CHAPTER 3:

Decoupling environmental pressure from economic growth: from pollution control to improving eco-efficiency of consumption and production

Meeting future needs for poverty reduction based on current patterns of production and consumption implies further unsustainable demand for ecosystem goods and services. Keeping growth within the environmental carrying capacity requires an increase in the efficiency with which humans use these ecosystem goods and services – decoupling economic activity from its environmental impacts.

Eco-efficiency concepts, as currently applied by the private sector at the firm level, can be scaled up to assess whether economies and societies are progressing towards reducing environmental impacts as they continue to grow and improve human well-being. At high enough levels, eco-efficiency improvements are a key step towards achieving environmentally sustainable economic growth.

A preliminary look at a few eco-efficiency indicators and at a series of decoupling graphs for Asian, Pacific and other countries show that many economies have been able to improve the eco-efficiency of production processes over time.

This may reflect real improvements in the efficiency of resource use and cleaner production, or result from structural changes to these countries' economies and shifts in production of resource-intensive and polluting industries to other countries. However, per capita use of resources and the consumption-related waste and pollution tends to increase – i.e. the eco-efficiency of consumption decreases as incomes rise. As a result, total environmental pressures continue to mount. However, these analyses also show that economic growth and increased human well-being do not necessarily imply higher levels of environmental impact.

3.1 Economic growth and its impact on environmental sustainability

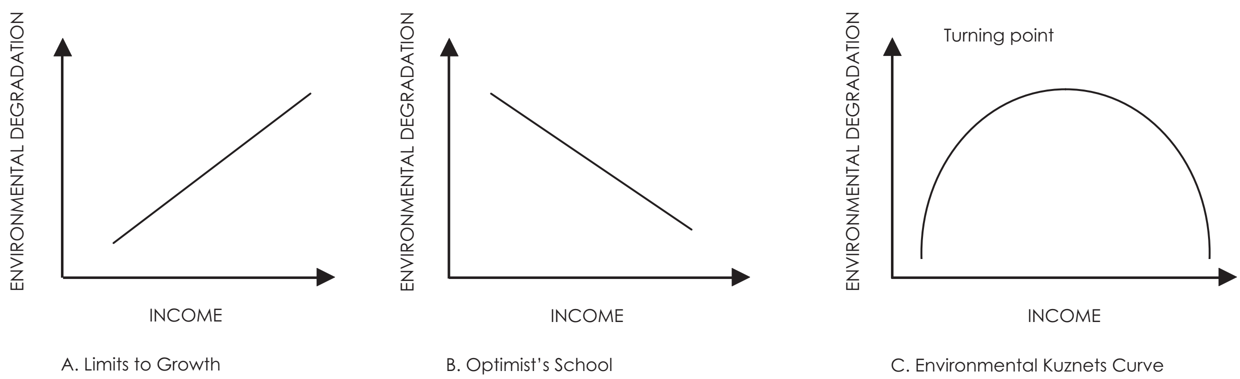
Many people in the region still lack access to the basic resources needed for a productive and healthy life. The greatest challenge facing mankind may be to find ways to increase access to resources in a manner that does not exceed the earth's carrying capacity. In order to understand these challenges we must improve our understanding of the nature of the relationship between income growth and environmental impact. Several theories have been advanced on the impact of increasing incomes on environmental quality and three major schools of thought have emerged.[1]

In 1972 a group of scientists from the Massachusetts Institute of Technology (known as the "Club of Rome") published *The Limits to Growth,*[2] which warned that increased resource usage, waste and pollutants resulting from income growth could eventually lead to ecosystem 'collapse'. Economic activity was predicted to overshoot the earth's limited environmental carrying capacity at different periods, the predictions being based on different assumptions relating to consumption patterns and natural resource endowment, among other factors. One ecosystem 'collapse' scenario was predicted to occur soon after the turn of the twenty-first century. In updates published 20 and 30 years after the original publication,[3] the authors concluded that overshoot (in the form of climate change, for example) had occurred, but had not yet led to collapse. Some critics of *The Limits to Growth* fault its failure to consider the importance of the progress made in using natural resources more efficiently through the use of technology, in addition to the rapid globalization of production that has resulted in changing distributions of environmental pressure.[4] The relationship between income and environmental pressure as suggested by the authors of *The Limits to Growth* is represented by a linear function that increases as income increases (Figure 3.1A).

Another school of thought, known as the 'Optimist's School', maintains that economic growth reduces environmental degradation or improves environmental quality. This belief is due in large part to the observation that environmental quality is a normal or even a luxury good; in other words, it is something that people demand more of as their incomes increase.[5] A graph of this relationship would be represented by a linear function of environmental degradation that decreases as income rises, as shown in Figure 3.1B.

Grossman and Krueger proposed a third school of thought in a 1992 article examining the effect of the North American Free Trade Agreement on air pollution in Mexico.[6] They found that at low levels of income, certain types of air pollution increase (at a decreasing rate) as income grows. Once a certain level of income is attained, a turning point is reached and air pollution decreases (at an increasing rate) as income grows. Graphically this relationship appears as an inverted U which is now known as the Environmental Kuznets Curve (EKC) (Figure 3.1C).

Figure 3.1 Theories of income-environment relationship



In recent years, the EKC has received the majority of attention given to the hypotheses concerning the relationship between economic growth and the environment and various empirical studies have tested for the relationship, using several measures of environmental quality, several types of economy and several methodologies. Research reviews have found that although evidence of an EKC exists for some forms of environmental impact, the relationship does not hold for all forms.[7] In addition, the EKC may not hold true for more critical indicators such as the eco-efficiency of consumption, as discussed in sections 3.3 and 3.4. More importantly, several non-income determinants of environmental quality improvements, including proper governance, have been identified and would suggest that levels of, and changes in, income alone may not be adequate to explain levels of, or changes in, environmental quality.[8]

It is important to bear in mind when applying the EKC to Asia and the Pacific region, that the majority of people in the region live in developing countries where incomes are low. This would imply that, if the EKC does in fact describe the true relationship between income and environmental degradation, a majority of the world's population may continue to exert significant amounts of pressure on the environment until enough growth has occurred in the low-income countries of Asia and the Pacific region. Whether the turning point will be reached before there is an irreversible decline in ecosystem functioning is a major source of uncertainty.

While recognizing the limitations of these uni-dimensional models of what, in reality, is a complex relationship, each of these theories can provide the basis for different policy interpretations. For the "Limits to Growth" hypothesis, the policy conclusion is that economic growth must halt or economic collapse will result. The policy implication of the "Optimist's School" hypothesis is that policies that lead to economic growth will automatically result in environmental improvement. Some have suggested that the EKC is a prescription to "grow first and clean up later." Others maintain that it implies that economic growth should be encouraged while at the same time the proper policies to minimize environmental degradation are implemented, especially in economies that are positioned near the turning point. This will effectively decrease the height of the curve.

None of these theories explicitly account for rising 'discretionary' consumption, which exerts new types of environmental pressure as economies and incomes grow. They therefore provide a less-than-satisfactory explanation of the relationship and a less-than-informative basis for policy action. A fourth theory, advanced in this chapter, maintains that as incomes increase, the production patterns of countries become more eco-efficient and economic structures shift to a higher dependence on service-based and knowledge-intensive activity, and increasingly import, rather than produce, resource- and pollution-intensive goods. However, rising per capita consumption levels linked with increased incomes can counteract gains in production eco-efficiency and result in continued increases in total environmental pressure.[9]

3.2 Delinking environmental pressure from economic growth

The major challenge facing the Asian and Pacific region is how to continue the economic growth required to improve quality of life and meet the basic needs of its inhabitants while reducing the pressure on environmental carrying capacity. Specific policies are needed to separate economic growth and environmental pressure.

