international aid programs. The state of aid support for developing countries began to decline in the mid 1980s and, by 2000, international aid was less effective (by a large margin) than it was in the 1950-1980 period. (See the discussion in Part VII)

III. The Economic Argument for Technology Capital

Lecture 2 makes much of the case for Technology Capital and its role in agriculture. In this section I use the invention model as a starting point and develop public/private value ratios to make the case for Technology Capital.

Methods of technology acquisition are then considered. Data from studies of returns to research and extension programs in both public and private R & D organizations are then reviewed to assess public-private value magnitudes.

A. The Invention Model with IPRs

Consider the basic economics of an invention model where the demand for an invention when the invention is commercialized (i.e., an innovation) is expressed in present value terms. In Figure 1 this demand is depicted in terms of royalty rates and royalty units, and denoted as D_1D_1 .

The demand for inventions in a given economy is fundamentally based on the contribution that the invention makes to cost reduction and/or product improvement in actual use. Thus, a country without skills to actually use the invention will have little demand for the invention. The demand curve slopes downward because few units are demanded at high royalty rates, but as royalty rates are lowered, the invention becomes economically viable in more units of use (Evenson, 2000).

Intellectual property rights provide IPR owners with a limited or partial monopoly right (i.e., the right to exclude) and the effective monopoly demand is depicted as M_1M_1 . The M_1M_1 curve lies below the D_1-D_1 demand curve because monopoly rights are limited in terms of time (17 to 20 years) and scope. But, perhaps more importantly, they are limited by competitive

inventions. There is a good chance that this invention will have a reasonably close substitute before many years have passed. (This is one of the features of an effective patent IPR. The requirement that the invention be disclosed stimulates subsequent invention.) The monopoly rents that the IPR owner can collect then will be P (where $MR = 0$) and the royalty rate will be R_m and U_m units will be sold.

In the case of this IPR protected invention then the private value will be P and the public value will be $A + B$. The area A can be thought of as the “normal” economic surplus associated with this invention and the inventive effort and innovative effort required to produce it.¹ The area B represents an “extra” public value associated with the limited monopoly right and with disclosure-induced substitutes for this invention. Note that with IPRs the areas $C + D$ are not realized until the IPR expires. It is sometimes argued that the area $C + D$ constitutes a “welfare loss” but that is not a proper interpretation if this invention would not have been produced in the absence of IPRs. In that case, the areas $B + A$ represent welfare gains that would not have been realized otherwise.²

Figure 2 also depicts a situation where the public sector undertakes the invention and does not charge a royalty fee. This would be the situation for an agricultural experiment station developing new crop varieties. The average costs of scientists are depicted in Figure 2 as E and total public value is $E + F$, the full area under the demand (or average revenue), evidence will be presented in Part C that indicates that the ratio of F to E in Figure 2 is approximately the same as the ratio of $A + B + C + D$ to P in Figure 1.

A natural question to ask regarding these figures is why do countries use IPR systems for invention when these systems do not allow full public value to be captured (i.e., the areas $C + D$ are not realized) until after the IPR expires? Note, however, that if IPR systems are the only

¹ All factors of production can be thought of as having produced consumer surplus. In Figure 1 the area A is normal producer surplus. The area B is added surplus associated with IPR protection.

² In Part C of this section below, rate of return study evidence for agricultural inventions is reviewed to suggest that, at least in developing countries, the areas A and B are large relative to P (3 to 5 times as large) and that the “extra” public value B is probably quite large (2 to 4 times P).

alternative (i.e., public programs are unwilling or unable to invent), then the IPR system does create public value in terms of the areas A + B that would not otherwise be available to society.

IPRs are widely regarded to be a very “blunt” instrument for providing incentives for invention. But their use is almost universal in all developed market economies, and IPRs are being steadily increased in strength and scope in all developed market economies (Kremer, 1998, discusses issues associated with attempting to capture the area C + D).

Are public sector R&D organizations unable and unwilling to invent? No, there are many fields where IPR systems haven't been effective or available to stimulate private sector invention and public sector invention systems have emerged. The agricultural experiment station is a case in point. Traditional patent protection was not available to plant and animal breeders in the U.S. until the 1970s when courts broadened the scope of patent protection.³ The public agricultural experiment station research “model” was developed in the mid-1800s to provide biological invention for agriculture. And those public experiment stations have achieved a distinguished record of invention in the form of modern plant varieties and animal improvements. But chemical, mechanical and electrical invention for agriculture has been dominated by private firms even in cases where the public sector has attempted to compete. With the expansion of IPRs to plants and animals and potentially to biotechnology inventions, the competitive edge of private firms has become pronounced in all fields of agricultural inventions.

