Environmental hazards during economic development: the risk transition and overlap

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Abstract Arguably, the most important trend in human history has been the reduction of traditional environmental risks as part of the economic development process. Traditional hazards include infectious and parasitic diseases, many associated with poor food, water and air quality at the village level, which are still important in many poor countries today. At the same time, economic development brings a number of modern hazards through agricultural modernization, industrialization and urbanization. As part of managing this risk transition so as to continue reduction of traditional risks but mitigate the rise of modern risks, some developing countries face special problems during the period when substantial risks of both sorts, traditional and modern, co-exist. Examples of the unfortunate synergisms that can occur during such risk overlaps are most frequent among the urban poor, who often bear the brunt of modern risks such as chemical pollution, while still being subject to traditional risks such as water contaminated with human waste. This paper explores several aspects of the risk transition with particular focus on the implications for risk assessment and management.

INTRODUCTION

During the extensive study of the links between health and economic development that has been undertaken in recent decades, several conceptual frameworks have emerged that greatly assist in systematically organizing information and comparing the experience of different nations. Of most influence have been the Demographic and Epidemiologic Transitions, which focus on changes in fertility, mortality and morbidity, all relatively easily quantifiable parameters. These transitions are key components in the overall Health Transition, which has been defined much more broadly to include cultural, social and behavioral factors as well (for detailed discussions of the Health Transition framework, see Caldwell *et al.*, 1990 and Frenk *et al.*, 1991). Absent until recently, however, was a way to systematically include environmental determinants of health such as human exposure to waterborne biological and chemical pollutants (Bowonder, 1981; Kjellstrom *et al.*, 1990; Hall, 1990).

Concurrently, but usually isolated from this progress in the health and development literature has been the birth and growth of environmental health risk analysis and assessment methods in the environmental and technology-assessment literatures (e.g.

Kates *et al.*, 1983; USNRC, 1983; USEPA, 1984; USDHHS, 1986; Carpenter *et al.*, 1990; Edgerton *et al.*, 1990). The purpose here is to illustrate how these two strands of thought (health transition and environmental health risk assessment) can be melded together by the conceptual framework termed the "Risk Transition" (Smith, 1990; Smith, 1995) and thereby linked to poor water quality.

Demographic transition

The demographic transition, first described before mid-century (Teitelbaum, 1975), involves a shift from Stage 1 (Traditional Equilibrium), in which population sizes are stable, due to high death rates as well as high birth rates; to Stage 2 (Population Explosion), when death rates decline more rapidly than birth rates; and eventually to Stage 3 (Modern Equilibrium), when birth rates decline and catch up with death rates (further elaboration has been suggested since, e.g. by Olshansky & Ault, 1986). Although many countries have gone through such a transition, it is neither inevitable nor irreversible. Rather it is a pattern with many local variations and influenced by many factors.

The third stage, where low death rates are matched by low birth rates, is clearly the most desirable, but has been slow in coming for many developing countries. There is no need to let it occur at its own speed, however, for it can be accelerated by proper management, i.e. death rates can be lowered more quickly by addressing specific risk factors, e.g. through vaccinations, sewage management and mosquito control; and birth rates can be lowered, e.g. by enhancing the availability of birth control technologies and women's education.

Epidemiologic transition

As shown in Fig. 1, the two components of the Demographic Transition are linked, one weakly, one strongly, to the "Epidemiologic Transition," a concept first proposed in the late 1960s (Omran, 1971). It takes into account that the majority of developing countries are experiencing great reductions in some kinds of ill-health along with increases in others. The historically high "traditional" diseases associated with rural poverty trend downward during economic development although at different rates in different places and periods. Indeed, this overall downward trend in traditional disease is arguably the most important curve in human history (Caldwell, 1990).

The great reduction in traditional diseases that has generally accompanied development has usually led to a reduction in total ill-health as can be seen in both national and international and both longitudinal and cross-sectional studies of trends in infant mortality, life expectancy and other indicators of overall health.