Decoupling environmental pressures from economic growth is identified by the Organisation for Economic Cooperation and Development (OECD), in its *Environmental Strategy for the First Decade of the 21st Century*, as one of five objectives in the context of sustainable development.[10] "Decoupling" is said to occur when a given form of environmental pressure (for example pollution or resource use) grows more slowly than a driving force (economic activity, population growth or another measure of human activity) over a period of time. When the environmental pressure does not change or decreases while the driving force increases, decoupling is said to be "absolute" (Figure 3.2).

Relative decoupling is exhibited when the growth rate of the environmental pressure is positive but less than the rate of growth in the human activity. Whether or not decoupling is occurring can be investigated using decoupling indicators[11] or may be represented graphically, as shown in figures 3.2 and 3.3.

Decoupling analysis is best applied to policy-relevant indicators of specific types of environmental pressure and their impacts (see box 3.1).

Figure 3.3 applies this approach, illustrating the growth in CO_2 emissions, GDP and population for several Asian and Pacific countries and developed countries outside of the region for the period 1990 to 2000. These graphs show a wide variation in the relationships between the rates of growth of GDP and population growth, as drivers of energy use, and the resulting CO_2 emissions.

In the Republic of Korea, Australia, New Zealand and developing countries like the Islamic Republic of Iran, India, Pakistan and Indonesia, the growth in CO_2 emissions is strongly tied to economic growth. In a few countries such as Thailand, Sri Lanka, Nepal and Bhutan, CO_2 emissions are growing even faster than GDP growth; this is probably due to the rapid growth in electricity production in these countries and the switching from biomass to fossil fuels for domestic energy use, or to the growth of energy-intensive industry. On the other hand, there are some countries in which the data indicate significant decoupling of CO_2 emissions from economic growth. China, for example, slowed CO_2 emissions while its economy maintained a high growth rate during the 1990s.[12] The Philippines and Cambodia also seem to be making progress on this front. The Philippines has invested in improving its energy mix by capitalizing on its considerable geothermal energy potential. Of the developed countries outside the region, Denmark, Norway, the United Kingdom and Germany have achieved a significant degree of decoupling of CO_2 emissions from economic growth.[13]

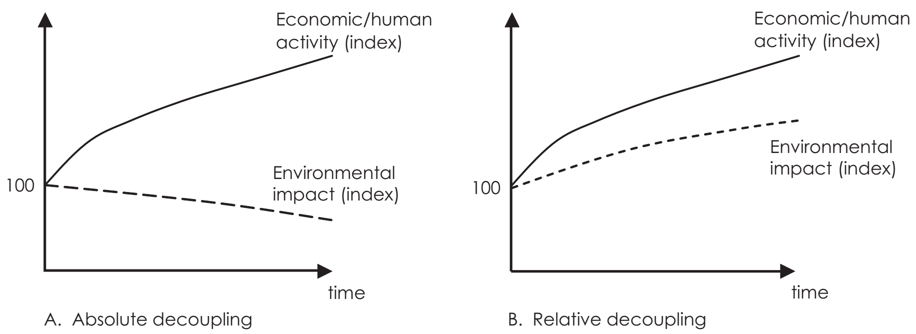
These observations indicate that a relatively high rate of growth in GDP does not necessarily imply a correspondingly high rate of growth in CO_2 emissions. This would suggest that there is room for policymakers to implement policies that encourage

Box 3.1 Examples of decoupling measures

- Economic growth from the use of water resources and emissions of greenhouse and other gases
- Household consumption expenditure from water consumption, total waste and un-recycled waste
- Agricultural productivity, output volume and value from water used for irrigation, the use of mineral fertilizer and methane emissions
- Gross value added of manufacturing industry from emissions of CO_2, SO_2, NO_x and PM10
- Electricity use from the environmental impacts of electricity generation
- Passenger transport from emissions of fossil fuel use, greenhouse gas and other emissions

Adapted from: National Statistics and Department for Environment, Food and Rural Affairs, United Kingdom (2005). *Sustainable Production and Consumption Indicators: Revised basket of decoupling indicators*, E-Digest publication accessed on 12 September 2005 from <http://www.defra.gov.uk/environment/statistics/scp/index.htm>.

Figure 3.2 Decoupling environmental impact from economic/human activity



greater levels of decoupling, thereby delinking economic growth from environmental degradation.

Economy-wide analysis based on GDP gives a good idea of broad trends, but cannot show changes in environmental impacts related to changes in economic structure, or due to trade in resource- or pollution-intensive goods. There are other caveats regarding decoupling analysis that relate specifically to the situation of developing countries.[14]

It is also important to note that decoupling in and of itself may not be sufficient to achieve environmental sustainability. The authors of one report write that "it is important to note that, even if decoupling is occurring, in reality environmental damage may be increasing unsustainably."[15] This can occur because decoupling analysis focuses on rates of growth in environmental pressure rather than considering changes in the total amount of environmental damage. It can also occur when existing levels of environmental pressure are causing increased environmental impacts, even though the pressure itself may be decreasing (for example, when some impact threshold has been passed, or there are positive feedback effects from the natural system itself).

Figure 3.3 CO_2 emissions, GDP and population growth (indexed values) time series[16]

A. Asian and Pacific developed countries

Figure 3.3 CO_2 emissions, GDP and population growth (indexed values) time series[16] *(continued)*

B. Asian and Pacific least developed countries

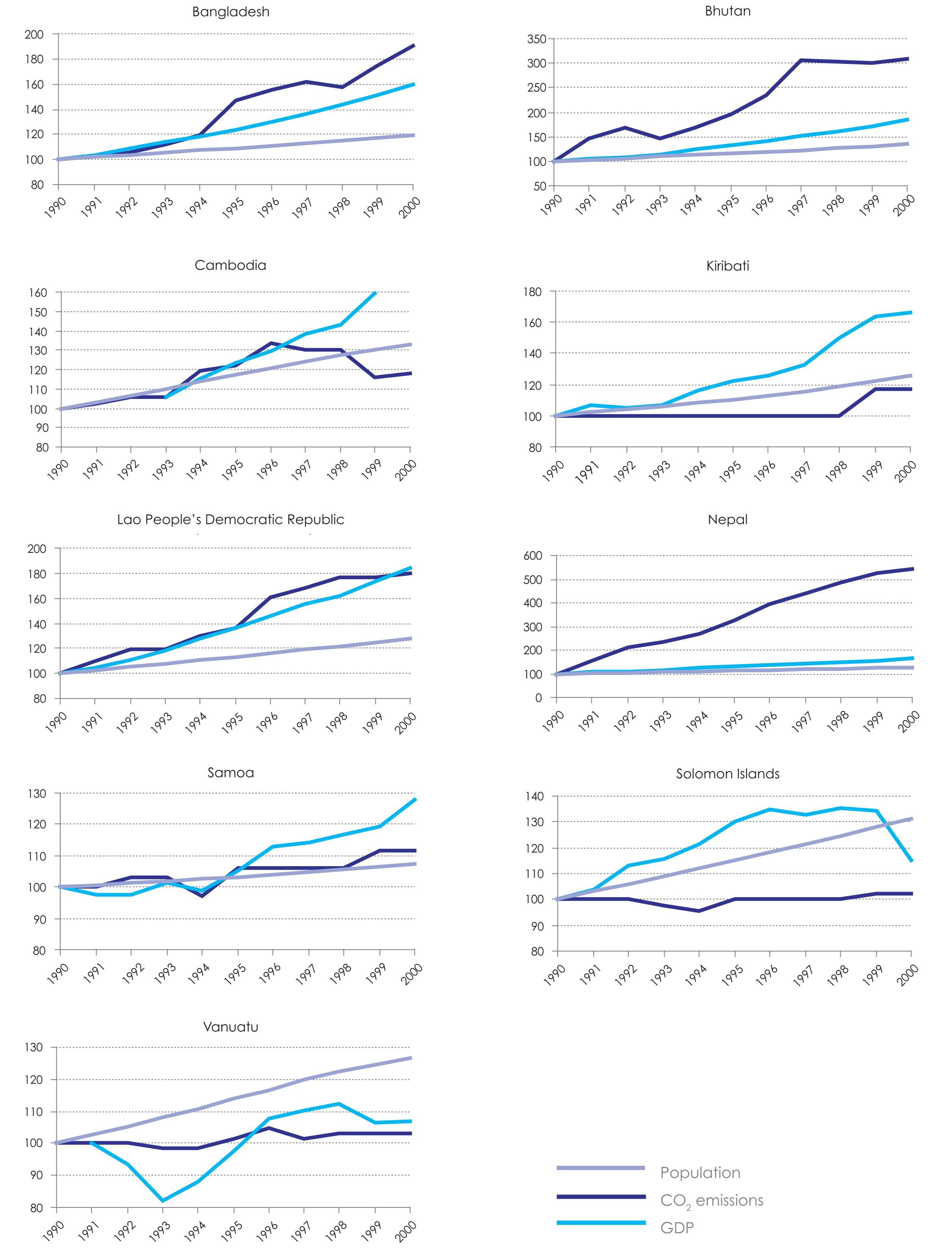


Figure 3.3 CO_2 emissions, GDP and population growth (indexed values) time series[16] *(continued)*