But private sector invention is itself located in a larger system of public research and public and private academic system support. The modern agricultural invention system in public sector programs features the development of the applied agricultural sciences. These science fields support both private and public sector inventors (Huffman and Evenson, 1993).

³ Actually in 1930 the Plant Patent Act did provide patent protection to asexually reproduced plants. But this was not regarded to be a major incentive for private sector breeding. In 1970, the Plant Variety Protection Act extended this protection to sexually reproduced plants. In the 1980s conventional patent protection was extended to plants and animals.

B. International Issues: Why Should Developing Countries Recognize the IPRs of Developed Country Inventors?

Two issues govern the internationalization of IPR systems. The first is the relative competitiveness of domestic versus foreign inventions. The second is the location or country specificity of technology.

International patterns in invention data inform the first issue. Most OECD countries are characterized by approximate competitiveness between domestic inventors and inventors in other OECD countries. This is reflected in the fact that inventors in one country often obtain IPR protection in other countries (including developing countries). They thus have a “technology sellers” stake that is important. By contrast, inventors in developing countries protect few of their inventions in other countries. Most of their domestic inventions are adaptations of “upstream” inventions. They have very limited technology sellers’ stakes to protect.

One measure of the degree of location specificity of invention is the ratio of domestic inventions protected abroad to total domestic invention. For agricultural crop inventions (i.e., modern crop varieties), inventions made in one country have low rates of use in another country. The proportion of crop varieties developed in a National Agricultural Research System (NARS) and released in another country is typically less than ten percent of varieties developed domestically. The proportion of varieties developed in international agricultural research centers (IARCs) and released in several countries is much higher. Virtually no crop varieties produced for developed countries are actually planted in developing countries.⁴

These two issues create policy problems for developing countries. The asymmetry between the technology sellers’ and technology buyers’ interests in OECD countries is low and these countries have long recognized each other’s IPRs. But the asymmetry between the technology sellers’ rights of developed and developing countries has long been expressed in the

⁴ See Evenson and Gollin (2002), Chapter 21.

form of efforts by developing countries to avoid or evade the recognition of the IPRs of developed country inventors. It has also inhibited the development of IPR systems in developing countries to stimulate domestic adaptive invention and related tacit knowledge acquisition vital to their growth (see the following section).

When location specificity is high, as it is in agriculture, the policy remedy is simple and straightforward. You either build adaptive invention programs or you don't get technology-based growth. For agricultural invention, the tradition of public sector research in the absence of effective IPRs has led to a broad-scale development of invention capacity (the Green Revolution was created by public sector national and international experiment stations). But for many other fields of invention, developing country hostility to IPRs has meant that they have not built domestic adaptive invention capabilities, and many have not built a capacity to effectively "imitate" foreign origin technology.

C. Rate of Return Evidence and Relevance to Higher Education Programs

In this section, rate of return evidence for agricultural research and extension programs is summarized and an attempt made to consider the magnitudes of public values (areas A and B in Figure 1 and area F in Figure 2). It should be noted that this evidence is from programs where a high degree of location specificity is present.

Table 1 reports a summary of calculated "internal rates of return" to agricultural research and extension programs.

These estimates are reviewed in detail in Evenson (2001) and are summarized here. The review considered 81 estimates of IRRs for extension programs (from 50 different studies) and 375 estimates of IRRs for public sector agricultural research programs (from 175 different studies). The percentage distributions of these IRRs by region are reported for IRR classes (0-20, 21-40 etc.) and median IRRs are reported as well. In addition, IRRs are reported in the same format for studies of pre-invention or basic science research, private sector R&D

programs producing inventions “used” in the agricultural sector and for ex ante studies of expected research impact.