At the same time as the traditional diseases decline, there tend to be an increasing (a) fraction of deaths due to modern diseases, (b) number of disease types and (c) morbidity. Modern diseases include the degenerative diseases, such as cancer, heart disease and stroke, along with certain new types of accidents and occupational hazards. Industrialization, urbanization and agricultural modernization bring attendant environmental pollution hazards that cause mainly "modern" diseases.

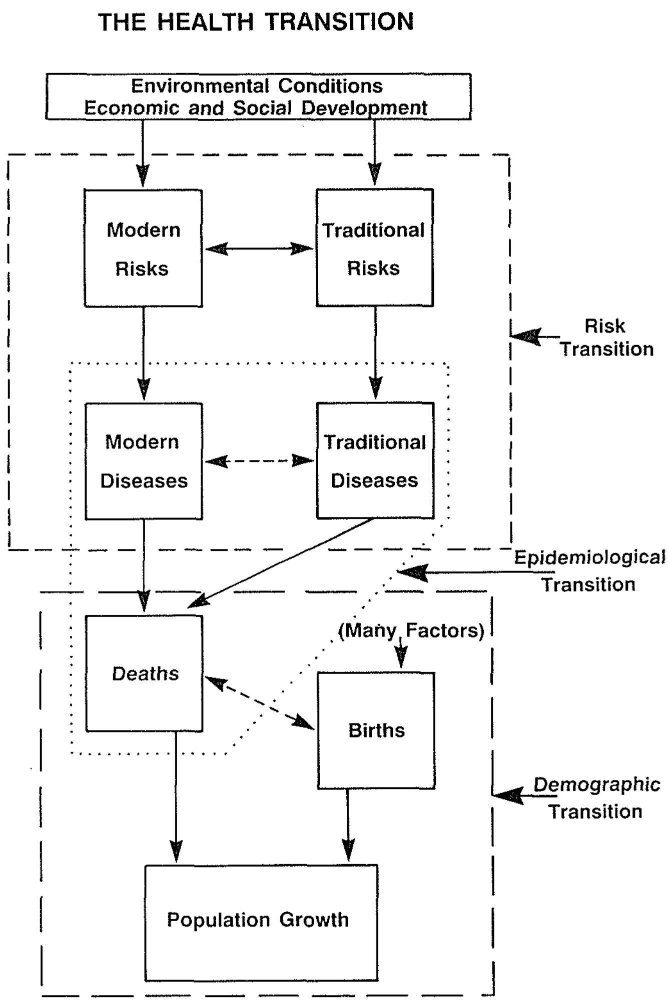

Fig. 1 Three major parts of the Health Transition shown in relationship to one other. Note that the Epidemiologic Transition (shifts in the amount and fraction of traditional and modern diseases) is a response to the Risk Transition (shifts in the underlying risk factors), which may have occurred many years previously.

Since everyone must die of something, a more revealing index than distribution of mortality is life years lost to each class of risks. Overall life years lost has generally decreased with development. Historically, loss due to modern diseases does not match that lost from traditional diseases until overall life expectancy reaches about 60 years. Total ill-health has generally decreased with development because the reduction in traditional diseases more than counterweights the rise of modern ones. In some cases, however, a stage may be reached where traditional diseases are all but squeezed out but modern diseases are still rising. There was evidence of this kind of upturn for infant mortality in the Soviet Union in the 1980s, for example (Dinkel, 1985). In recent years, the world has also witnessed too often the situation where large groups of people or even whole nations have moved back up the traditional disease curve because of setbacks in development caused by wars, natural disasters, or government mismanagement. Even in the two dozen (mainly sub-Saharan) countries experiencing negative growth in per capita income since 1960, however, there was no overall deterioration in basic health indicators (life expectancy, childhood mortality), although the rates of improvement were often slow (UNDP, 1994). In Eastern Europe, anecdotal reports tell of mounting ill-health through failure to control such modern risks as industrial pollution.

THE RISK TRANSITION

The shift of disease patterns from traditional to modern is due to changes in the underlying risk factors for the various forms of ill-health, as shown in Fig. 1. Since one inevitably follows the other, it might be argued that there is no particular advantage in differentiating between the two, i.e. between ill-health and risk. This might be so for some classes of disease, particularly those where there is a fairly short delay between changes in the risk factors and changes in ill-health. For these, monitoring disease rates can be expected to be a fair indicator of what is happening and, thus be a reasonably good guide for decision making.