C. Asian and Pacific developing countries

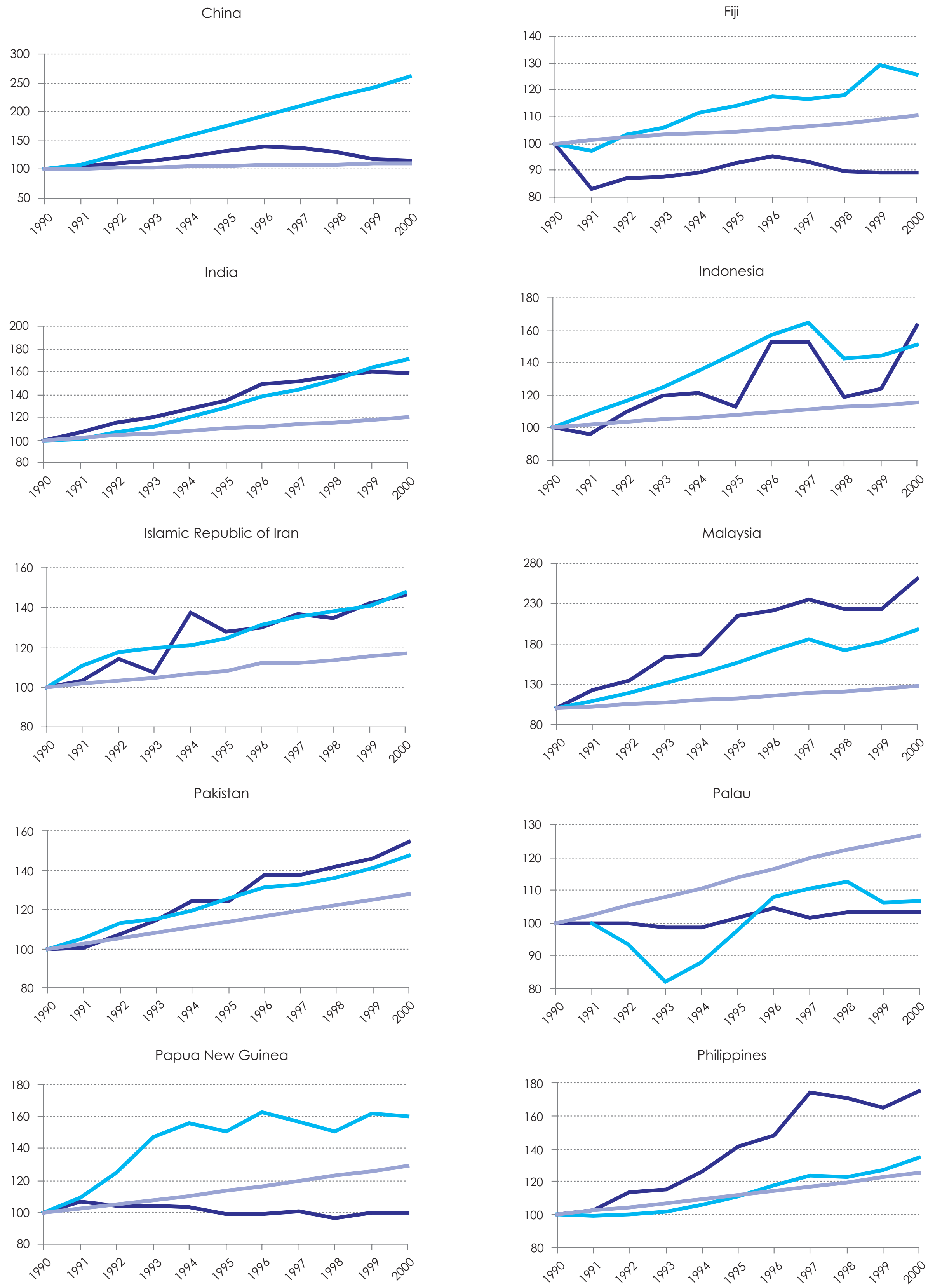
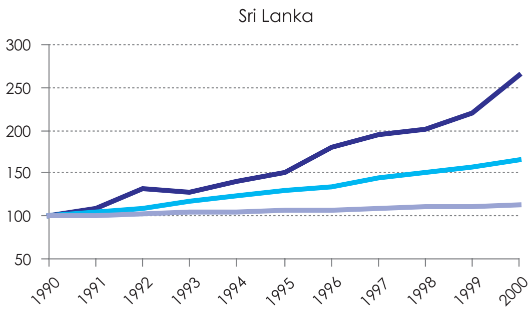
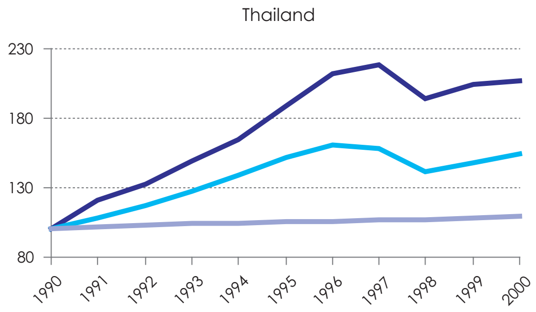
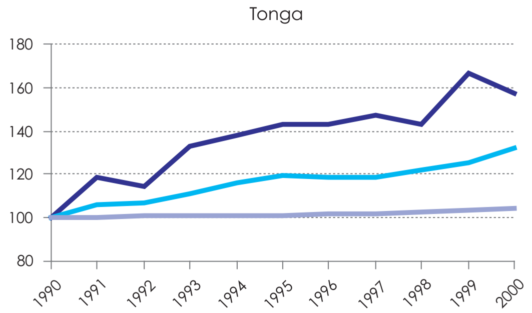


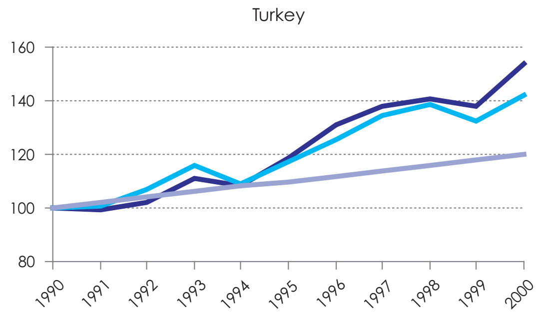
Figure 3.3 CO_2 emissions, GDP and population growth (indexed values) time series[16] *(continued)*

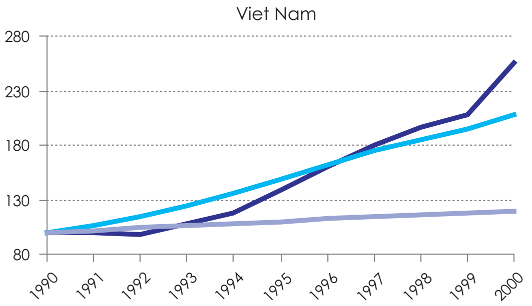
C. Asian and Pacific developing countries *(continued)*