Two features characterize all classes of IRR estimates. The first is that the range of estimates is broad, ranging from zero IRRs indicating no measurable program impacts on agricultural production to very high IRRs measuring high program impacts. The second feature of these estimates is that the median IRRs are high and generally well above “equilibrium” returns to investments in a market economy. The methodology employed in the studies reviewed captured the “social” or public return to investment in research and extension programs. (The area A+B in Figure 1 and F in Figure 2), (Both producers and consumers surpluses were counted as benefits). In a world of efficient resource allocation, these social returns and investment would be roughly equivalent to private returns, but in the real world of inefficient public sector resource allocation, these high median IRRs are consistent with the observation that IRRs to private sector R&D are much lower than the social returns reported in Table 1.

Actually, the IRRs reported for private sector R&D programs are entirely in the form of external benefits realized in the agricultural sector. That is they include area A+B in Figure 1 but not area P, because private returns (area P) are captured in the prices that farmers paid for farm machinery, chemicals and seeds from the private sector. Using the time weights in the IRR studies we can estimate the ratio of the area A+B to P in Figure 1, assuming that private sector returns are in the 20 to 25 percent range. This ratio is approximately four.

We can also compute the ratio of public values to “normal” private values (20 percent IRRs) for extension programs using extension time weights (which are shorter) and for public sector research program using the time weights estimated in the research studies. This is the ratio of the area F and to the area E in Figure 1. These estimates for extension programs’ range

from 2 to 3. They are roughly three for countries outside Africa and two for Africa. The “extra” surplus (as measured by B in Figure 1) is one to two times P (Figure 1).

For research programs these ratios are higher. They range from 5 to 7, being approximately five for African programs and seven for Asian programs. The “extra” public values from these calculations ranges from three to five times P or E. In addition, there is a dynamic element associated with the fact that investments shorten the period required to move up an additional Innovation Capital class. The TFP change from moving up one class was approximately .7 percent. Cutting the average time from 20 to 10 years adds .35 percent TFP growth.

For agricultural invention, the IRR evidence is quite clear. Many of these IRRs, were estimated for plant breeding programs. Effective development of modern crop varieties requires “frontier” technical capabilities. The breeding problems of genetic resource evaluation, of identifying sources of host plant resistance to plant diseases and insect pests, and of host plant tolerance to abiotic stresses require advanced skills. Progress requires years of commitment and of scientific exchange by specialized breeders, plant pathologists, entomologists, geneticists, physiologists and other scientists. This generally means Ph.D. training and Ph.D. training at the “frontier,” It also means long-term commitments of people and institutions. Plant breeders often invest ten or more years of effort before the release of their first variety.

Not only are crop inventions demanding in terms of skills and of institutional support for skills, but also the demands for success are, if anything, higher in the poorest countries where production environments are often highly unfavorable. Thus, in many African countries the challenges for biological inventions are great and the public value of highest level skills is highest in this context.

V. Implications for Capacity Building

Do public values associated with higher education change the investment implications based on private values only? This lecture suggests that they do, but for specialized types of higher education associated with economic growth production, i.e., with inventions and innovation. The paper also argues that some part of this public value is associated with international experience, which may be acquired in a higher education program in a developed country.

In this section, three policy issues are discussed. The first is to review and refine public value calculations and relate them to costs. The second is to address the specialized nature of the calculations. Is it the case, for example, that a Ph.D. program in a developed country can be justified for an agricultural scientist, but not for an art historian? And finally, the matter of the inherent risk of “brain drain” in international higher education programs is discussed.

A. Public Value Calculations

Private value calculations of returns to schooling show highest returns to primary schooling and literacy achievement, with lower returns to secondary schooling and lowest returns to college and graduate education. In many low income (and low TC) countries, academic salaries are low (even when housing and related benefits are included), and the added salary increments associated with completing a doctorate are low. It is not unusual to observe non-doctoral monthly salaries as low as \$200 per month and increments to salaries associated with a doctorate of \$100 or \$200 per month in low TC countries. As countries move to Group III and Group IV status, these numbers become much higher.

Clearly, an income stream increment of say, \$200 per month cannot justify an international Ph.D. program investment. The present value of an income stream of \$2,500 per year for 30 years is \$24,000 using a ten percent discount rate and \$38,000 using a five percent

discount rate. It is conceivable that these numbers could justify a domestic Ph.D. program but not a foreign degree program.

Can public values raise these numbers to more viable levels? And how do public values compare as between primary, secondary, college and graduate training? How do they compare between disciplines?