For other classes of disease, however, present patterns of ill-health are quite poor indicators of actual risk. Consider the nearly archetypal case of cigarette smoking. Today's patterns of lung cancer reflect risk factors (smoking patterns) existing 10-40 years back. Because of this, it is possible to predict continued increases in ill-health from smoking for US women, who started smoking in large numbers some decades after men. Similarly, it is fair to say that Chinese men are today undertaking substantial risk due to their present smoking habits, even though, to date, there has been relatively little actual expression of that risk as ill-health.

The distinction between risk and ill-health is also important for another category of hazards, pollutants that make their way slowly through the environment, eventually reaching humans via food, air or water. The release of the pollutant represents the creation of the risk (i.e. commitment to the health effect), even though there may be many years between the release and the disease, due to environmental and physiological latencies.

There are also situations in which risk is accrued, although not actually resulting in health damage. Although most nuclear power plants apparently operate without creating any significant ill-health, all do create risk, i.e. even if a community nearby experiences no accidental radiation releases over the lifetime of the plant, it still has experienced risk and needs to take protective actions. Thus, an important difference between "ill-health" and "risk" is the inclusion of, perhaps weighted, contributions from low-probability events in one, but not the other.

In a related way, modern risks also tend to differ from traditional in that many important outcomes do not have a unique cause. Unlike cholera, for example, which is caused by a limited number of identifiable agents, a particular lung cancer cannot usually be confidently linked to a particular cause. It might have been air pollution (human or natural), asbestos, environmental tobacco smoke, a combination or spontaneous. We can only make probability statements, at best.

This is true even when the impact is large. Consider again the archetypal case, smoking. The risk is huge, one-third of smokers die young from their habit. This risk is much higher than almost all major wars and plagues, but by being delayed and non-specific, it is not perceivable by normal human senses. We require help from sophisticated scientific study and statistical interpretation to "see" it.

A more identifiably environmental example is lead pollution in food, water and air. This is now thought to have had disturbingly large impacts on children and adults throughout the world (Shy, 1990). Because its impacts are delayed and non-specific (lowered intelligence and birth weight, stroke), even though large, they have been difficult to "see"'.

Global modern risks

There are examples of these kinds of modern risks (non-specific, long latency, low-probability–high-consequence) not only locally, but also globally:

- The manufacturing of chlorofluorocarbons (CFCs) represent an addition to global risk, although it may be decades before they are released, reach the stratosphere, increase UV radiation, cause changes in body cells and result in skin cancer deaths, which are non-specific.
- In a similar manner, releases of CFCs and other greenhouse gases represent a risk of global warming with attendant non-specific health impacts, although there is also a probability that the risk never will be expressed in actual health damage, i.e. climate feedbacks will mute the effects.
- Global thermonuclear war is an extreme example of a never-yet-occurred but high-consequence hazard that has imposed substantial risk and need for protective actions, but little direct health effect to date (and, if we remain lucky, never).

The risk overlap and resulting interactions

There are significant differences within, as well as between, countries in the risk patterns of different population groups. Reporting average improvements, for example, masks the relatively greater progress made by women, children and rural people when traditional risks decline (Greenberg, 1986).

The pace of the risk transition has changed such that traditional risks persist while modern risks start earlier in development. This results in a larger degree of "risk overlap," where some populations are exposed to a significant amount of both types, but in a rapidly changing pattern.

At the point marked A in Fig. 2, modern risks have begun to rise but traditional risks are still significant, although rapidly dropping. An example is where pesticide runoff starts to add to water pollution caused by poor sanitation. Another example is offered by those places where urban air pollution from fossil fuel combustion is rising while large village and urban air pollution exposures from household combustion of traditional biofuels still exist.

If these effects were merely additive, there might be no special need to consider interactions. Unfortunately, however, risk overlap can lead to interactions with important implications for risk assessment by magnifying or masking the separate impacts of modern and traditional risks. Six kinds of interaction can be identified:

Risk genesis where risk overlap may lead to creation of an entirely different sort of risks, e.g. mixing modern (motorized) and traditional (muscle-powered) vehicles leads to new kinds of accident risks and risk management needs.