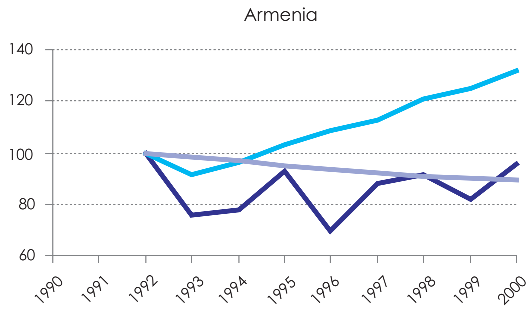


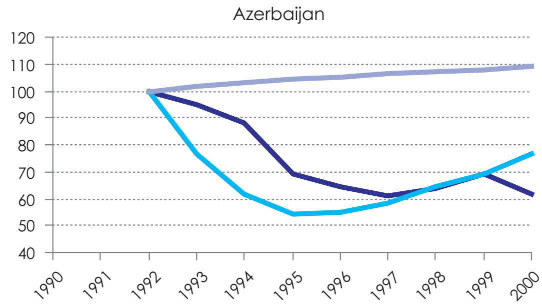


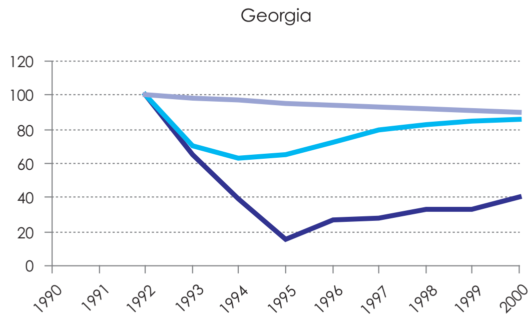




D. Asian and Pacific economies in transition







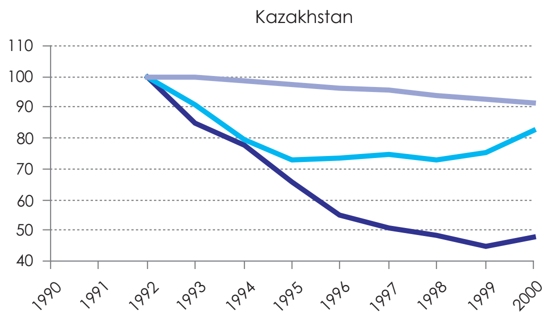
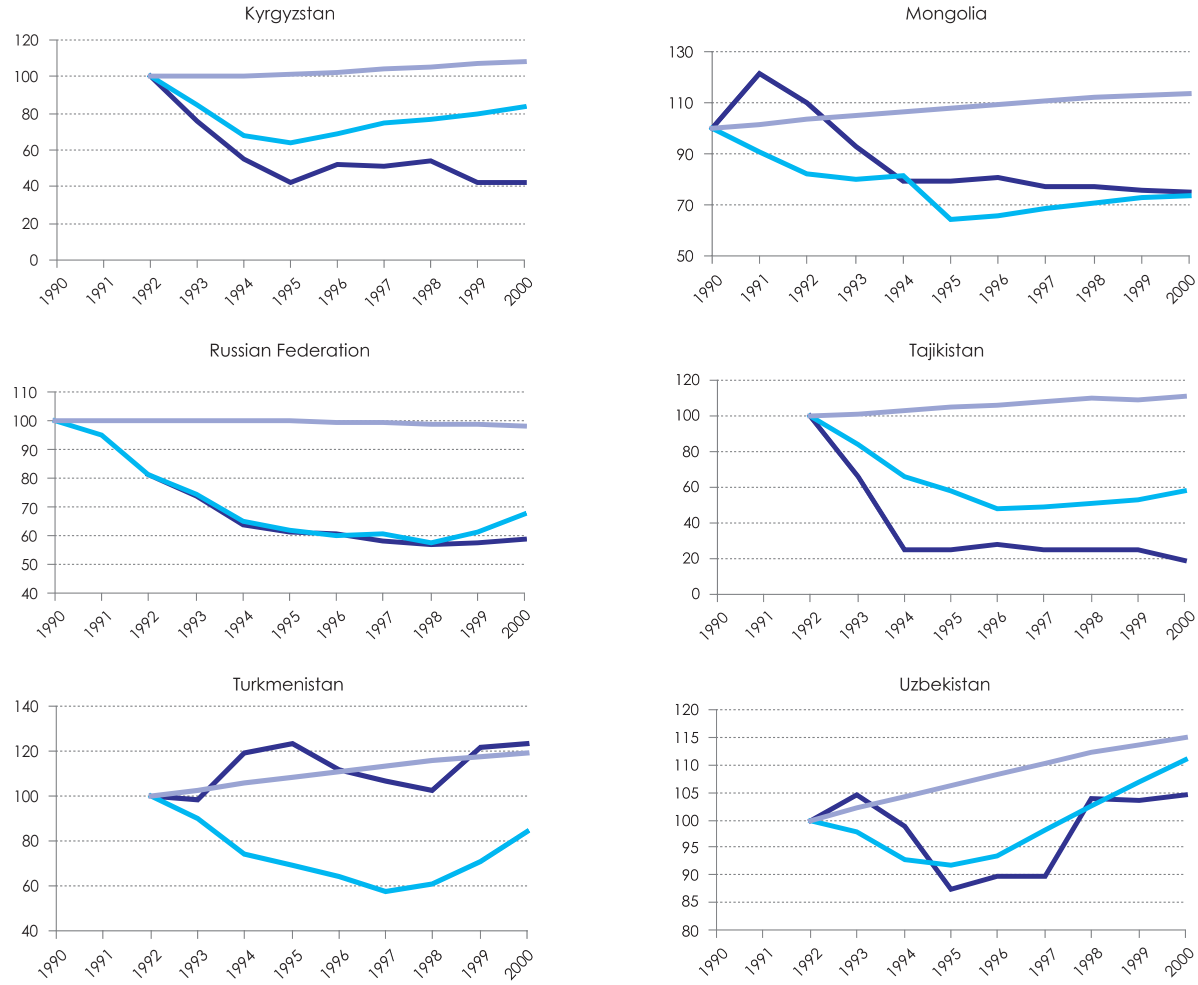
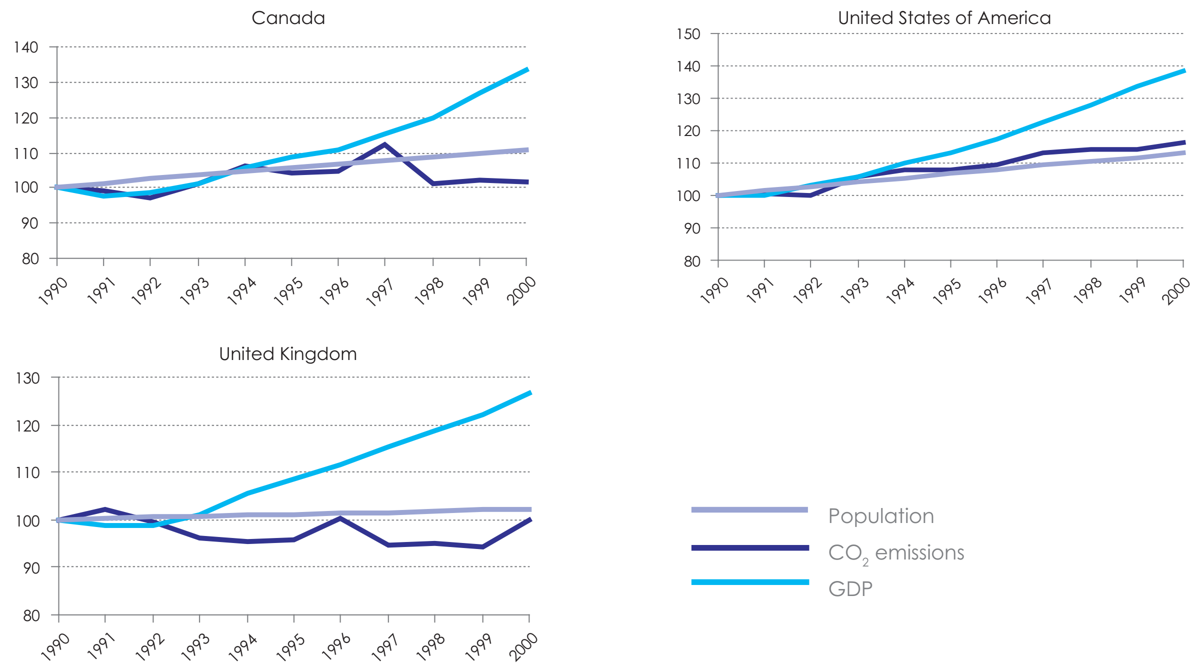


