in the population. If the perceived marginal benefits of children to parents in old age were to be reduced (by being substituted for in this case), the desired number of children per family would fall. As the tax instrument merely redistributes income, its effect on welfare can be neutral. But by reducing the private marginal benefits of children it can succeed (at little or no social cost) in reducing desired family size.

- The most powerful means of reducing desired family size is almost certainly economic development, including the replacement of subsistence agriculture by modern farming practices, giving farm workers the chance of earning labour market incomes. There may, of course, be significant cultural losses involved in such transition processes, and these should be weighed against any benefits that agricultural and economic development brings. Nevertheless, to the extent that subsistence and non-market farming dominates an economy's agricultural sector, there will be powerful incentives for large family size. Additional children are valuable assets to the family, ensuring that the perceived marginal benefits of children are relatively high. Furthermore, market incomes are not being lost, so the marginal cost of child-rearing labour time is low. Important steps in the direction of creating markets for labour (and reducing desired family size) can be taken by defining property rights more clearly, giving communities greater control over the use of local resources, and creating financial incentives to manage and market resources in a sustainable way.

2.2.5.2 Affluence and technology: the EKC

The *World Development Report 1992* (World Bank, 1992) was subtitled 'Development and the environment'. It noted that 'The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments'. If we consider, for example, the per capita emissions, e, of some pollutant into the environment, and per capita income, y, then the view that is being referred to can be represented as

$$e = \alpha y \qquad (2.7)$$

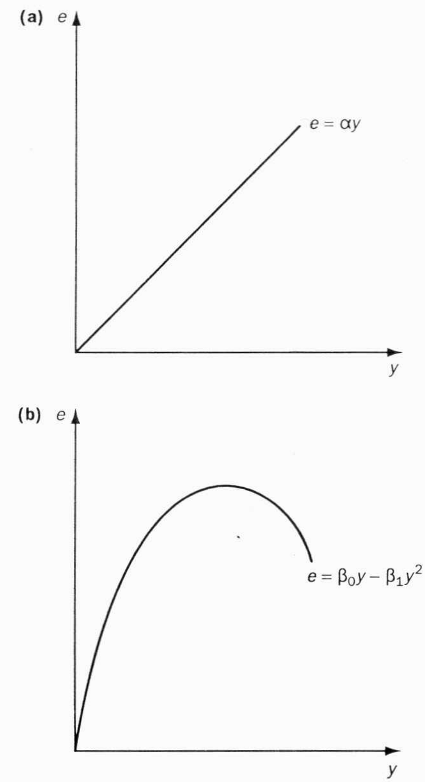

Figure 2.8 Environmental impact and income
Source: Adapted from Common (1996)

so that e increases linearly with y, as shown in Figure 2.8(a). Suppose, alternatively, that the coefficient α is itself a linear function of y:

$$\alpha = \beta_0 - \beta_1 y \qquad (2.8)$$

Then, substituting Equation 2.8 into Equation 2.7 gives the relationship between e and y as:

$$e = \beta_0 y - \beta_1 y^2 \qquad (2.9)$$

For β_1 sufficiently small in relation to β_0, the e/y relationship takes the form of an inverted U, as shown in Figure 2.8(b). With this form of relationship, economic growth means higher emissions per capita until per capita income reaches the turning point, and thereafter actually reduces emissions per capita.

It has been hypothesised that a relationship like that shown in Figure 2.8(b) holds for many forms of environmental degradation. Such a relationship is called an 'environmental Kuznets curve' (EKC) after Kuznets (1955), who hypothesised an inverted U for the relationship between a measure of inequality in the distribution of income and the level of income. If the EKC hypothesis held generally, it would imply that instead of being a threat to the environment as is often argued (see the discussion of *The Limits to Growth* below), economic growth is the means to environmental improvement. That is, as countries develop economically, moving from lower to higher levels of per capita income, overall levels of environmental degradation will eventually fall.

The argument for an EKC hypothesis has been succinctly put as follows:

> At low levels of development both the quantity and intensity of environmental degradation is limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As economic development accelerates with the intensification of agriculture and other resource extraction and the takeoff of industrialisation, the rates of resource depletion begin to exceed the rates of resource regeneration, and waste generation increases in quantity and toxicity. At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in levelling off and gradual decline of environmental degradation.
>
> *Panayotou (1993)*

Clearly, the empirical status of the EKC hypothesis is a matter of great importance. If economic growth is actually and generally good for the environment, then it would seem that there is no need to curtail growth in the world economy in order to protect the global environment. In recent years there have been a number of studies using econometric techniques to test the EKC hypothesis against the data. Some of the results arising are discussed below. According to one economist, the results support the conclusion that

> there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich.
>
> *Beckerman (1992)*

Assessing the validity of this conclusion involves two questions. First, are the data generally consistent with the EKC hypothesis? Second, if the EKC hypothesis holds, does the implication that growth is good for the global environment follow? We now consider each of these questions.