Risk synergism where exposure to one agent causes immunity or sensitivity to other agents, e.g. where traditional intestinal diseases due to poor water quality increase sensitivity to waterborne and airborne modern pollutants.

Risk mimicry where morbidity and mortality may be attributed to traditional sources of risk but may be actually due to modern or synergistic risks, e.g. lung cancer being attributed to acute or chronic lung diseases.

Risk competition where abnormally high or low risks of one disease may actually be an indication of the decrease or increase in the risks of an entirely different disease, e.g. where low lung-cancer rates may not necessarily mean that the risk of lung cancer is low but just that people are dying of other diseases first and not living long enough to develop cancer.

Risk layering where the movement of people or their activities concentrates risk in one region and dilutes risk in another, e.g. where rural-urban migrants are healthier than the average person left back in the villages.

Risk transfer where efforts to control risk from traditional hazards may enhance modern risks (or vice versa), as when pesticides are used to control malaria (Whipple, 1985).

A recent extreme example of transfer between waterborne risks was reported in Peru during the early 1990s (Anderson, 1991). In an apparent effort to avoid the modern risk of carcinogenic chlorinated compounds, Lima authorities lowered the chlorine treatment level in city water supplies. As a result, cholera spread much more rapidly than might

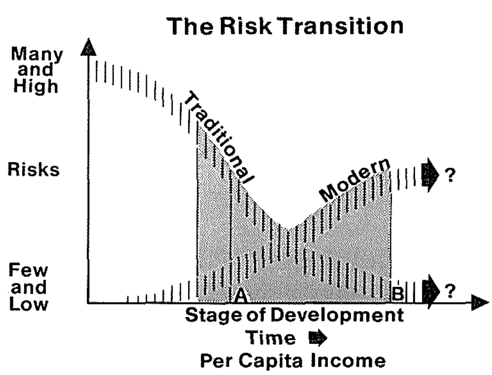

Fig. 2 A conceptual illustration of the Risk Transition showing the decline of traditional and the rise of modern risks. These curves precede the expression of the risk in damage, as portrayed in the Epidemiologic and Demographic Transitions. The shape of the two curves is not inevitable, but rather a combination of intrinsic environmental and social conditions, economic development and risk management efforts. Each country has the opportunity to guide its own transition. The fuzziness of the lines indicates the considerable uncertainty involved in validating risk indicators and monitoring their movements. The patterned area represents the risk *overlap* where there may be important interactions between traditional and modern risks. As discussed in the text, point A marks the position of the developing country risk assessor and point B is the position of the developed country counterpart. The total risk (traditional plus modern) declines throughout the range, as it has for most parts of the world where economic development has continued (indicated, for example, as annual individual or population death rates).

have occurred if drinking water had been thoroughly treated. Here, to avoid a, by comparison, low, modern risk, protection against a large traditional risk was foregone (methods that allow quantitative comparison of drinking water risks have been reported, e.g. by Regli, 1993; Haas *et al.*, 1993).

It may also be useful to distinguish two general types of risk overlap, local and global. Listed above were cases of local risk overlap involving the interaction of traditional and modern risks on a local scale, e.g. scavengers at a municipal dump also exposed to industrial waste. These can be serious, but are amenable to various local fixes. If the hazardous materials are dumped somewhere else, overlap interactions are essentially eliminated (although not necessarily the individual traditional and modern risks).

Global risk overlaps, in contrast, will continue as long as there are great disparities anywhere on Earth between the risk patterns (and other characteristics) of different groups. The most important examples are ozone- and climate-threatening chemical releases. Although mostly created by modern activities in countries well along in the Health Transition, these pollutants affect the whole world. Indeed, they will probably have their biggest impacts among peoples still burdened by traditional risks, including those with high vulnerability to environmental stress. Unlike local risk overlaps, the modern global versions cannot be avoided by releasing the pollution at another place. With these pollutants, for all practical purposes, emissions anywhere are emissions everywhere. (AIDS can perhaps be considered a local disease made global by human activities. Given the worldwide movement of people and lifestyles, an AIDS case anywhere is beginning to be like an AIDS case everywhere.)

