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TECHNOLOGY GENERATION AND THE
TECHNOLOGICAL SPACE

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This paper is being circulated in a pre-publication form to elicit comments from readers and generate dialogue on the subject at this stage of the research.
1. DEFINITIONS

Technology is one of the most discussed terms and that is probably why it is often implicitly understood without resort to definition. For our purpose, we need a definition if only to collect our thoughts in discussing the whole question of technology generation. The concept of "technological space" is new. It was first introduced by Herrera\(^1\) to refer to the set of assumptions or paradigms that were used in the making of a given technology. This concept is central to our theme; therefore we need to define it both for limiting our discussion and clarifying what we mean by it.

1.1. What Is Technology?

A technology is a specific combination in the form of a tool or a procedure (a recipe) of a scientific principle or principles conceived by a person or persons for solving a defined problem or set of problems. In the context of technology, a problem may be defined as a state of the environment\(^2\) or a part thereof which has been designated as having undesirable properties. A technology is therefore the use of knowledge to change an undesirable environment to one with less undesirable properties.

The specific nature of a technology will depend on the following determinants among others:

- the nature of the environment
- the conception of some part of this environment as undesirable and hence a problem
- the preconception by the maker of the technology of what the technology is and does

\(^{1}\) Herrera
\(^{2}\)
— other existing technologies in combination with which the new technology is to be used
— the nature and availability of the materials that go into the making and maintaining of the technology (if a tool) and those that go into applying it (if either a tool or a recipe)
— the repertoire of knowledge and technical skill at the disposal of the user of the technology both for effective application and for maintenance
— the financial ability of the maker of the technology to translate his conceptions into outputs in the form of technologies (this is especially true in technologies which are manifested as tools)
— the financial ability of the user to afford to buy, use, and maintain the technology
— the cultural setting of the maker of the technology since this filters the aspects of the environment which are to be designated as "problems" by him and influences the priorities given to these "problems" and hence to the corresponding technologies
— the political setting in which the maker of the technology is found since it also influences the designation of "problems"
— the cultural setting of the user since this goes into determining whether he accepts or rejects a technology
— the political setting of the user since it influences the availability of the technology, his accepting it, his affording it, and his using it effectively
— the existence of cheaper or more convenient imported products
— the similarity in the knowledge and values and therefore in the reciprocal empathies between the maker and the user of the technology.

These determinants of a technology are of unequal weights in their effects. They also differ in their being amenable to precise definition and quantification — some of them, e.g., the cultural values, are for all practical purposes impossible to quantify. The majority are capable of further splitting into more precisely definable components. The intention in enumerating them is not to be exhaustive but to obtain an insight into how they function. There is thus a reason for their incomplete listing.
1.2. What Is Technological Space?

The success or failure of a technology depends on the above and other determinants. If each discrete determinant — as noted already, most of the above itemized determinants are capable of further subdivision into more discrete determinants — were visualized as an axis of variation, we would have a hyperspace, the coordinates of whose axes determine (define) unique technologies. Some of these technologies, though theoretically definable by coordinates in this hyperspace, are impracticable, e.g., an engine whose parts are made out of cotton, or a machine that could be built using all the financial resources in the world. Some of them are, even conceptually, purely imaginary, e.g., a technology which will enable the proverbial number of medieval angels to stand on the tip of a needle not in medieval discomfort but in modern ease without modifying the dimensions of the tip of the needle.

In short, the technological hyperspace defines technologies which would be right for solving specific problems, other possible technologies thought not right for the problem, and still other impossible and imaginary technologies. It is the collection of all the points in the hyperspace that determines some real (non-imaginary) and possible technologies that we call the technological space. In the context of whether a technology is good or bad, the issue becomes one of determining whether it is the one which, assuming that all the determinants of technology are quantitatively known, would be defined by the correct point in the technological space or not. Even if we could completely quantify the axes of the hyperspace, any position in the vicinity of the correct point would define the needed technology sufficiently, thus making it possible to visualize a set of definite technologies to separately solve a range of slightly varying problems rather than an infinite variation of technologies corresponding to an infinite variation of problems. For example, we can accept that a technology user with the financial means of a few dollars more or less than another user will find a technology more or less equally acceptable.
In order to intensify our visualization of how these determinants of technology function, let us briefly look at each of those enumerated above.

2.1. The Nature of the Environment

In extreme cases, it is easy to see that technologies are environment-specific: nobody would use oars for flying or wings for moving on the ground. Environmental differences are, however, not always as obvious as the differences among aquatic, terrestrial, and atmospheric conditions would suggest.

The tractor as we know it was developed for temperate soils. Is it appropriate to use in the more fragile tropical soils? Perhaps the concept of a tractor is, but perhaps the already developed heavy machine is not.

The salting of perishable foodstuffs to preserve them is an old tradition in societies whose inhabitants live in the not so sunny temperate countries. The traditional equivalent in tropical countries is sun drying. If you have sunny weather, sun drying is more cost-effective and more thorough in preserving. What is more, it obviates the tedious process of desalting before eating. These technologies are appropriate in their respective environmental settings. Trying to introduce sun drying into temperate countries, though possible through the use of modern techniques of concentrating radiation in a small area and optimizing the heating effects of sun's light, would not have been possible in the past and is probably impracticable even now compared
with other forms of food preserving. Introducing salting to the tropics and giving up sun drying would certainly be a retrograde step. It is therefore obvious that there is an environmental dimension to technology.