Figure 3.3 CO_2 emissions, GDP and population growth (indexed values) time series[16] *(continued)*

D. Asian and Pacific economies in transition (*continued*)



E. Selected non-Asian and Pacific OECD-member countries



3.3 Eco-efficiency as a means of decoupling

Eco-efficiency concepts, most often applied by the private sector at the firm level, can be scaled up to assess whether economies and societies are progressing towards decoupling negative environmental impacts from economic growth and improvements in human well-being. At high enough levels, eco-efficiency improvements contribute to making economic growth more environmentally sustainable.

In 1997, the United Nations General Assembly's Nineteenth Special Session convened to review progress on implementing the outcomes of the 1992 Rio Earth Summit. Resolution S-19/2 adopted at that session identifies eco-efficiency as an important tool for making consumption and production patterns more sustainable, and recommends action to promote "international and national programmes for energy and material efficiency with timetables for their implementation, as appropriate." It also advises that attention be given to "studies that propose to improve the efficiency of resource use, including consideration of a tenfold improvement in resource productivity in industrialized countries in the long term and a possible factor-four increase in industrialized countries in the next two or three decades."[17] In the *Johannesburg Plan of Implementation*, the main outcome of the World Summit on Sustainable Development convened in 2002, governments worldwide commit to "encourage and promote the development of a 10-year framework of programmes", requiring, *inter alia*, action to "increase eco-efficiency" and to "increase investment in cleaner production and eco-efficiency in all countries."[18]

Eco-efficiency is often described very generally as "doing more with less impact." Its origins are in the private sector and activities at the firm level. The World Business Council for Sustainable Development (WBCSD) states that:

> *"Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity."*[19]

In the private sector context, the concept is accepted as a basis for monitoring the environmental impact of the production activity or services delivery of a firm. However, its use is also proposed to describe and assess the environmental impact of a wider scale of economic activity: of entire economic sectors, economies and societies. In this wider context, "eco-efficiency" is used as a measure of the efficiency of the use of ecosystem goods and services by human populations. As in the private sector, the term "use" does not only cover the direct use of natural resources as inputs for the production process; it also encompasses the indirect use of natural resources as waste-sinks. As with the life cycle analysis approach taken by the private sector to improving eco-efficiency, broadening the concept to apply to the national context also requires its application not only to production activity, but also to the environmental impacts of consumption levels and patterns and a wide range of human activities.

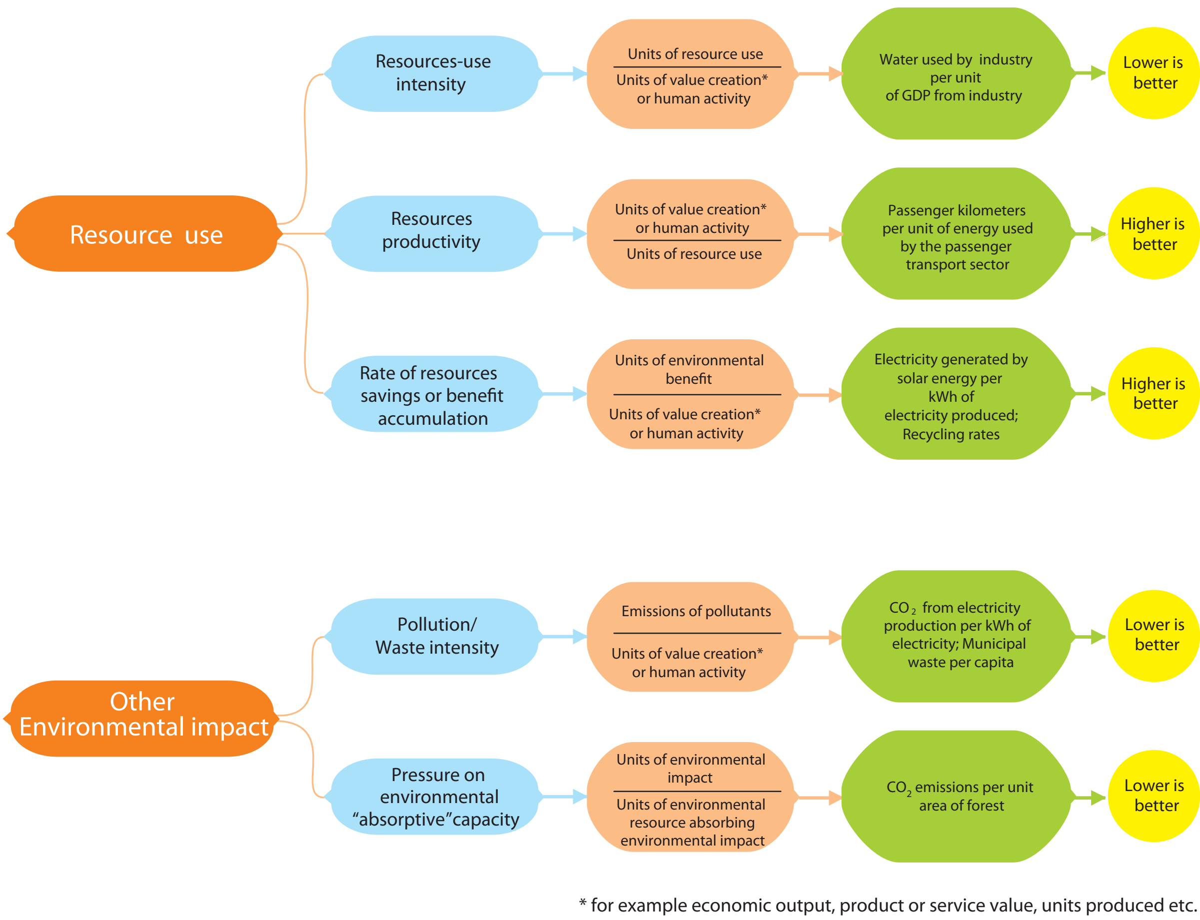
There are several ideas about what constitutes a 'valid' measure of eco-efficiency. The main point of consensus is that eco-efficiency measures are expressed as ratios that directly relate a given environmental impact (in the form of resource use, environmental benefit or waste produced) to its economic or human driving force (in the form of value created, outputs, consumption or other measures of human activity). Some interpretations of eco-efficiency, particularly as applied to enterprise-level eco-efficiency, have restricted eco-efficiency measures to those expressed as a ratio of an economic variable (in monetary terms) to an environmental one.[20] It has also been proposed that eco-efficiency may be described as the efficiency with which inputs are transformed into outputs.[21]

However, the types of eco-efficiency measure used at the firm level cannot reflect the wide range of human activities that comprise any economy and that impact on natural resource use, produce waste or pollution or change landscapes. Scaling up eco-efficiency concepts and applying them at the national level therefore requires the examination of a wide range of economic driving forces, reflecting production and consumption activity, as well as the basic human activities that contribute to economic growth and increased human welfare. With this in mind, potential eco-efficiency measures are presented in figure 3.4.

They include several eco-efficiency types that are already well recognized (such as resource productivity and resource intensity), along with others that take a more holistic view of the use of environmental resources, such as rate of resources savings or benefit accumulation, and that recognize the limitations of the natural resource endowment, such as pressure on environmental absorptive capacity (Figure 3.4). Eco-efficiency measures make a direct link between environmental impact and economic or human activity, and allow the flexibility to develop and adapt indicators relevant to the local context.