2.2.5.2.1 Evidence on the EKC hypothesis

In one of the earliest empirical studies, Shafik and Bandyopadhyay (1992) estimated the coefficients of relationships between environmental degradation and per capita income for ten different environmental indicators as part of a background study for the *World Development Report 1992* (IBRD, 1992). The indicators are lack of clean water, lack of urban sanitation, ambient levels of suspended particulate matter in urban areas, urban concentrations of sulphur dioxide, change in forest area between 1961 and 1986, the annual rate of deforestation between 1961 and 1986, dissolved oxygen in rivers, faecal coliforms in rivers, municipal waste per capita, and carbon dioxide emissions per capita. Some of their results, in terms of the relationship fitted to the raw data, are shown in Figure 2.9. Lack of clean water and lack of urban sanitation were found to decline uniformly with increasing income. The two measures of deforestation were found not to depend on income. River quality tends to worsen with increasing income. As shown in Figure 2.9, two of the air pollutants were found to conform to the EKC hypothesis. Note, however, that CO_2 emissions, a major contributor to the 'greenhouse gases' to be discussed in relation to global climate change in Chapter 10, do not fit the EKC hypothesis, rising continuously with income, as do municipal wastes. Shafik and Bandyopadhyay summarise the implications of their results by stating:

> It is possible to 'grow out of' some environmental problems, but there is nothing automatic about doing so. Action tends to be taken where there are generalised local costs and substantial private and social benefits.

Panayotou (1993) investigated the EKC hypothesis for: sulphur dioxide (SO_2), nitrogen oxide (NO_x) suspended particulate matter (SPM) and deforestation. The three pollutants are measured in terms of emissions per capita on a national basis. Deforestation

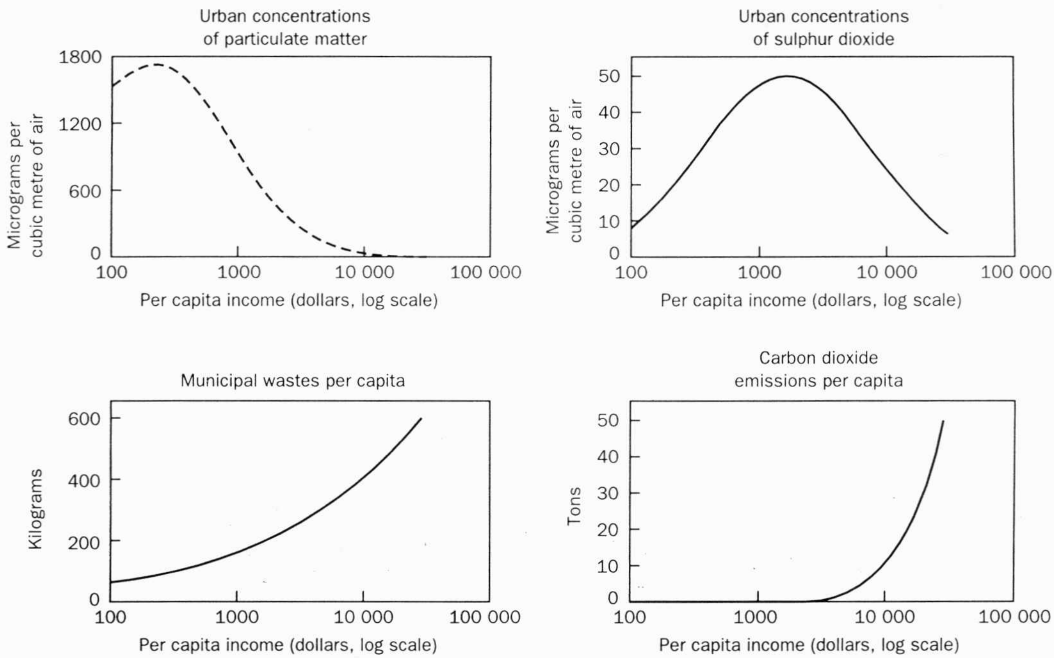

Figure 2.9 Some evidence on the EKC. Estimates are based on cross-country regression analysis of data from the 1980s
Source: Adapted from IBRD (1992)