2.2. The Realization by the Technology User and the Formulation by the Technology Maker of the Problem to Be Solved

If a problem is not fully realized by the user and correctly formulated by the maker of the technology, it cannot have a technology which is right for its solution. This is self-evident. Nonetheless, it should be discussed further even at the risk of belabouring it.

If a technology is to be successful, the formulations of the problem as made by the maker and its realization as a problem by the user have to correspond. The more divergent the formulation and realization are, the less effective the technology becomes. These divergences range from a non-formulation by the technology maker while the problem is the most pressing to the technology user, through various shades of differences resulting in diminished suitability of technologies, such as a wrong formulation by the maker, to the formulation of a non-existent problem, and the development of an irrelevant technology.

2.2.1. The Absence of Formulation by the Technology Maker of the User's Pressing Problems. The bulk of the problems that prevent underdeveloped countries from developing are unformulated ones. By the very fact that they are not formulated, their extent is unknown. Only a few examples can be drawn from rural Ethiopia to illustrate this, although unformulated problems are universal in underdeveloped countries, and even if a person dedicated all his life to this task, he could identify only a small fraction of the ignored problems, even in rural Ethiopia. The following are therefore only examples:

- The most important cereal in Ethiopia is teff — *Eragrostis tef* (Zucc.) Trotter. Virtually none of its ecophysiological problems has been formulated. It does reasonably well under waterlogged as well as well-drained conditions. Its adaptive mechanisms are unknown.
- The most important oil crop in Ethiopia is noug, niger seed — *Guizotia*
abyssinica (L. fil.) Cassini. The same comments made for teff are applicable to noug.

— Enset — Ensete ventricosum (Welw.) Cheesman — is the important root crop in Ethiopia; it is excelled only by teff in importance as a carbohydrate source. It is as unknown as teff and noug.

— The donkey is the most important means of transportation in rural Ethiopia as well as in many other rural countries. It is a domestic animal which has so far attracted no research interest in Ethiopia and very little interest in the world at large.

— In three centuries since the sixteenth century, the Oromos, a nomadic group, swept across Ethiopia in spite of its clearly defined feudal social order and long military tradition. The Oromos are essentially no longer nomads: those in the areas suitable for cultivation are successful cultivators; those in the arid areas are nomads; and those in the towns are the mainstream of Ethiopian society. Where did their strength as nomads lie? Where did their versatility come from to render them, in historically such a short time, farmers in the agricultural highlands and professionals in the towns as good as any of the long-established nationalities in Ethiopia? What conscious choice can Ethiopia make to use this strength and versatility of the Oromos for the whole of society and for posterity? These problems have never been formulated with the idea of generating a technology (a recipe) for Ethiopia's development. Indeed, only some of them, and then only partly, have been formulated even by the scholars who get tickled by exotic ethnic groups.

2.2.2. The Imperfect Correspondence between the User's Realization and the Maker's Formulation of Pressing Problems. Every underdeveloped country has countless anecdotes of machines and items of equipment imported at incredible expense and left lying idle or partly idle, or broken down and locally irreparable. Obviously, these machines do not solve the problems felt by the user. In the case of imported machines, the formulation of the problems which produced them as technological answers was made in another society: a society different in the nature and intensity of the realization of the problems.
Even when the maker develops a technology specifically aimed at a given society, his formulation of the problem and the user's realization of it can be at variance. The traditional ox-drawn Ethiopian plough is considered by most agriculturalists as light and ineffective in turning the soil over. An ox-drawn mulboard-type plough was therefore developed by the Chilalo Agricultural Development Unit (now the Arsi Agricultural Development Unit) to replace the traditional plough. The scientists who developed this plough had well-fed and well-cared-for oxen from their own experimental station to draw it. Experimentally, the plough was a success. When the peasants tried it, however, their badly fed, weak oxen could not pull the plough. Obviously, the formulation of the ploughing problem by the scientists was not in complete agreement with the same problem as experienced by the peasants. Weak oxen were part of the problem of the peasants and feeding the oxen enough for them to pull the improved plough is not possible without first raising their labour productivity. If the plough has to be improved for labour productivity, and yet it can be used only after the labour productivity has been improved, the improved plough becomes a technological hardware example of the principle in logic of "begging the question."

The obverse of the kind of lack of correspondence between the technology maker's formulation of problems and the peasant's realization of them also occurs. Many implements made for a specific purpose by the technology makers are often used successfully for the solution of pressing problems of the peasant, but these implements are far removed from the problem formulation of the technology makers. Tins which were meant for conserving food by the makers have successfully replaced earthenware as cups for drinking water and beverages in many peasant societies. The rubber inner tubing of car tyres is now fast replacing water bottles made of skin among the eastern and north-eastern dry lowland nomads of Ethiopia. Lids of steel barrels have effectively replaced the ceramic hot plate for all purposes other than baking injera,\(^3\) for which the metal plate apparently does not have the required stable temperature properties when over the flame of variable intensity as produced by burning wood.
2.2.3. The Formulation by the Technology Maker of a Non-existent Problem. Considering that the normal situation is to ignore the problems of peasant communities, it may sound absurd that examples of technology of this category occur at all. Sometimes, however, revolutionary changes, reactions to large-scale calamities, or even expediency force an establishment to pay attention to the peasants.