Consider whether the ratio of public value of an educated person changes the calculations based on private values. It is important to note that all workers generate “economic surplus.” We normally associate this with goods markets, but in principle, goods surpluses can be translated into factor market surpluses.⁵ The calculations based on inventions in Figure 1 are a case in point. Are public surpluses higher for workers with secondary schooling, college or graduate degrees? Are the public values/private values different? This paper suggests probably not, except for inventors and innovators.

For inventors/innovators two sources of public value were identified. The first was illustrated in Figure 1 where “extra” economic surplus was associated with IPR system drive private sector inventions/innovations and with public sector underinvestment in research and possibly in extension (B in Figure 1).

Rate of return evidence suggested public value/private value ratios in the 2 to 4 range for extension type programs. Of this, the “extra” surplus might be in the 1 to 2 range.

For invention/innovation programs with larger payoffs, the public value/private value ratios could be in the 5 to 7 range with the extra economic surplus being perhaps 3 to 5. Thus, for higher education programs producing inventors and innovators, one could reasonably multiply the private values noted above of 24,000 to 38,000 by a factor of 3 to 5. This would bring them into the range of viability for international degree programs.

⁵ We usually associate “consumers surplus” with goods markets. But these consumer surplus values can be translated into factor market surpluses.

A second source of public value is associated with a shorter transition from one level to the next. As noted above, pursuing an aggressive technological capacity strategy could halve the time required to move from one level to the next (23 countries actually moved in 10 years instead of 20). The growth dividend associated with this is an added .35 percent per year. If this required an increase in public and private educational spending of one percent of GDP, the added growth component would increase the extra public value/private value ratio for research from 3 to 5 to 4 to 6.

An additional source of public value is associated with the establishment of a training capacity in a developing country. India now has approximately 25,000 agricultural scientists in its public research system. A number of these scientists have graduate degrees from developed country programs, but most have graduate degrees from Indian universities. The quality of these Indian degree programs was at least partially the product of International Higher Education support programs. Many of the Indian degree programs had affiliations with U.S. Land Grant universities and many faculty members were produced in this program.

How much added public value is associated with the successful development of such degree granting programs and the “leverage” created through students (and students of students) If each faculty member produces say 15 Ph.D. students over a career, the public value added can be quite considerable. At a discount rate of 10 percent the present value of this contribution would roughly double the values calculated above.

It is also noteworthy that the effective conduct of agricultural research calls for international participation in the international science community. Almost all agricultural scientists working on rice in India have been to the International Rice Research Institute (IRRI) and all rice breeders in India use breeding germplasm produced by IRRI. The international system of rice nurseries administered by IRRI facilitates the use of this breeding germplasm..

Science, applied science and invention fields are inherently international in today's globalized world, and this means that practitioners must be linked to the leading institutions producing new science, applied science and inventions.

B. Invention/Innovation and Fields of Higher Education

The argument presented for the extra public values calculated above is couched in growth production terms. Which higher education programs produce "growth producers" (i.e., how are invention/innovation and technology acquisition skills acquired)? And how does one weight the different fields of invention?

The arguments presented in this paper made a distinction between specific invention/innovators and In/Im enhancing activities. TC enhancement entails a broader range of educational programs including literacy achievement in primary and secondary educational programs. It also included college programs that support (and spawn) the growth producers. Many college programs support skill acquisition that is growth producing. But it is almost certainly the case that college curricula and fields of emphasis should emphasize the engineering-sciences and the "hard social sciences" more than the humanities relative to the curricula mixes in high-income countries.

The relative weight to different fields of invention activity should depend on the stage of development of the economy. For TC-I countries (see Lecture 2) with little industry, achieving agricultural productivity growth is of paramount importance. This is both because of the weight of agriculture in the economy and because these economies lack the institutions and infrastructure to make anything else work. The experience of the past 50 years shows that TC-I countries achieve TFP gains only in agriculture and given limited investments, they achieve few gains there.

In TC-II countries, agriculture also dominates TFP growth and this is because they actually invest in agricultural research and extension. Many TC-II countries have achieved

agricultural gains from Crop Genetic Improvement (CGI) or plant breeding inventions. The Green Revolution has reached many TC-II countries (it has not reached many TC-I countries but it is about their only option for growth). The Group II countries, however, receive considerable World Bank and other support for industrial growth. They do realize industrial growth but little industrial TFP growth. These countries do not acquire technology easily, and because the aid agencies have not stressed industrial R & D for these countries, their industrial growth comes at high cost.