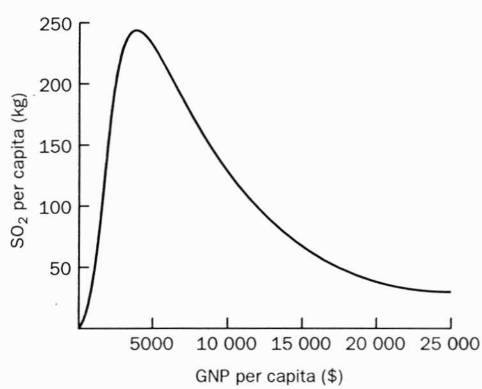

Figure 2.10 An EKC for SO_2
Source: Adapted from Panayotou (1993)

is measured as the mean annual rate of deforestation in the mid-1980s. All the fitted relationships are inverted Us, consistent with the EKC hypothesis. The result for SO_2 is shown in Figure 2.10, where the turning point is around $3000 per capita.

There is now an extensive literature investigating the empirical status of the EKC hypothesis. The Further Reading section at the end of the chapter provides points of entry to this literature, and the key references. Some economists take the results in the literature as supporting the EKC for local and regional impacts, such as sulphur for example, but not for global impacts, such as carbon dioxide for example. However, Stern and Common (2001) present results that are not consistent with the existence of an EKC for sulphur. The EKC hypothesis may hold for some environmental impacts, but it does not hold for all.

2.2.5.2.2 *Implications of the EKC*

If the EKC hypothesis were confirmed, what would it mean? Relationships such as that shown in Figure 2.10 might lead one to believe that, given likely future levels of income per capita, the global environmental impact concerned would decline in the medium-term future. In Figure 2.10 the turning point is near world mean income. In fact, because of the highly skewed distribution for per capita incomes, with many more countries – including some with very large populations – below rather than above the mean, this may not be what such a relationship implies.

This is explored by Stern *et al.* (1996), who also critically review the literature on the existence of meaningful EKC relationships. Stern *et al.* use the projections of world economic growth and world population growth published in the *World Development Report 1992* (IBRD, 1992), together with Panayotou's EKC estimates for deforestation and SO_2 emissions, to produce global projections of these variables for the period 1990–2025. These are important cases from a sustainable development perspective. SO_2 emissions are a factor in the acid rain problem: deforestation, especially in the tropics, is considered a major source of biodiversity loss. Stern *et al.* projected population and economic growth for every country in the world with a population greater than 1 million in 1990. The aggregated projections give world population growing from 5265 million in 1990 to 8322 million in 2025, and mean world per capita income rising from \$3957 in 1990 to \$7127 in 2025. They then forecast deforestation and SO_2 emissions for each country individually using the coefficients estimated by Panayotou. These forecasts were aggregated to give global projections for forest cover and SO_2 emissions. Notwithstanding the EKC relationship shown in Figure 2.10, total global SO_2 emissions rise from 383 million tonnes in 1990 to 1181 million tonnes in 2025; emissions of SO_2 per capita rise from 73 kg to 142 kg from 1990 to 2025. Forest cover declines from 40.4 million km^2 in 1990 to a minimum of 37.2 million km^2 in 2016, and then increases to 37.6 million km^2 in 2025. Biodiversity loss on account of deforestation is an irreversible environmental impact, except on evolutionary timescales, so that even in this case the implications of the fitted EKC are not reassuring.

Generally, the work of Stern *et al.* shows that the answer to the second question is that even if the data appear to confirm that the EKC fits the experience of individual countries, it does not follow that further growth is good for the global environment. Arrow *et al.* (1995) reach a similar position on the relevance of the EKC hypothesis for policy in relation to sustainability. They note that

> The general proposition that economic growth is good for the environment has been justified by the claim that there exists an empirical relation between per capita income and some measures of environmental quality.

They then note that the EKC relationship has been 'shown to apply to a selected set of pollutants only', but that some economists 'have conjectured that the curve applies to environmental quality generally'. Arrow *et al.* conclude that

> Economic growth is not a panacea for environmental quality; indeed it is not even the main issue

and that

> policies that promote gross national product growth are not substitutes for environmental policy.

In Box 2.2 we report some simulation results that indicate that even if an EKC relationship between income and environmental impact is generally applicable, given continuing exponential income growth, it is only in very special circumstances that there will not, in the long run, be a positive relationship between income and environmental impact.