An interesting story was told by the head of extension services of Ethiopia's Agricultural Development Department of a zealous extension drive to help peasants build grain stores. The peasants were not very keen, but some did build stores. Those built were, however, not used. Further inquiry showed the simple fact that the peasants had no extra produce to store!

The author visited a settlement site near Kobo in north-eastern Ethiopia where destitute people from the notorious Wello famine of 1971-1974 were being helped to start a new life. Good, solid, modern-looking buildings had been made for them. The settlers refused to use these buildings and made their own improvised stick and straw huts. Yet, only a few kilometres away, another settlement had built good houses, though from much cheaper material. These houses were liked by the settlers and they live in them. The reasons for this are not known, and there has not been an opportunity to pursue this question further. But then, as studies by the MAYA Group — the Mexican participants in the R&D Systems in Rural Settings Project — have shown, this phenomenon is common and there are many well-documented examples from other countries.

2.3. The Preconception by the Maker of the Technology of What the Technology Is and Does

Given a formulated problem, the maker often has a wide range of possible technologies to try. Let us consider the problem of unavailability of drinking water for a village community. Storage dams could be built and water piped either by gravity or by pumping. The water could be filtered and chlorinated. Wells could also be dug and water pumped out. It could even be brought by tanker lorries or aircraft. Or even
icebergs could be towed from the polar regions, as was once considered for Saudi Arabia.

Even when a serious technology maker tries to take the constraints of the rural poor into consideration, his visions of what his technology will do when it "solves" the problem may be different from what it actually does. Let us look at the example of malting barley in Ethiopia.

Ethiopia is known for its large genetic pool of food barley, but malting barley is new to the country. Malting barley was introduced for use by the home beer industry. Barley grows best in the densely inhabited highlands, and large-scale commercial production is thus impracticable. An effort was therefore made to convince the peasant communities to produce it as a cash crop. A new technology, intended to solve the problems of the brewing industry and to bring cash to the peasants, was thus introduced. The peasants took up producing malting barley, and the problem of the brewing industry was partially solved. This created a new situation that was viewed as a problem by the technology makers but not by the peasants. The peasants started using the malting barley for food. To them, barley was barley, and this new barley made excellent injera. But the essence of malting barley is that it has been bred to produce the least possible in the way of proteins; the traditional food barleys are high in protein and thus make better food.

2.4. The Preconception by the User of What the Technology Is and Does

The user often fails to try a technology with an open mind: he has a preconception of what it should be like, at least in some important aspect, and what it should do. In many rural areas in Ethiopia and indeed in most of Africa a prevalent belief is that a drug to be effective has to be administered by injection. Tablets or liquids to be swallowed are of secondary importance. It is claimed that often doctors have to give injections of distilled water to please their patients; in other words, the doctors are forced to make the technologies they provide agree with the preconceptions of the users. This is tantamount to pandering to prejudice and it may not sound right to do.
Nevertheless, it illustrates that if the users have prejudices of what a technology is like or what it should appear to do, their prejudice will be an important factor in the acceptance or rejection of a technology.

2.5. Other Existing Technologies Used in Combination with the New Technology

Whether the first hominoids used stone tools or stick tools first may be debated. As soon as they used both of them, the tools must have shown their advantage when used in combination. You stun a prey with a big stone, you cut a branch with a sharp stone, you take the bark off and tie the carcass onto the stick, then two of you can carry the carcass quite easily — this is one combination. Then you sharpen the stick with a sharp stone, and spear another animal — another combination, using a new tool. The materials that now go into making new implements are different; we mostly talk of alloys, but the principle remains the same. Both for the generation, adoption, and maintenance of new technologies, the existing technologies have a very important influence. In the combination of technologies fulfilling different functions in the productive cycle of a commodity, the overall efficiency is determined by the least efficient member. That is where there usually is need for another technology.

In the producers' co-operatives now forming in Welmera, ploughing was the stated need at the beginning. The peasants had too few oxen for effective land preparation. They now have access to tractors. Their stated need now is for a technology for threshing. Lagging behind a little is the need for farm transportation for moving the harvested crop to the threshing ground and the chaff and grain from the threshing ground.

Though they find it ineffective, they have a traditional technique for threshing; they prepare a clean, circular area and spread the harvest, then they walk their cattle over it; after that, they winnow.

The traditional solution to the transportation problem is physically
carrying the harvest or using donkeys as pack animals. The members of the young producers' co-operatives — who were mostly destitute at the beginning — have few donkeys, but they have some oxen. They have now "invented," unaided by any scientist, an ox-drawn sledge. Since wheel technology is a recent introduction into Ethiopia,⁷ and even then only in the form of manufactured vehicles, the peasants have not made a cart. A sledge is, however, something they could do with their existing skills.

During discussions with peasants and scientists in one of these pre-producers' co-operatives prior to sowing during the 1981 growing season, the author discovered a dimension to the rejection of technologies which he had not realized. The discussion was on land preparation for linseed (*Linum usitatissimum*, L.). This led to a wider discussion on land preparation for oil seeds in general. The scientists maintained that the field has to be ploughed for oil seeds as well as for cereal cultivation. The peasants insisted that ploughing should be done only during sowing and that the plough should only scratch the soil just below the surface. This led to a debate. The peasants told the scientists that if they prepared the land well, then they could not prevent the plough from going deep into the soil during sowing and thus from burying the seeds too deep for successful germination. The scientists then realized that the traditional plough, though a good enough "seeder" for the larger seeded crops (the cereals and pulses), was not appropriate as a seeder for the small seeded oil crops. (The smallest seeded crop, teff, is sown on a well-prepared, moist seedbed and it germinates on the surface without burying.) When the use of a new implement, a seeder, was proposed to the peasants, the idea was immediately accepted, and they agreed to prepare their fields as suggested by the scientists. A technology very well known to the peasants, land preparation, had so far been rejected by them when it came to cultivating oil crops because of their lack of a complementing technology for a successful sowing.