NET RISK

Consider the different world views of the risk managers working in countries represented by points A and B in Fig. 2. The risk manager at point B sees an increasing number and, in some cases, intensification of modern risks from development. The traditional risks have been mostly controlled and are of less concern. Thus, understandably, assessment efforts have been focused on quantifying and managing modern risks. At point A, however, important hazards of both traditional and modern sorts exist side by side, although trending in opposite directions. Introduction of technology and the resulting development (interpreted as a movement along the horizontal axis) will, therefore, have a substantially different impact on overall risk in developing countries than in developed countries. On average a country at point A will experience a significant degree of risk **lowering** (movement down the traditional risk curve) from new technologies as well as risk **raising** (movement up the modern risk curve).

Although the overall result of development may be general risk lowering as shown in Fig. 2, each technological project will have its own pattern, which may not be risk lowering in aggregate. To understand the overall or **net** risk from any particular project, policy, regulation, or activity, therefore, will require evaluation of both classes of risk. The developing-country risk manager will find that to adopt risk assessment methods from developed countries, which focus solely on modern risks, will be misleading.

In principle, assessments on both sides of the risk transition should incorporate consideration of risk-lowering as well as risk-raising aspects of development. Indeed, focusing only on the modern risk curve for each new project, as part of what might be called micro-risk analysis, leads to the manifestly absurd macro-risk result that those communities with the most technology should be the least healthy, that Switzerland should be more unhealthy than Nepal.

Earlier this century, direct improvements in health care and public health seemed to be the principal causes of risk lowering. Recent analyses, however, seem to indicate weaker dependence after mid-century on factors other than income and education in enhancing life expectancy and decreasing childhood mortality. In general, health status seems now to be influenced by economic development more than previously in the developing countries of Asia and the Americas and to a lesser degree in Africa (Hill, 1985). This seems to have occurred mostly through diminution of the impact of the direct variables, rather than an increase in the effect of income.

These might be called "indirect" routes to risk lowering, to contrast them with "direct" routes such as health care. Indirect routes to risk raising include, for example, the impact of urban stress, as contrasted to such direct routes as waterborne chemical pollution. That they are indirect, however, need not mean that they are small, as in the well known relationship between women's education and health (Preston, 1985; World Bank, 1993). Indeed, not only are the best environmental health investments likely to be indirect, e.g. women's education, but so may those aimed at ecosystem sustainability, i.e. local land use control.

In practice, little effort has gone into developing methods for assessing risk lowering. Whatever the resulting misrepresentation in developed countries, failing to conduct net risk analysis in developing countries will produce much larger distortions because of the more important role played by traditional risk. Many studies have been made of the overall relationship of economic development with health status, but few have conducted project-level analysis. It is at the project level, however, where individual decisions are made and policies are implemented. To do such an analysis would necessitate understanding first the changes wrought by a project on income, employment, training/education, housing and other relevant factors and then the impact of each of these on risk (see Sagan, 1987, for a provocative discussion of the role of family structure on health, for example).

An important component of developing-country risk assessment, therefore, should be net risk analysis. This would acknowledge that the risk-lowering and the risk-raising aspects of projects need to be examined. To some readers, this may seem to be a thinly veiled rationalization for continued lax environmental and safety standards in developing countries. This is not the case. Rather, it is a call to judge technologies on a net risk basis so those that do not or only weakly reduce net risk can be rejected or modified to meet risk goals of the society. The criteria remain just the same as in past risk assessments focusing only on modern risk (i.e. those projects that are associated with much risk raising will be penalized). It seems appropriate in many circumstances, however, to also penalize those projects that bring little risk lowering (Shrader-Frechette, 1985). Risk is only one of the criteria by which projects are compared, but it is best done on a net risk basis.