Eco-efficiency measures have been used as the basis for national target-setting. China is targeting significant eco-efficiency improvements as an important element of its drive to create a resource-saving society, as is Japan (see chapter 4). One basic measure of eco-efficiency is the per capita or per GDP total material requirement of a country. The total material requirement is a measure of the physical materials used by an economy, i.e. the sum of domestic and imported primary natural resources and their hidden flows.[22] In 2001, it was reported that the total material requirement of Australia was about 180 metric tons per person per year, more than twice that of other OECD countries. The total material requirement per person has been reported to be levelling off at between 75 to 85 metric tons per year in Germany, the Netherlands and the United States, while Japan's requirement is about 45 metric tons per capita. In 1997, OECD environmental

Figure 3.4 Potential eco-efficiency measures



ministers stated that "eco-efficiency is ... viewed as highly promising to enable industry, governments and households to decouple pollutant release and resource use from economic activity." Later agreeing to "promote innovative approaches, such as eco-efficiency, aiming to achieve substantial improvements in resource productivity," they adopted the eco-efficiency improvement target of a tenfold increase in resource productivity in the long term, as first formulated by the Factor 10 Club.[23]

Eco-efficiency measures have also been recognized as a critical element of monitoring progress on sustainable development. In April 1995, the Commission on Sustainable Development (CSD) of the United Nations approved a work programme on indicators of sustainable development. The CSD Theme Indicator Framework includes potential measures of eco-efficiency, such as resource use intensity (m^3 or metric tons of material used per US$1,000 GDP or energy use per dollar of GDP).[24]

The use of eco-efficiency measures in assessing the potential impacts of economic development policy (such as industrial sector development) and infrastructure development is yet to be explored. The use of these measures as a basis for ensuring that economies grow in more environmentally sustainable directions could represent a critical advance in policymaking and one in which a wide range of stakeholders could participate. To serve as useful indicators of environmental sustainability, eco-efficiency measures should:

1) Not be interpreted as measuring total levels of pressure on the environment. For example, even if the per capita CO_2 emissions of a country are very low, a large population still translates to significant contributions to climate change processes. High levels of eco-efficiency of production and/or consumption do not mean that the environment is not being endangered, they just mean that resources are being used, and waste emitted, at a slower rate while economies grow;
2) Be appropriate for the context. In particular, they should be used with caution in situations of resource scarcity. For example, in many least developed countries, access to energy is insufficient to meet basic requirements. In these cases, low levels of energy consumption per capita do not indicate eco-efficiency but levels of scarcity;
3) Be used to monitor changes over time. The direction and rate of change in eco-efficiency will be as important as the actual indicator values in determining whether economies are growing in more or less environmentally sustainable directions, and how quickly;
4) Facilitate comparisons between economic sectors. Where data availability allows, the measurement of eco-efficiency across sectors allows for the identification of the sectors with the lowest levels of eco-efficiency and thereby for the development of prioritized action for the improvement of sustainability.[25] Economy-wide eco-efficiency measures (e.g. those based on GDP) are strongly influenced by economic structures and can be far less policy-relevant. For example, a country with a high dependence on energy-intensive industry will necessarily seem less eco-efficient if compared with another country with lower levels of dependence on such industry;
5) Not be constructed in a way that can send mixed signals. For example, the economic value-added produced per unit of agricultural land may be an indicator of the efficiency of use of agricultural land in meeting the income and livelihood needs of farmers, but intensive use of agricultural land is too often associated with land degradation. A high indicator value is therefore very likely to imply decreasing sustainability, and therefore cannot be considered a reliable measure of eco-efficiency; and
6) Be chosen carefully to ensure their relevance to the societies and countries concerned. Choosing indicators that reflect the real pressures on the natural environment is critical, and will vary by country and natural resource endowment.

3.4 More eco-efficient consumption – achievable, but overlooked

As income increases, eco-efficiency related to production processes tends to improve, reflecting cleaner production processes, increasing value-added in production and contributions from the services sector. However, increased income leads to increased per capita consumption; as economies grow and production eco-efficiency improves, the eco-efficiency of consumption deteriorates.

This conclusion is supported by the consideration of selected eco-efficiency indicators (energy use, CO_2 and SO_2 emissions per unit GDP) which show that while least developed countries and economies in transition require relatively high resource inputs and produce relatively large amounts of pollution in producing one unit of GDP, resource inputs and pollution outputs ranging from relatively low to high per unit of GDP were observed for developing countries. It has been observed that developed countries require the least resources and emit the lowest pollution per unit of GDP (see selected indicators, Annex II).

Reinforcing these observations, chapter 2 and section 2.2 showed that emissions of SO_2 and industrial organic water pollution per unit of GDP decreased for most countries over the period 1990 to 2000. In 1997, the United Nations General Assembly observed that there had been "progress in material and energy efficiency, particularly with reference to non-renewable resources [but] overall trends remain unsustainable."[26] Higher levels of income, implying greater access to resources, are generally observed to increase the environmental impact per person, as indicated by the comparisons of energy use, CO_2 emissions and ecological footprint per capita values for developed, developing and least developed countries, as well as for economies in transition.

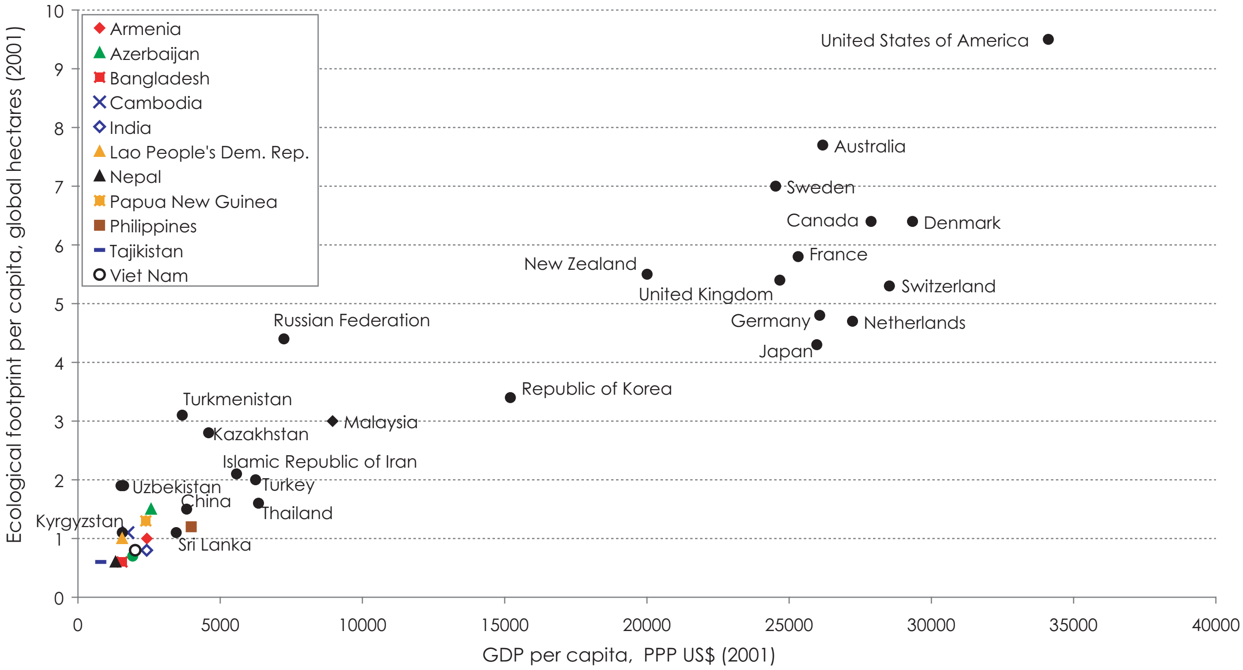
This finding is supported by the work of the World Resources Institute (WRI), which investigated the flow of materials through five developed countries and found that, over time, there were substantial declines in waste produced for every unit of GDP produced in all five countries, reflecting resource-use efficiency gains and shifts to service- and knowledge-based economies. However, over the same time period, the waste produced per person increased in four of the five study countries and the total waste produced also increased. The authors of the World Resources Institute study conclude that "the resource efficiency gains brought about the rise of e-commerce and the shift from heavy industries toward knowledge- and service-based industries have been more than offset by the tremendous scale of economic growth and consumer choices that favor energy- and material-intensive lifestyles".[27]