For TC-III countries, agricultural TFP growth is high and industrial TFP growth is beginning to emerge. They continue to underinvest in industrial invention, and most have great difficulty developing the IPR systems and associated institutions to move them into the rapid growth class of the TC-IV countries.

Even among the TC-IV countries, not all have achieved the policy and institutional environments for NIC performance even though they do have the TC environments for super growth.

African countries face major challenges in upgrading their TC levels. Advanced training at the PhD level is required. Non-government organization (NGO) programs have not invested in TC capacity, except marginally. Government support of higher education is required.

C. International Experience, Migration and University Development

Investment levels in general science, the applied or pre-invention science and in R & D invention/innovation programs are such that developed economies are the natural originators of science findings and of inventions/innovations. The OECD countries share in this originating leadership role. Developing countries range from the TC-I countries who are largely outside the

system except as buyers of products embodying inventions, to the TC-IV NICs (and potential NICs) who specialize in adapting OECD inventions to meet demands in their own and upstream markets.

Yet, for all TC levels, there is value to international experience including obtaining degrees in developed country programs. For TC-I and TC-II countries this is largely due to the fact that domestic programs, even at the MA level, are often not really available. For TC-III and TC-IV countries, even if good programs are available, there is added value in the international experience: the opportunities to observe and learn from originators.

The risk associated with international experience is that the potential inventor/innovator will not return. The “brain drain” problem has been a factor for decades, and if anything, it is getting more severe as the income differentials between OECD countries and TC-I and TC-II countries widen (See Prewitt on replacement migration). Past experience suggests that brain drain problems are most severe in TC-I and TC-II countries and not too serious in TC-III and TC-IV countries.

How serious does the brain drain have to be to defeat programs to create inventor/innovator skills? Certainly a 50 percent loss will defeat these programs and even a 30 percent loss is costly. Such losses have destroyed these programs in the past and the fact that they are most severe for the TC-I and TC-II countries presents a real dilemma. How does one move the TC-I and TC-II countries out of their current conditions of mass poverty?

D. Mentoring and University Support for Capacity

The modern university in the OECD countries and particularly in North America is international in two senses. First, recruitment of graduate students is international. At many leading U.S. universities, foreign graduate students dominate. Because U.S.

Universities have “excess capacity” for graduate training, i.e., capacity in excess of that needed for U.S. students, the real “price” of the raw material (Ph.D. students) if our graduate schools has gone up. Universities like Yale no longer expect tuition from Ph.D. students and pay significant stipends to them.

Second, faculty recruitment is also international. No preference is given to new U.S. Ph.D.'s in U.S. university recruitment. This creates a difficult "culture" for Ph.D. students planning to return to a flagship university program in their home countries. Combined with the fact that demographic changes in OECD countries means that the rate of labor force entry is lower (birth rates declined some years ago), the African Ph.D. from a respected U.S. or European university program will have little difficulty finding employment in the U.S.

But this can be counteracted with more creative support programs. The flagship university programs themselves must be supported. This means visiting faculty and faculty exchanges. It means "sandwich" Ph.D. course programs with the home university granting the degree. (Some observers argue that all training should be in Africa.) But, most importantly, it means that the host government must support the development of its leading universities.

VI. Institutional Reforms in Africa

Most Asian and Latin American countries have made substantial institutional improvements and have achieved market efficiencies. Africa appears to have less efficient markets (see Lecture 1 on the Green Revolution).

One of the issues in Africa is the growing degree of civil conflict. Experience appears to indicate that periods of civil conflict are periods of delay in achieving institutional reform and support in development projects. These are costly. A 30-year civil war means lost ground in the population-food race.

The advent of biotechnology products changes the situation regarding IPRs in developing countries. This is particularly important for Intellectual Property Rights.

Group I (see Lecture 2) developing countries lack the institutions to meet anything but the most minimal regulatory conditions. Group II countries do not presently have institutional settings to meet WTO-TRIPS or CBD and related terms. They could develop them in 20 years or so, but most of these countries still conclude that they can succeed with minimal institutional development. They also imagine that they do not need substantive investments to imitate and acquire technical capability from more developed countries. In this, they are simply wrong. They are far from being competitive in industrial production and they do not have efficient service sectors. Their only dynamic sector is typically the agricultural sector.