To be most useful, risk assessment in developing countries should be able to give guidance not only about individual actions, such as siting a particular facility or embarking on a new industry, but also on pathways of development that may incorporate trade-offs between economic growth and risk over many years. An example of this type of decision, apparently made without systematic quantification however, is that of one Asian country in which government policy consciously chose cheaper high-sulfur fuels for a defined period in order to quicken economic growth. Once a trigger level of income was achieved, however, cleaner fuels were phased into use. More persistent or long-range pollutants or those with irreversible effects would clearly complicate this type of assessment.

Another dynamic is the trend of some modern risks to become significant at earlier stages in the development process than in the past because of the impact of international and internal trade, communication and foreign aid. Consequently, the period of risk overlap and need for net risk assessment may be increasing.

RISK MONITORING

A further rationale for focusing on risk rather than ill-health is suitability for management. Waiting to count who dies of what may be an adequate approach to understanding and controlling some traditional risks, dysentery for example, but is clearly inadequate for decoupled risks such as toxic metal poisoning and ozone depletion, for which the changes in risk factors greatly precede changes in ill-health. By the time there are actual changes in health, it is too late to do much.

For these hazards, we need to monitor further back along the causal chain, which runs, for example, from pollutant emissions, to environmental concentrations, exposures, doses, pre-clinical changes and ill-health, before leading to death (Smith, 1988). Where along this chain it is best to measure depends on a range of factors, including not only the time constants involved but also ease and cost of monitoring. Generally, points further back on the chain tend to be easier to monitor than those, like dose, relatively closer to effects. On the other hand, they are more removed in causation, introducing uncertainties because of gaps in knowledge about, for example, how emissions are translated into human exposures. The causal chain, and thus risk monitoring, can also be extended back even further, to the basic decision steps involved in embarking on this or any technology at all, as compared, for example, to exploring other ways to meet human needs and wants (Hohenemser *et al.* 1985).

URBANIZATION AND THE RISK TRANSITION

Urbanization has been one of the most important influences in the transition from traditional to modern risks. The tendency has been to focus on the terrible modern risks imposed by the mega-cities of the developing world; the air and water pollution, the traffic jams, the garbage dumps and unfettered pollution of all sorts. Although it may seem contradictory, however, the, admittedly poor, evidence is that cities in general bring health. Their residents eventually seem to become better off than they were before or than they would have been if they had stayed or been born in the rural areas. (Immediately after arrival, however, rural migrants may often be in worse shape, Basu, 1990). Thus, even if the net risk for any mega-city has never actually been negative (risk lowering), looking only at the risk-raising side can be misleading (Smith & Lee, 1993). In addition, although one might equally think of these mega-cities as ecological disasters, urbanization is one of the only historically proven ways to actually reduce pressure on forests and other endangered natural hinterlands.

Risk overlap probably exhibits its strongest interactions in such cities. Perhaps the most striking examples of this are when villagers bring rural behavior patterns with them when they move to the city. Use of biomass fuels for cooking and open ground for defecation, for example, are risky enough in a rural setting, but more so in the city.

In many countries, urbanization now seems to be taking on a different character. Called "Kotadesasi", which is a combination of the Indonesian words meaning "town" and "village," this new process results in widespread increases of peri-urban areas, often linked to an urban center but themselves not being urban in the usual sense. "Kotadesa" regions are characterized by rapid increases in the variety and intensity of workplaces and land uses intermixed within traditional farming areas. This can lead, for example, to releases of toxic materials from small-scale industrial activities like electro-plating directly into wet rice paddies, creating a particularly acute form of water pollution.

Kotadesa regions are also characterized by a high degree of population mobility; increased female participation in the workforce; and uncertain, inconsistent and incomplete governance by urban authorities (Ginsburg *et al.*, 1990). Such characteristics create additional challenges for the risk manager because they would seem to describe an area where traditional risk may linger on while modern risks are being introduced earlier and with less control than elsewhere. This underscores the special need to evaluate the risk interactions and net risk implications of alternative actions.

CONCLUSION

Like the Demographic Transition, the Risk Transition is not set in stone. Indeed, a major role for governments in the presently developing countries is to manage the Risk Transition such that traditional risks continue to fall as rapidly as possible, while modern risks and risk overlaps are contained. The burden on risk assessment in all the media, including water, however, is greater and significantly different than in developed countries where such techniques were first used.

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