2.6. The Nature and Availability of Materials

In October 1980 in a little school in Axum, Northern Ethiopia, some
students were displaying their handicrafts. Among them were some beautifully made plastic combs. They had got hold of large broken bits of plastic ware and carved them into beautiful combs. They were hoping to make more handicraft pieces and sell them to earn money for their school. Their plastic combs certainly have limited horizons: the students would have to wait very long to obtain other broken pieces of the very rare plastic crockery in Axum! Of course, they had other combs of wood, and these have a better prospect.

To many home or university backyard makers of "intermediate technology" in this age of the great threat of environmental pollution with the virtually undegradable plastic, the fact that plastic is very rare in Axum may sound unbelievable. But it is true. And the author believes that this is as true in other truly rural societies — after all, plastic is only a few decades old even in the highly industrialized societies. The backyard makers of intermediate technology should know that broken motor cars, dumped old refrigerators, or even old wheel rims are virtually non-existent in Axum; they are rare even in Addis Ababa. They all too often forget that a society which produces these as its refuse in quantities enough to enable them to be used as small substitutes of large factory-made machines is one which is already industrialized or, as happens occasionally, one which is so endowed with some peculiar wealth (e.g., petroleum) that it is a good market for industrialized societies. In either case, backyard intermediate technology is inappropriate and, in such situations, one should think of a full-fledged integration into the industrial societies rather than opting for the "fringe." The plight of the rural poor cannot get enough consolation from the rubbish bins of the industrialized societies: if the rural poor have to have technologies, they must use the resources which exist within their respective rural societies.

This is not to say that imported technologies or inputs into technologies cannot be used. They can, but there must be a system which guarantees the availability of the import. Considering the poverty and political weakness of rural communities, this is often not possible. Some of the peasant communities in Ethiopia have accepted the use of artificial
fertilizers as a technology. For a few years during and just after the war with Somalia, these fertilizers became virtually unavailable. They are as yet not fully available and, considering the price rises that have occurred in the last few years and Ethiopia's poverty, their future seems unassured even with a return to peace and normality.

2.7. The Repertoire of Scientific Knowledge and Technical Skill at the Disposal of the Technology Maker

The development of the atomic theory by the late nineteenth- and early twentieth-century physicists was a prerequisite for the development of nuclear technology, ranging from the use of isotopes for ground-water prospecting to the use and threat of nuclear bombs which can wipe us out. So was the technical skill in grounding glass a prerequisite to the microscope. The point that the maker of a technology has technological horizons limited by scientific knowledge and technical skill is easily made, and there is no need to pursue it further.

The aspect that may need discussing lies in the selection of the technology maker's knowledge and the application of skills for a particular technology. The choice should be governed by the feasibility of the technology in producing and running it as well as in having it accepted by the user. This is the main theme under discussion, and it will be pursued further in the following sections. Pre-empting that, it should be stated that the selection of the knowledge and its combination as well as its manifestation in the form of a tool or a recipe should be done in the interest of the user. This means that the maker should take the position of the user. The extent to which the maker can assume the identity of the user will determine the extent to which the maker will filter the scientific knowledge into a technology suitable for the user.

2.8. The Repertoire of Scientific Knowledge at the Disposal of the Technology User

The most important killers in rural Ethiopia are infectious diseases.
There is a technology, or rather a whole set of technologies, developed in the industrialized countries to prevent these. They are based on the germ theory of diseases. They are all very easy to apply, provided that the process of infection is clearly and explicitly known. The main reason for the inapplicability of these preventive health-care technologies in rural Ethiopia and in other rural societies is the lack of knowledge of the germ theory of diseases and the resulting lack of appreciation of the process of disease transfer. It is true that for some diseases (for example, typhus) there is a traditional appreciation of communicability through contact. Typhus patients are thus traditionally isolated until they either recover or die. This traditional technology is empirical in nature. It does not implicate the vector – the louse. Since this technique of preventing typhus lacks explicitness, it has not been extended to the other communicable diseases. The body of knowledge of the technology user is obviously important in the widespread and effective use and maintenance of a technology.

2.9. The Financial Ability of the Technology Maker

The financial ability of the technology maker is important in determining the ability to translate conceptions into outputs in the form of technologies.

Ethiopia is an agricultural country and yet it has no fertilizer industry: it imports fertilizer. It has much potential hydrothermal and geothermal power for electricity generation. A fertilizer industry could be built to use electric power. This is clear to the scientists and to the authorities. But such an undertaking is expensive. It is claimed that the existing fertilizer market would not justify the investment, even if it could be raised abroad. And yet the fertilizer market is small precisely because fertilizer is not easily available. If financial ability were not the issue, the electricity generation and the fertilizer plants would be built, and the availability of fertilizer would change the large potential market into an actual one.
2.10. The Financial Ability of the Technology User

The very example of fertilizer mentioned above can illustrate this point. Fertilizer is now expensive and difficult to acquire. If the peasants of Ethiopia had large financial resources, there is no doubt that fertilizer would somehow travel to their doorsteps and force them to realize that they "need" the technology. In fact, they do. But many other "technologies" which are not at all necessary for a comfortable life would also be pushed on them. As it is, many technologies which could have made much difference to their lives are unavailable to them. They know of modern medicines that would cure most of their illnesses and their domestic animals' illnesses; many of them even know of cars, lorries, tractors, combine harvesters, etc. But they have no money, and the technologies remain elusive to them.