In principle, the WTO-TRIPS requirements should (unless completely avoided or "sand bagged") move them in the direction of becoming competitive. These countries do not presently have rDNA or genetic engineering capacity (except for minimal capability), and it will be some

time before they acquire it. But, the IARCs could deliver Gene Revolution products to Group II countries if they were more aggressive in bargaining for IPRs on their behalf. Many rDNA products can be delivered in plants and breeding lines that can then go into conventional breeding programs. An IARC (or some International Foundation), for example, could purchase rights to drought-tolerant IPR protected products and distribute breeding lines to a specified set of NARS programs.

For Group III developing countries, the situation is somewhat different. These countries have the institutional capacity to meet international regulatory standards. At present, they do not have the political interests to do so. Most see IPRs as dominated by commitments to obligations to pay for foreign inventions that should in some sense, be “spill-in” gains and available for “free-riding.” Almost all of those countries downplay or neglect the potential benefits from stimulating domestic inventions.

Most Group III countries have benefited from FDI and they could probably be more demanding for MNCs by requiring more R&D programs in their countries as part of FDI. These countries may be under the illusion that they can meet WTO-TRIPS conditions easily – and build weak Breeders’ Rights programs. But they probably do not appreciate the full implications of patent protection for biotech processes and products outside the “plants and non-human animals” issues in Article 27.3(b). They will also have to address CBD provisions.

Group III countries will continue to be served by Green Revolution gains from public sector IARC-NARS programs. As with Group II, IARCs (or other agencies) could negotiate for IPR biotechnology rights for these countries. But suppliers may be reluctant to provide them, especially to countries like India. But India, (which is about to move to Group IV) has the skills and the institution to negotiate on its own. Countries interested in Gene Revolution access in the next 20 years will have to develop the biosafety institutions and the market institutions to support such access.

Group IV developing countries are candidates for “getting their institutional act together” and using IPRs, biosafety and environmental regulations to their own best advantage. They have the skills, the markets, and the industrial competitiveness (after many years of investment) to realize super growth. Those not realizing super growth usually suffer from self-inflicted wounds (Argentina).

The implicit penalties from foreign technology suppliers’ “withholding access to latest technology” are sufficiently high that this group of countries should have little interest in playing

the piracy game. In effect, Group IV countries should actually buy the WIPO-WTO package in pretty much the same form as do the OECD countries.

Group IV countries have either acquired or can quickly acquire the capacity to produce Gene Revolution products. They are not very proficient at acquiring rights to these products or addressing consumer issues through the development of GM free food products.

VII. The International Aid Climate

In this author's judgment, the international aid climate for Africa is at its lowest ebb since the 1950s. The aid climate for most Asian and Latin American countries was the "golden age" of aid support from the mid-1950s to 1980 or so. Most aid was dedicated to raising the incomes and the earnings potential of farmers and laborers. The building of the IARC system was motivated by the objective of delivering higher yielding varieties to as many farmers as possible. Health programs were dedicated to serving as many people as possible. Asian economies and Latin American economies benefited from this Golden Age of Aid, but by the time many African economies were positioned to benefit, the quantity and quality of international aid began to "unravel".

During the 1980s and especially during the 1990s, aid support levels declined. This is at least partly attributable to the end of the "Cold War" with the dissolution of the Soviet Union. But it had begun before that.

This is perhaps best illustrated by the experience of USAID. In the early 1980s, USAID had programs of direct assistance to farmers (where the objective was to raise incomes) of roughly two billion dollars per year. By 1997 or so, USAID had almost entirely abandoned support for farmers (with less than 100 million dollars in program support) and was actually party to programs that destroyed the livelihood of many farmers. These were biodiversity programs where protected areas were expanded and large numbers of "slash and burn" farmers and indigenous people were driven from their homes in the interest of "saving species".

While USAID continues to support health programs and emergency food aid programs in Africa, it has effectively abandoned African farmers. Much of USAID's resources are channeled through NGOs. And many NGOs do not serve Africans. (There is now some movement to restore assistance to farmers.) And this abandonment of African farmers took place over three administrations (Bush, Clinton and Bush).