Box 2.2 The environmental Kuznets curve and environmental impacts in the very long run

The environmental Kuznets curve (EKC) implies that the magnitude of environmental impacts of economic activity will fall as income rises above some threshold level, when both these variables are measured in per capita terms. Here we assume for the sake of argument that the EKC hypothesis is correct. Common (1995) examines the implications of the EKC hypothesis for the long-run relationship between environmental impact and income. To do this he examines two special cases of the EKC, shown in Figure 2.11.

In case **a** environmental impacts per unit of income eventually fall to zero as the level of income rises. Case **b** is characterised by environmental impacts per unit income falling to some minimum level, *k*, at a high level of income, and thereafter remaining constant at that level as income continues to increase. Both of these cases embody the basic principle of the EKC, the only difference being whether environmental impacts per unit income fall to zero or just to some (low) minimum level.

Box 2.2 *continued*

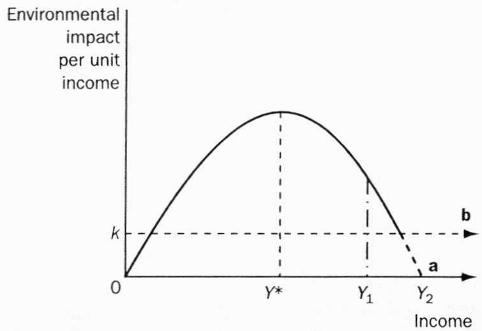

Figure 2.11 Two possible shapes of the environmental Kuznets curve in the very long run
Source: Adapted from Common (1995)

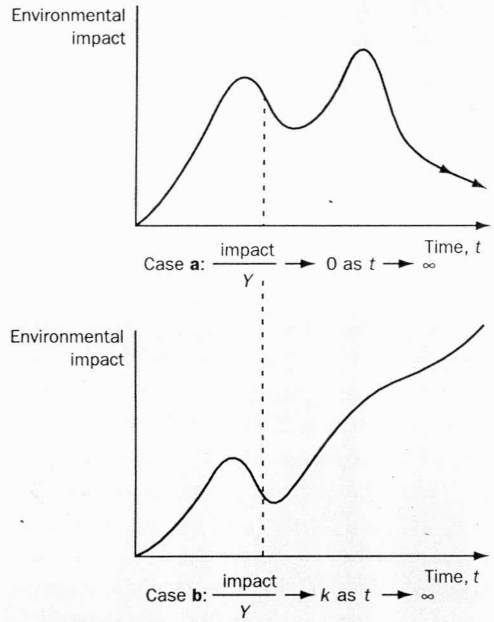

Figure 2.12 Two scenarios for the time profile of environmental impacts
Source: Adapted from Common (1995)

Suppose that the world consists of two countries that we call 'developed' and 'developing' which are growing at the same constant rate of growth, *g*. However, the growth process began at an earlier date in the developed country and so at any point in time its per capita income level is higher than in the developing country. Common investigates what would happen in the long run if case **a**, the highly optimistic version of the EKC, is true. He demonstrates that the time path of environmental impacts one would observe would be similar to that shown in the upper part of Figure 2.12. Why should there be a dip in the central part of the curve? For some period of time, income levels in the two countries will be such that the developed country is on the downward-sloping portion of its EKC while the developing country is still on the upward-sloping part of its EKC. However, as time passes and growth continues, both countries will be at income levels where the EKC curves have a negative slope; together with the assumption in case a that impacts per unit income fall to zero, this implies that the total level of impacts will itself converge to zero as time becomes increasingly large.

But now consider case **b**. No matter how large income becomes the ratio of environmental impacts to income can never fall below some fixed level, *k*. Of course, *k* may be large or small, but this is not critical to the argument at this point; what matters is that *k* is some constant positive number. As time passes, and both countries reach high income levels, the average of the impacts-to-income ratio for the two countries must converge on that constant value, *k*. However, since we are assuming that each country is growing at a fixed rate, *g*, the total level of impacts (as opposed to impacts per unit income) must itself eventually be increasing over time at the rate *g*. This is shown in the lower part of Figure 2.12.

What is interesting about this story is that we obtain two paths over time of environmental impacts which are entirely different from one another in qualitative terms for very small differences in initial assumptions. In case a, *k* is in effect zero, whereas in case b, *k* is greater than zero. Even if environmental impacts per unit of income eventually fell to a tiny level, the total level of impacts would eventually grow in line with income.

Which of these two possibilities – case **a** or case **b** – is the more plausible? Common argues that the laws of thermodynamics imply that *k* must be greater than zero. If so, the very-long-run relationship between total environmental impacts and the level of world income would be of the linear form shown (for per capita income) in panel a of Figure 2.8. The inference from the inverted U shape of the EKC that growth will reduce environmental damage in the very long run would be incorrect.