Some of the peasants have acquired "modern" pressure lamps which require kerosene for running. They mostly now lie rusting; petroleum products have lost their way to the peasant! There is no doubt that the financial ability of the technology user to afford to buy and maintain a technology as well as to use it is an important determinant in the success or failure of a technology.

Sometimes increased financial ability can mean the rejection of a technology. The bicycle, which gave way to the motor car in the industrialized countries when petroleum was cheap, is now, it seems, coming back. The peasant's problem, though, remains one of not affording even the bicycle.

2.11. The Cultural Setting of the Technology Maker

Culture weighs heavy in the process of choosing. The culture of the technology maker is a major factor in the history of the development of a technology.

The R&D system in Ethiopia is small. Nevertheless, its achievements can
be looked at critically. The research done on crops has so far emphasized wheat and barley. Yet of all the crops teff feeds the largest number of people. Some researchers believe that, apart from research on teff, they would campaign for its elimination. Why? They state that teff has a low productivity. Is this not a very good reason for research? The answer is simple. The first scientists were expatriates, and the Ethiopians who have followed them have been influenced by their prejudices. They have started from the correct premise that underdevelopment is bad. They have often made the wrong conclusion that the whole culture of underdeveloped countries is bad, and the whole culture of industrialized countries is good. Both expatriate and Ethiopian scientists have thus been the same in their implicit condemnation to oblivion of the culture of the most underdeveloped component, the epitome of underdevelopment — the Ethiopian peasant. Incidentally, most of the anti-teff scientists, like all Ethiopians, prefer teff as a carbohydrate source for their own consumption. If they have at all thought about it consciously, they must put their idiosyncrasy into a lapse of cultural integrity.

This may sound hard on our scientists. But how can one explain the following examples?

- In rural Ethiopia, milk production is secondary to animal-draught power. Beef production is mostly a necessary by-product to the more useful exercises of milk production, the production of draught animals, and, ultimately, draught power. Yet, the little research on cattle done is on beef and milk production. Regarding donkeys as pack animals, it is not only Ethiopian scientists but the whole world that has ignored them.

- Noug is the most important source of food oil in rural Ethiopia. Rape seed is used for other merely secondary purposes. Yet more work has been done on rape seed than on noug.

- Virtually all cattle in Ethiopia are free range, foraging for themselves in the natural vegetation. Comparatively much has been done on alfalfa, fodder beet, fodder oats, etc., and yet very little is known about the natural pastures.
2.12. The Political Setting of the Technology Maker

The author has been involved in trying to identify and document traditionally used medicinal plants since 1970. Up to 1975 such an activity was considered almost tantamount to indulging in unseemly rituals. The official stand was that there is only one kind of medicine: "modern medicine"; everything else is quackery. And yet it is estimated that more than 80 per cent of Ethiopians depend entirely on traditional medicine for their health care.8

The revolution came. The problem of the peasants has to be looked at. The Ministry of Health has opened an office for traditional medicine. Research in traditional medicine is now multidisciplinary, involving several institutions. There has even been a national seminar in which modern doctors, traditional doctors, and scientists participated. That a political status determines the prevalent technology is a very obvious fact.

2.13. The Cultural Setting of the Technology User

The use of farmyard manure as fertilizer is well known in Ethiopia and in many other equally rural countries. The peasants also know that human excrement has the same effect as farmyard manure. In most of the countries which use manure, the human population exceeds the domestic animal population. Ethiopia is an exception. But only the Chinese have put the obvious conclusion into effect by using human excrement as fertilizer. The taboo of using human excrement is widespread.

More definite examples can be mentioned. In Ethiopia, as indeed in most rural societies, firewood is the main fuel for cooking. With deforestation, firewood has been becoming less and less available. The story of a rejected solar cooker was told to us by the Commissioner of the Ethiopian Science and Technology Commission. A simple solar cooker with a gypsum parabolic surface and aluminium foil reflectors has been developed recently in Addis Ababa. One of these was given on an experimental basis to a poor woman who was finding it difficult to
obtain firewood. She used it happily for a few days. She then caught a cold and stopped using it. She blamed her cold on the cooker.

This rejection was culturally based. In Ethiopian tradition, diseases come from dirt in the biological system. This dirt is eliminated with sweat via the pores. Anything that blocks up pores causes illness. Exposure to the sun or fire or both while handling food and, at the same time, being in the way of a wind draught causes the pores to be blocked and results in colds and similar ailments.

2.14. The Political Setting of the Technology User

It is obvious that the author as an individual would not be allowed, even if he could afford it, to own a nuclear arsenal. In many countries, he would not be allowed even to own simple firearms. This is very good indeed!

But certain restrictions of technology can be bad. The author would not be allowed to board certain buses and trains in South Africa. Of course, he would prefer to be able to own firearms there!