Rising consumption levels may therefore reduce the impact of production eco-efficiency gains. However, changing entrenched consumption patterns without impacting on economic growth remains a challenge even in many of the most developed countries. In 27 OECD countries (for which data exist) there has been significant decoupling of greenhouse gas emissions from growth of GDP over the period 1990 to 1999. However, only 11 of the 27 countries for which data were available managed to decouple growth in greenhouse gas emissions from population growth. On the bright side, the OECD's work on decoupling also shows that several countries have achieved significant decoupling of waste production from population growth, illustrating the potential for increasing eco-efficiency of consumption in this area.[28]

The idea that the environmental pressure from human consumption can be delinked from economic growth is reinforced by figure 3.5. High GDP per capita does not always imply correspondingly high consumption pressures, as indicated by the ecological footprint (see chapter 1), particularly at the higher income levels. More importantly, high levels of socio-economic progress, as measured by the Human Development Index (HDI), are not necessarily linked to high consumption pressures, as shown by the widely varying ecological footprints per capita at the higher HDI values (Figure 3.6).

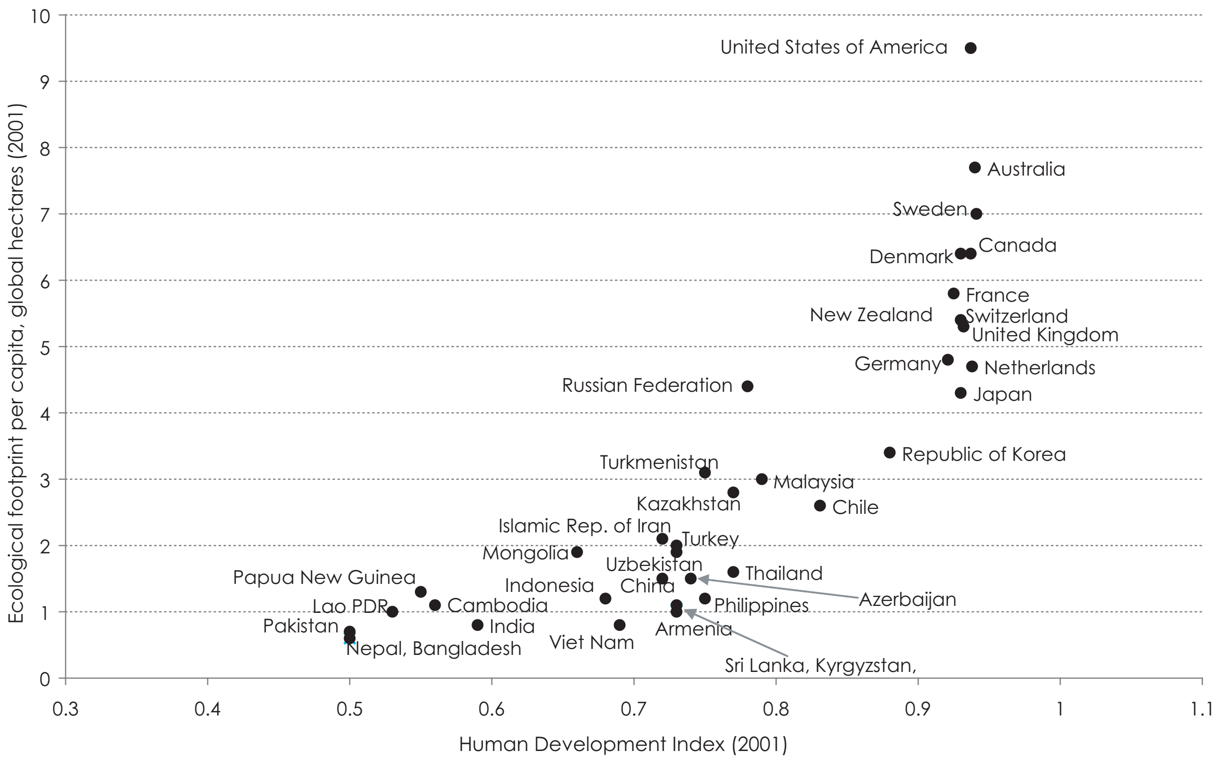
Operationalizing eco-efficiency concepts in the realms of economy-wide and society-wide development planning and policy formulation is critical to ensuring that the heaviest environmental pressures are relieved, and that this takes place on a broad enough scale to ensure that growth does not

Figure 3.5 Ecological footprint vs. GDP per capita, 2001



Source: Ecological footprint per capita: data provided by the Global Footprint network, July 2005; GDP per capita: World Bank,World Development Indicators database, downloaded on 5 July 2004 from <http://devdata.worldbank.org/dataonline/>.

Figure 3.6 Ecological footprint vs. Human Development Index, 2001



Source: Ecological footprint per capita: data provided by the Global footprint Netork, July 2005; Human Development Index: UNDP, Human Development Report website, online database, accessed on 2 February 2006 from <http://hdr.undp.org/statistics/>.

exceed environmental carrying capacity. As one presentation puts it, "if you do the wrong thing and then do it extremely efficiently, well it's still wrong."[29] This statement emphasizes that looking at eco-efficiency from the private sector perspective alone may engender a false sense of security, putting economies and societies at grave risk.

Developed countries may therefore contribute most to reducing the global impact of anthropogenic activity on the environment by increasing the eco-efficiency of consumption – in other words, reducing excessive per capita resource usage and production of waste. Fast-growing developing countries need to pay greater attention both to increasing the eco-efficiency of production and to implementing effective policies to prevent high-impact consumption patterns from becoming entrenched. Policymakers in least developed countries and economies in transition should use the opportunity presented by the current low levels of access to resources and industrialization to consider how to increase access to resources in the most eco-efficient manner possible as their economies grow, and to ensure the highest levels of production eco-efficiency.

Several factors can work together to improve the eco-efficiency of development planning. Not least of these are good governance and an improved means of valuing ecosystem goods and services. These issues are explored further in chapter 4.

End Notes

[1] See for example, Panayotou, Theodore (2003). *Economic Growth and the Environment*. Paper prepared for and presented at the Spring Seminar of the United Nations Economic Commission for Europe, Geneva.

[2] Meadows, Donnella H., Dennis L. Meadows, Jorgen Randers and William W. Behrens III (1972). *The Limits to Growth* (New York,Universe Books).

[3] Meadows, Donnella H., Dennis L. Meadows, and Jorgen Randers (1992). *Beyond the Limits* (Post Mills, VT: Chelsea Green Publishing Company) and Meadows, Donnella H., Dennis L. Meadows, and Jorgen Randers (2004). *Limits to Growth: the 30-Year Update* (London, Earthscan).

[4] See for example, Southgate, Douglas, Douglas Graham, and Luther Tweeten (2006). *The World Food Economy* (Oxford, Basil Blackwell).

[5] See for example, Beckerman, W. (1992). Economic Growth and the Environment: Whose Growth? Whose Environment? *World Development*, vol. 20, pp. 481-496.

[6] See Grossman, Gene M., and Alan B. Krueger (1991). *Environmental Impacts of a North American Free Trade Agreement*, National Bureau of Economic Research Working Paper No. 3914.