It is difficult to fully understand why this happened. But it did happen when "Sustainable Development" was the dominant aid philosophy. Were African farmers the victims of U.S.

politics where “environmentalists hate farmers and ranchers” (at least in most debates over environmental policy this is reasonably accurate)? And did environmentalists capture USAID under the Sustainable Development banner with the result that “USAID hates farmers”? It does not appear to be the result of USAID program evaluations since USAID has little or no capacity to evaluate programs. Or it may have been the result of low farm prices in a “world awash with grain” where both U.S. farm groups and U.S. environmental groups supported the abandonment of support to farmers in Africa - and Africa is where this support counts most.

This has been a tragedy for USAID programs; after all, 70 percent of the people served by USAID are farmers and farm workers. And it has been a tragedy for U.S. foreign policy. The abandoned countries have long been seen as benign and weak by the State Department. But 9/11 has shown that the abandoned have destructive powers.

The other major aid philosophy is the poverty reduction philosophy. (As espoused by the World Bank, this is often considered the “Poverty Sanctimony” philosophy.) The implicit program design of these programs has two parts:

1. The setting of poverty reduction goals.
2. The design of programs to meet these goals.

In practice, the design element is often missing. Note that food aid and other humanitarian and welfare programs are important for maintaining human health and earnings capacity, but they do not increase earnings capacity.

Africa does have Sustainable Development issues associated with maintaining soil fertility under cropland expansion programs. But, surely, the saving of species has little or nothing to do with the real problems facing African farmers. Asking African farmers to produce goods valued by the Sierra Club is not in Africa’s interest.

Africa needs to give serious attention to transforming traditional agriculture. The fact that the world is “awash with grain” doesn’t address the problems of African farmers, who desperately need to transform traditional agriculture if they are to escape from mass poverty.

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Table 1: Internal Rates of Return (IRR) Estimates Summary

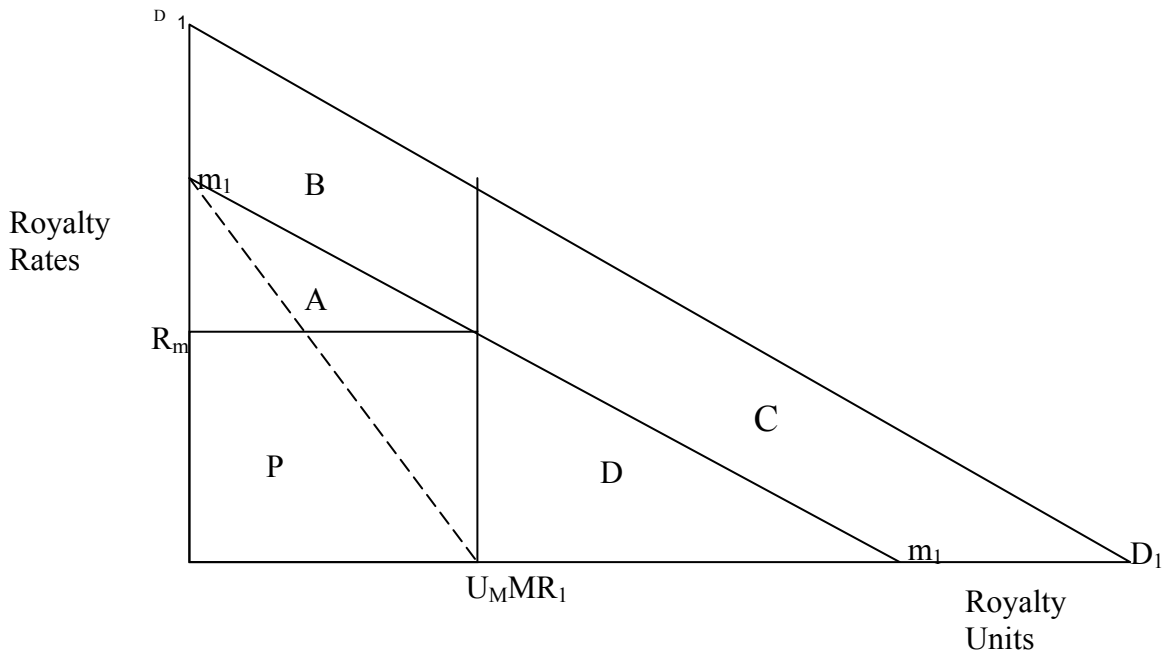
	Number of IRRs Reported	Percent Distribution of IRRs by IRR Range						Approx. median IRR
		0-20	21-40	41-60	61-80	81-100	100+	
Extension	81	0.26	0.23	0.16	0.03	0.19	0.13	41
<i>By Region:</i>								
OECD	19	0.11	0.31	0.16	0	0.11	0.16	50
Asia	21	0.24	0.19	0.19	0.14	0.09	0.14	47
Latin America	23	0.13	0.26	0.34	0.08	0.08	0.09	46
Africa	10	0.40	0.30	0.20	0.10	0	0	27
Applied research	375	0.18	0.23	0.20	0.14	0.08	0.16	49
<i>By Region:</i>								
OECD	146	0.15	0.35	0.21	0.10	0.07	0.11	40
Asia	120	0.08	0.18	0.21	0.15	0.11	0.26	67
Latin America	80	0.15	0.29	0.29	0.15	0.07	0.06	47
Africa	44	0.27	0.27	0.18	0.11	0.11	0.05	37
Pre-invention science	12	0	0.17	0.33	0.17	0.17	0.17	60
Private sector R&D	11	0.18	0.09	0.45	0.09	0.18	0	50
Ex ante research	87	0.32	0.34	0.21	0.06	0.01	0.06	42