In feudal establishments, countless stories can be recounted of how a petty (or not so petty) feudal lord snatches away a piece of land or an ingenious implement, or even a well-built house, if its legitimate owner is lower down the hierarchy. In pre-revolution feudal Ethiopia, a rural development scheme, the Chilalo Agricultural Development Unit, was funded by the Swedish Government and implemented in the Chilalo Province, Arsi Region, in central Ethiopia. The aim of the scheme was to introduce modern agricultural methods to the peasants so they could produce more and improve their lives. Enough improvements took place in the agricultural production to render it attractive for the landlords to evict the peasants and run their farms as mechanized large-scale commercial enterprises either themselves or by letting them to commercial entrepreneurs. For these peasants the adoption of improved techniques meant the loss of their most important means of production. Would hindsight have blamed them for being "too traditional" if they had
refused innovations? The answer is obvious, but would there usually be enough foresight to appreciate their problems? The answer is equally obvious and it is no. The fear of this kind of net loss from "improvement" is probably the main dampener of initiative in feudal societies that tend to be universally unimaginative and virtually devoid of innovations. Peasants have their roots in feudal societies. They have the "if you improve, you lose" principle built into their reactions. Their plight is often not fully appreciated. They are labelled "lazy" and "stupid." Apartheid arouses much resentment and rightly so. Feudal systems and feudal values in other systems treat the peasant in the same way that apartheid treats the blacks. But what fantasies of glory and piety go along with the memories of emperors and kings!

2.15. The Availability of Alternative Products

Most of Africa had iron long before the large-scale smelters and foundries of Europe and America were built. Iron smelting in Africa was a cottage industry. The European foundries produced cheap iron implements of better quality, and the iron markets of Africa were saturated. It made no sense to continue with the homestead production of iron.10

Iron smelting now is virtually a forgotten art in Africa. Imported iron is no longer cheap, and yet the home-based technology has been destroyed. African countries are often too poor to afford the building of their own smelters and foundries, and their peasants have lost the alternative technology.

Similar statements could be made about many other technologies:
- Aniline dyes have replaced natural dyes.
- Factory-made glass and aluminium crockery has more or less replaced ceramic alternatives made by artisans in each community as well as gourds grown in the backyard.
- Cloth from textile factories seems to be fighting a promising war against homespun and homewoven cloth.
- Even machine embroidery is fast replacing hand embroidery.
The idea is not to lament these. In fact, some of these items, e.g., embroidering with a machine rather than by hand, can be and often are done at the homestead or at least are of small scale and can be incorporated among the local activities. And textile factories require smaller investment, as compared, for example, with steelworks and chemical industries and are thus usually found even in African countries. The idea is to illustrate that alternative imported products can determine the future of a technology.

2.16. The Similarity in Culture and Knowledge between Technology Maker and User

The more similar are the technology maker and user in their repertoires of knowledge, cultural values, and political settings, the more towards identity veer their visions of problems and solutions and even specifications of a needed technology. A technology thus developed stands a high chance of being successful.

Knowledge, and especially communication about knowledge, is intimately linked with language. In industrialized countries, the language of the technology maker, which has a large amount of jargon, often acts as a barrier, but usually a mild one. In Ethiopia and, no doubt, in many other developing countries, the barrier is almost completely impregnable because it is made not only of jargon but of a technical language, usually English or French, which bears no relation to the language of the technology users.

The technology maker has to keep the repertoire of scientific knowledge at his disposal as large as possible; he has, therefore, to communicate with the international body of scientists. For this reason, a common language like English is essential. But it is equally important, perhaps more so, to communicate in the fullest sense of the word, with the technology users. For this reason, for an R&D system to be successful, the development of a local technical language is indicated as essential besides an adoption of an international technical language.
If the hyperspace with the determinants of technology as axes could be completely defined, and the coordinates in this hyperspace of a needed technology could be quantitatively specified, the technology could immediately be seen to be possible or impossible and acceptable or unacceptable. Unfortunately, the required quantitative precision is not possible. "Technological space" is, therefore, useful for placing problems of the generation and utilization of technologies into perspective, but not useful as a source of formulae for producing technologies. It gives a vantage point for an overview of all the efforts at generating "appropriate," "intermediate," and "small" technologies. All these efforts try to simplify the technological hyperspace into a few axes — usually only one. For example, simplicity as against complexity (sophistication) is advocated by some and all the other axes of the hyperspace are ignored.

A simplification of the hyperspace is needed, but it has to be one which is not biased in favour of one or only a few of the axes and ignores the others. Ideally, it should not leave out any axis. Is such a simplification possible?

Before trying to answer this question, let us first look at some problems of quantification and data reduction in technological hyperspace.

3.1. The Impossibility of Complete Quantification

Some of the axes (determinants of technologies) would indeed be amenable to quantification, e.g., financial capabilities. Some are quantifiable in many component parts, though they may still leave unquantifiable
components, such as the environment. Others, for example, cultural and political settings, are not quantifiable in any meaningful manner, though proxy phenomena, such as the number of times a day a person swears or the number of times a year a peasant goes to the market, could be quantified. Nevertheless, the non-quantifiable axes are vitally important technology determinants.

3.2. The Problem of Correlation among the Axes

Many of the technology determinants are correlated. In a quickly changing political situation, cultural and political variables may, to some extent, be discernible. In a long-established status quo, such as a feudal system that has ruled for centuries, politics become culture. Nobody would argue whether "good manners" is cultural or political. "Good manners" in deference to the "upper classes" is, likewise, usually simply accepted as a cultural trait. The "upper classes" form the ruling class, and this is blatantly their propaganda permeating society.