[7] See for example Panayotou, Theodore (2003). *Economic Growth and the Environment*, paper prepared for and presented at the Spring Seminar of the United Nations Economic Commission for Europe, Geneva; Yandle, Bruce, Madhusudan Bhattarai and Maya Vijayaraghavan (2004). "Environmental Kuznets Curves: A Review of Findings, Methods and Policy Implications," Property and Environment Research Center, Research Study 02-1 UPDATE, accessed on 15 October 2005 from <http://www.perc.org/pdf/rs02_1a.pdf>; Arrow, Kenneth, Bert Bolin, Robert Costanza, Partha Dasgupta, Carl Folke, C.S. Holling, Bengt-Owe Jansson, Simon Levin, Karl-Goran Maler, Charles Perrings, and David Pimmetel (1995). "Economic growth, carrying capacity and the environment," *Ecological Economics*, vol. 15, issue No. 1, pp. 91-95; Dasgupta, Susmita, Benoit Laplante, Hua Wang and David Wheeler (2002). "Confronting the Environmental Kuznet's Curve," *Journal of Economic Perspectives*, vol. 16, issue no. 1, pp. 147-168 and; Ekins, Paul (2000). *Economic Growth and Environmental Sustainability* (London, Routledge).

[8] These include the emergence of markets, evolving and strengthening property rights, economies of scale, political economy effects (income-induced changes in the political decision-making processes), changes in economic production structures and relative openness of economies. See, for example, Yandle, Bruce, Madhusudan Bhattarai, and Maya Vijayaraghavan (2004), op. cit.

[9] This is more formally illustrated by reference to the equation proposed by Commoner and Erlich (see Ekins, Paul (2000), op. cit.) which deconstructs the total impact of human activity on the environment:

$$I = p*c*t$$

$$impact = population * \frac{GDP}{population} * \frac{impact}{GDP}$$

where "I" represents total environmental impact, "p" stands for total population,"c" is GDP per capita and "t" is the environmental impact divided by total GDP. Eco-efficiency is represented by "t" and we see that a decrease in t or an improvement in eco-efficiency may be accompanied by an increase in "c" or "p" that is large enough that "I" actually increases. Therefore, it would seem that although improved eco-efficiency can help to reduce total environmental impact, it is not a sufficient condition for reducing total environmental impact.

[10] OECD (2001). *Environmental Strategy for the First Decade of the 21st Century* (Paris, OECD) accessed on 12 October 2005 from <http://www1.oecd.org/env/min/2001/products/EnvStrategy.pdf >.

[11] The OECD decoupling indicators have a numerator, which is a measure of the rate of growth of the environmental impact and a denominator, which is a measure of the rate of growth of environmental pressure.

[12] The International Energy Agency cautions that emission trends should be identified with caution due to uncertainty surrounding the reliability of data (see International Energy Agency (2004). CO_2 *emissions from fuel combustion: 1971-2002* (Paris, OECD/IEA)). One investigation concludes that CO_2 emissions from China decreased significantly between 1996 and 2000. See Knight, Daniel (2001), "China Cuts Greenhouse Gases, Contradicting U.S.", Inter Press Service, Thursday 29 November 2001, accessed on 12 May 2005 from <http://www.globalissues.org/EnvIssues/GlobalWarming/Articles/ChinaCuts.asp>.

[13] Some have linked declining CO_2 emissions with increasing imports of energy-intensive products which are associated with high CO_2 emissions. See Black, Richard (2005). "Trade can export CO_2 emissions" accessed on 17 December 2005 from <http://news.bbc.co.uk/1/hi/sci/tech/4542104.stm>.

[14] Disproportionately rapid increases in environmental impact (e.g. rapidly increasing CO_2 emissions) that may indicate that large numbers of people are gaining basic levels of access to resources (such as energy) may be misinterpreted as rapidly declining resource-use efficiency. In developing countries, decoupling analysis based on GDP growth may not account for the informal economic activity which supports significant numbers of people.

GDP measures also do not attribute value to changes in human, social and ecological capital and welfare.

[15] Department for Environment, Food and Rural Affairs, United Kingdom (2005). *Sustainable Consumption and Production Indicators: Revised basket of 'decoupling' indicators*, accessed on 12 March 2006 from <http://www.defra.gov.uk/environment/statistics/scp/index.htm>.

[16] GDP (constant 2000 US$), population and CO_2 emissions data from the World Bank, World Development Indicators database, accessed on 25 June 2005 from <http://devdata.worldbank.org/query/>.

[17] See United Nations General Assembly Resolution S-19/2, accessed on 2 November 2005 from <http://www.un.org/documents/ga/res/spec/aress19-2.htm>.

[18] See section III, paragraphs (f) and (g) of the Johannesburg Programme of Implementation. Text accessed on 20 April 2006 from <http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/WSSD_PlanImpl.pdf>.

[19] The participants of the first Antwerp Workshop on Eco-efficiency, organized by the World Business Council for Sustainable Development in November 1993 agreed on this definition, as quoted in World Business Council for Sustainable Development (1996). *Eco-efficient Leadership for Improved Economic and Environmental Performance*, accessed on 11 November 2005 from <http://www.wbcsd.ch/DocRoot/DlFMcUZj32ZOMj5xNMXq/eeleadership.pdf>.

[20] Huppes, Gjalt (2004). "Summary of conference results," presentation at the First International Conference on Eco-efficiency. Eco-efficiency for Sustainability: Quantified Methods for Decision-Making, 2-4 April 2004, Leiden, Netherlands.

[21] See Ekins, Paul (2005). "Resource Productivity, Eco-efficiency, Green Growth: A New Path for Human Welfare and Environmental Sustainability", presentation at the ESCAP Regional Policy Forum Towards Green Growth in Asia and the Pacific: Eco-efficiency through Green Tax and Budget Reform, 8-9 November 2005, Seoul, Republic of Korea, accessed on 15 December 2005 from <http://www.unescap.org/esd/environment/mced/tggap/index.asp>.

[22] Hidden flows cover "incidental" material losses, such as earth moving for construction, mining overburden and soil erosion. See World Resources Institute (1997). *Resource Flows: The material basis of industrialized economies* (Washington DC, World Resources Institute), accessed on 19 May 2005 from <http://materials.wri.org/pubs_content_text.cfm?ContentID=627>.

[23] This group of international experts from the academic, business and environmental circles was founded in October 1994 in Provence, France. In its 1997 Carnoules Statement to Government and Business Leaders, the group argued that a ten-fold increase in the average resource productivity in industrialized countries was a prerequisite for achieving long-term sustainability. OECD environment ministers adopted this target in 1998. Factor 10 (1997). "Carnoules Statement to Government and Business Leaders", accessed on 2 March 2006 from <http://www.factor10-institute.org>.

[24] See the United Nations Department for Economic and Social Affairs, Commission for Sustainable Development Theme Indicator Framework, accessed on 2 March 2006 from <http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/table_4.htm>.

[25] An example of the use of eco-efficiency indices for this purpose is provided by Jollands and others who compare the total material requirement of various sectors in New Zealand. See Jollands, Nigel, J. Lermit and M. Patterson (2004). "Aggregate eco-efficiency indices for New Zealand – a principal components analysis", *Journal of Environmental Management* Vol. 73, p. 293-305.

[26] See United Nations General Assembly Resolution S-19/2.

[27] See World Resources Institute (2000). "Pollution and waste increasing in five countries despite more efficient use of resources", news release, 20 September 2000, accessed on 6 December 2005 from <http://materials.wri.org/newsrelease_text.cfm?NewsReleaseID=6>.

[28] OECD (2002). *Indicators to measure decoupling of environmental pressure from economic growth* (Paris, OECD), accessed on 9 September 2005 from <http://www.olis.oecd.org/olis/2002doc.nsf/LinkTo/sg-sd(2002)1-final>.

[29] Prasad, G. V. (2004). "Eco-effectiveness vs. eco-efficiency", presentation at the First International Conference on Eco-efficiency. Eco-efficiency for Sustainability: Quantified Methods for Decision-Making, 2-4 April 2004, Leiden, Netherlands, accessed on 10 November 2005 from <http://www.ewindows.eu.org/ManagementConcepts/ecoeffect/F1075213229/URL1075213771>.