(Evenson, 2002)

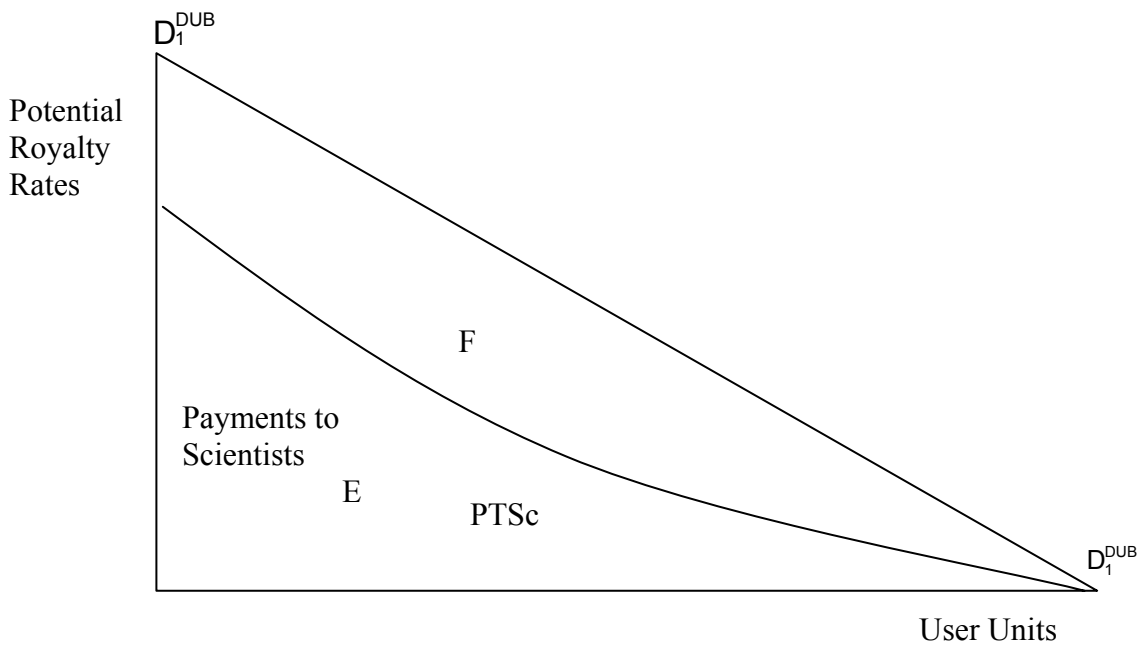
**Table 2: Total Factor Productivity Growth 1961 to 1996
Distribution by Technology Class (See Figure 5)**

Technology Class	Negative	0 to 1%	1% to 2%	2% to 3%	3% to 4%	Mean	Mean Value Added 1995 Per Agricultural Workers 1998-2000 US\$
111, 112 and 222	7	9	7	0	0	0.22%	232
223 and 233	6	11	11	0	0	0.6%	525
333 and 334	1	6	13	8	1	1.53%	1033
344 and 444	0	0	8	2	4	2.29%	3046

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II. Figure 1: Inventions with IPRs



I. Figure 2: Public Sector Inventions