There are also more intrinsically correlated determinants. A high scientific knowledge in the user necessarily implies an even higher knowledge in the maker otherwise the user would be forced to become a maker. The user often knows some specific aspect of the application of the technology more than the maker does. For example, the research physicist using a particle accelerator would be expected to know more about some of the theoretical aspects of high-energy physics than the physicists and technicians who made the accelerator. It is nevertheless true that when all the knowledge that goes into making particle accelerators starting from the raw materials — the ores from which the metallic components of the accelerator were made — and ending in the finished product is concerned, the cumulative knowledge embodied in the particle accelerator is greater in amount than whatever the greatest physicist can master in a lifetime. A higher total scientific knowledge of the maker and a lower one of the user is possible, but not the reverse. These degrees of knowledge are thus correlated.

Even if the axes of the technological hyperspace were all quantifiable,
their correlation would render them impossible for use as co-ordinates specifying the technological space; axes have to be uncorrelated for their quantitative values to be used in their unchanged amounts as co-ordinates, or else their degree of correlation has to be known well enough to determine the angle between them. In mathematical terminology, the axes of our hyperspace are not orthogonal.

3.3. Non-orthogonality of the Axes of the Technological Hyperspace and Technology User Participation

Techniques of multivariate analysis, variously known by such terms as principal components and canonical analysis, have tried to tackle the problem of lack of orthogonality among the axes of a hyperspace. These techniques generate quantified orthogonal (uncorrelated) axes. Sociologists and plant ecologists have tried to use them. However, they are not very helpful in our case, since the new orthogonal axes are not identifiable with any named phenomena. The correlated axes lose identity and anonymous orthogonal axes emerge. It is possible to attach some meaning to the first one or two new orthogonal axes by trying to find a correlation between them and the known variables. But all that this correlation indicates is that the variable correlated with the anonymous new axes is important. Not only is this method tedious, but it leaves, after the exercise, only a correlation — which may not be high — to suggest what the new mysterious variable partly but not fully is. In technology generation, the determinant which is of particular importance, that which is causing a bottleneck, should be known wholly. The anonymous axis, though mathematically "summarizing" a large part of the variability in the technological hyperspace, is not identifiable fully enough for taking a definite action. A system for identifying that critical determinant would enable a fuller understanding of the technological hyperspace and a more meaningful intervention either in the generation or in the distribution of the technology.

The required system for making full use of the hyperspace has, therefore, to be one that involves an implicit comprehension of all the relevant axes as already indicated; an explicit and exhaustive identification
would not want to cook in the sun. On the other hand, it is also highly likely that a scientist straight out of the laboratory would have paid no attention to her views.
4. THE SCIENTIST'S INITIATIVE

Assuming that the scientist would like to pay attention, the question still remains as to how to do so. Participation is a two-way process, and in interaction with the peasant, the scientist should first and foremost be prepared to hear what the peasant says and also to share knowledge in the way that seems easiest to communicate. The scientist should, however, put much effort into preparedness for easy communication with the peasant.

4.1. Preparatory Studies

If the scientist speaks the same language as the peasants — excluding jargon — the task of getting prepared is simple. The scientist should read whatever is written about that area where the peasants in question live. Often, there is nothing written and life becomes simple. The next task is to move around the whole area until all its physical features are known. This will enable the scientist to see the natural environmental problems of the area and, in the meanwhile, notice any small cultural peculiarities, such as the predominant colour of clothing, or whether drunkenness is common.

A scientist who does not speak the same language as the peasants is obviously culturally, at least to some small degree, different — even if from the same country. The scientist should then make sure to know the overall social, cultural, and political setting of the people speaking the peasants' language in the country as a whole. In underdeveloped countries, there is usually very little written on the topic. The scientist should then make use of colleagues who speak the language. These colleagues belong to the urban sector of the population.
and this should, therefore, be borne in mind whenever discussing peasants with them. The scientist's task is indeed difficult.

If the scientist is from another country or, as often happens, from another continent, the problems increase further. It is necessary to learn about the country and the ethnic group to which the peasants belong. The foreign scientist has to beware of written materials — although he has to know them — because they are usually at best oversimplifications and are often coloured by various shades of prejudice. The scientist's task is extremely difficult then, and only the unusual scientist can slog through it.

4.2. Information Gathering

The scientist should then start a dialogue with the peasants. This should include both serious discussions involving questions and answers from either side in meetings as well as communion through simple social mixing, such as at meals, in the market place, or in mourning.

After some accumulation of information on the social, economic, environmental, and technological conditions of the areas, the scientist should use the special skill of systematically arranging information to discern patterns. This will show gaps in the information accumulated as well as enable an identification of the interrelationships among the problems. The scientist should then try to fill these gaps using the combination of formal and informal discussions. This is a reiterative process: order imposed on information being used to identify missing information and show relationships, new information forcing a change in the order imposed, new gaps and relationships being identified, and so forth. Since a reiterative process takes long to stabilize, the scientist will have to decide when "knowing" more or less the whole picture of the peasant community in its technological setting is possible. A scientist should not wait for the reiterative process to stabilize in order to obtain a "complete" picture.

This cannot be done even if the iteration is carried out repeatedly,
because the peasant environment, contrary to the usual belief, is dynamic: new problems and relationships among problems, and even new technologies, will keep emerging. Nevertheless, at this cut-off point, the scientist should have the major problems in the peasant community and their traditional solutions.

4.3. Knowing the Peasant's Technological World

The traditional solutions embody what is empirically known to the peasant. The scientist should study these technologies.

If a new technology exists which is thought to be similar to a counterpart traditional technology, this new technology is likely not to appear alien; in other words, because its position on the technological space is close to that of the already accepted traditional one, it is likely to be acceptable. This could easily sound as if the idea is not to introduce new technologies; on the contrary, the scientist should indeed introduce new technologies. The idea is to enable the scientist to see how different from the usual the new technology is. When the scientist realizes that it will be very different from an existing technology, he still has his partner peasant to discuss that technology before it is made, to help make it, and to try it after it is made—in short, to place the technology in the right position in the technological space. The set of traditional technologies is, therefore, not to replace communication and joint efforts with the peasant, but to make this more effective by letting the scientist know more of the peasant's world relevant to study. At the same time, the peasant will know a little more of the scientist's world. In this way, maybe their children, or at least grandchildren, will have the same world!

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NOTES


2. The term "environment" is here used in its wide sense of referring to the natural as well as social milieus in which the individual or individuals who need a technology are found.

3. Injera is a thin, spongy, very flexible leavened bread. It is made from flour rolled into a thin dough which is fermented. A circular ceramic flat plate is heated, usually by burning firewood. The thin fermented dough is evenly poured on to the hot plate, which has to be of uniform temperature, and the plate is covered for a few minutes. The injera holds the wet (dish made from meat, pulses, or vegetables and usually of the consistency of a stew) well when small parcels are made at the table and eaten. Teff is the preferred cereal for making injera, but, in the absence of teff, any cereal flour will do.

4. According to Carl O. Sauer's Seeds, Spades, Hearths and Herds (MIT Press, Cambridge, Massachusetts, 1969), pp. 76-78, it is debatable whether barley was domesticated in Ethiopia or in Asia. Vavilov is reported as believing in an Ethiopian origin, and Schiemann is reported as believing in an Asian origin. The argument still continues, though opinion is now in favour of an Asian origin. In any event, all authors agree on the importance of Ethiopia for barley germ-plasm.

5. The first scientific investigation into the production of malting barley with a view to introducing it into the agricultural production of the country was started in 1968. See Institute of Agricultural Research, Holeta Guenet Research Station Progress Report for the Period March, 1968 to March, 1969 (The Institute of Agricultural Research, Addis Ababa, Ethiopia, 1969, pp. 8-9).

6. The author knows from experience that this is the case in Ethiopia. He became aware of its magnitude in Africa through discussions with delegates from nine English-speaking African countries in a workshop on "Consultation on Traditional Medicine in Health Services Development," convened by WHO in Accra, Ghana, on 4-8 August 1980, in which he was a participant.
7. The early history of Ethiopia is characterized by interactions with the Greek, Sabean, Hebrew, Roman, and Indian cultures. The earliest records are indeed in Greek and Sabean. Ethiopian ships sailed in the Red Sea and the Indian Ocean. For example, of the 230 ships Caleb used for transporting his 120,000 soldiers across the Red Sea in A.D. 523, 15 were hired from Elath on the Gulf of Aqaba, 20 from Clyisma in the Gulf of Suez, 7 from Iotabe in the Island of Tiran, 2 from Berenice, 7 from Pharaman in Persia, and 9 from India; and 170 were built in the Ethiopian port of Adulis. More detail on these points can be found in Sergew Hable Selassie, Ancient and Medieval Ethiopian History to 1270 (United Printers, Addis Ababa, Ethiopia, 1972), pp. 21-158. Given this historical setting, it is difficult to imagine that the absence of the wheel in Ethiopia until this century is due to a lack of exposure to the idea of a wheel. It is also difficult to imagine that the Axumites, who have left us the wonderful crafts we can now see in museums and built oceanworthy ships, found it impossible to adopt the wheel because they could not construct and maintain it. The Ethiopian highlands are very rough, and there is very little area where the wheel could become useful. This is probably another example of the natural environment determining the adoption of a technology; in very mountainous country, it is safer to use mules and horses as pack animals rather than for drawing carriages. Incidentally, the word for a chariot, seregella, exists in Geez, the Axumite language.

8. In his opening speech to the 13th Annual Meeting of the Association of Medical Schools in Africa, 23-27 April 1979, the Minister of Health of Ethiopia stated that 80 per cent of Ethiopians rely entirely on traditional medicine for their health care.

9. The eviction of tenants in 1969 and 1970 because of mechanization in the Chilalo Awraja has been well documented in Henock Kifle, Investigation on Mechanized Farming and Its Effects on Peasant Agriculture, CADU Publication No. 74 (Chilalo Agricultural Development Unit, Assela, Ethiopia, 1972).

10. In Ethiopia, especially in some of the remote areas, there is still some iron being smelted and used, though it is insignificant in its impact. In East Africa, south of Ethiopia, the indigenous iron industry has disappeared. Helge Kjekshus, Ecology Control and Economic Development in East African History (Heinemann, London, 1977), pp. 81-92, has described and discussed this problem.


13. The use by plant ecologists of these multivariate methods has been reviewed by P. Greig-Smith, Quantitative Plant Ecology (Butterworths, London, 1964), pp. 158-209.