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Growth and CO_2 Emissions

How Do Different Countries Fare?

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November 2007

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Abbreviations and Acronyms

Btu	British thermal units
CO_2	carbon dioxide
EIA	Energy Information Administration
GDP	gross domestic product
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LMDI	logarithmic mean Divisia index
MER	market exchange rate
PPP	purchasing power parity

Executive Summary

The recent Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report (2007) has deepened understanding of the magnitude of climate change, its consequences, and possible policies to reduce and mitigate its effects. The combustion of fossil fuels is the largest single contributor to carbon dioxide (CO_2) and total greenhouse gas (GHG) emissions and, of all major sources, has grown the most rapidly over the period 1970 to the present. Furthermore, the IPCC 2007 report shows that a long-observed trend in declining global CO_2 emission intensity per unit of GDP reversed around 2000. This means that, with world economic growth the strongest it has been in decades, global CO_2 emissions are growing faster than at any time since 1970.

The growth of CO_2 emissions over time has shown substantial variation among countries, and there is considerable interest about which countries have recently experienced rapid growth of emissions and why. The relationship between this growth and changes in various structural factors in the economies, such as energy intensity and the share of fossil fuels in total energy consumption, as well as between this growth and the growth of the economies themselves, has been the focus of a number of studies.

This report

- Provides comparative data on a number of measures of emissions for a wide range of countries, allowing comparisons to be made among the different measures. The main data sources are the Energy Information Administration (EIA) of the US Department of Energy and the World Resources Institute.
- Provides a decomposition of the change in fossil fuel CO_2 emissions between 1994 and 2004 into changes in five factors: the average emissions per unit of fossil fuel consumed (the carbon intensity of fossil fuel); the share of fossil fuel consumption in total energy consumption (including fossil fuel consumption and non–fossil fuel power production, but not solar heating of water and the like); total energy consumption per unit of GDP (energy intensity); GDP per capita; and population. This analysis excludes the use of biomass, for which there is no comparable data available
- Carries out this decomposition for the top 70 countries measured by 2004 emissions of CO_2 from fossil fuels. Half of these are developing countries. This provides a much wider coverage of emissions and their decomposition than given in previous studies.
- Bases the decomposition on changes in emissions and the related factors between 1994 and 2004, providing a more up-to-date study than others currently available. This update is important because of significant changes observed in the growth of CO_2 emissions for a number of countries around 2000.
- Splits the decade into two five-year subperiods (1994–99, 1999–2004) to identify how the relative importance of the different factors changed during the period.

The principal findings of the report follow:

1. The top 70 countries ranked by CO_2 emissions from fossil fuels in 2004 accounted for 95 percent of the global total. The top 20 were mostly drawn from higher income developed countries, but also included several major developing economies. In addition, several large oil-producing countries were in the top 30. During the period 1994–2004, some 15 countries experienced a fall in CO_2 emissions from fossil fuel consumption, and this group comprised mainly Eastern European and Central Asian countries. The percentage growth in emissions during the decade showed considerable variation among countries, with some large emitters experiencing large growth and others relatively low growth.
2. The ratio of CO_2 emissions from consumption of fossil fuels to total GHG emissions is more than 50 percent for 55 of the countries, and rises to more than 80 percent for 14 countries. The group of countries where the ratio is particularly low includes those where the most effective policies to reduce GHG emissions are likely to be distinct from those designed to reduce CO_2 emissions from fossil fuels.
3. The intercountry distribution of emissions per unit of GDP (emissions intensity) was measured using GDP at purchasing power parity (PPP) and at market exchange rates (MER). The emissions intensity was, for most countries, very much lower on the former measure. The ranking of countries by emissions intensity also changed substantially relative to the ranking by total emissions, and was not systematically related to GDP per capita. Because the ratio of the measure of GDP at PPP to GDP at MER stayed constant throughout the decade, the percentage change in emissions per unit of GDP was identical for the two measures, and this analysis of changes in emissions uses the PPP measure.
4. The ranking of countries by emissions intensity changed substantially relative to the ranking by total CO_2 emissions. Among large developing economies, Brazil, India, and Mexico ranked very much lower on emissions intensity than on total emissions among the group of 70 countries studied. Several middle-income countries were among those with the highest rankings.
5. Emissions per capita were positively but only moderately correlated with GDP per capita and showed no evidence of an eventual decline in emissions per capita at higher per capita income (the Environmental Kuznets Curve phenomenon). The rankings relative to those for total emissions, or emissions per unit of GDP, were quite different. Some countries with large populations, such as India and Indonesia, moved almost to the bottom of the ranking based on this measure, while some countries with small populations moved to the top of the rankings.
6. The decomposition analysis related the change in emissions during the decade to changes in the five factors. For the group of countries as a whole, GDP per capita was the dominant variable linked to the growth in total emissions, with population being only one-half as important. However, the decrease in energy intensity was so large that it offset about 40 percent of the combined influence of these two factors. The fossil fuel mix showed a small negative effect on the change in emissions, while the share of fossil fuels in total energy consumption contributed a small increase to the change in emissions.
7. The relative importance of the three factors that could be directly linked to policies to slow down the growth of emissions (fossil fuel mix, share of fossil fuels in total energy, and energy intensity of GDP) to the positive effects of GDP growth is measured by the "offsetting" coefficient. For the decade as a whole, 15 countries more than offset the combined impacts of GDP and population growth. This group consisted mainly of former

Soviet Union and Eastern European countries, but also included two Scandinavian countries, whose policies toward emissions may give important clues for other countries wanting to slow the growth of emissions. There were also 19 countries where the changes in the potential offsetting factors actually led to a further increase in emissions beyond that which would have been expected from the growth of GDP ("negative offsetting"). The group included several oil producers, but also some non-oil-producing, high-income developed countries.

8. Among countries with the largest absolute emissions, the United States was able to offset a sizeable fraction of its growth in emissions but, given the size of the economy, the increment was still large. By contrast, Japan, with relatively low income and population growth, experienced negative offsetting, but the total increment was relatively small. The Russian Federation fully offset the growth in emissions related to income and population during this period but, given that population decline and massive changes in sectoral structure and energy efficiency were stimulated by the political changes during this period, a similar performance may be difficult to maintain in the coming decade. China and India, while enjoying rapid economic growth during the decade, were also able to offset significant portions of the potential growth in emissions.
9. When the data was split into two five-year subperiods, it became apparent that for some countries large shifts in structure had taken place in the course of the decade. For one group of countries, the offsetting coefficient increased substantially—this group included several developing countries. An important group of 13 countries experienced negative offsetting in both subperiods, indicating that this was a longer term trend—the group included some major oil producers, and some high-income, non-oil-producing countries. Six countries moved from positive to negative offsetting between the two subperiods, indicating that they had actually seen emissions rise faster relative to GDP. The experiences of the countries with largest absolute emissions across the two subperiods were quite different. The United States and India both experienced substantial offsetting throughout the period, while China and Russia both experienced high offsetting in the first period, but much reduced offsetting in the second. For the group as a whole, there was no apparent correlation between the improvement in offsetting and the level of GDP, indicating that during the period studied higher income countries had not performed better in slowing the growth of emissions relative to GDP.

However, a number of countries did experience improved performance of emissions relative to GDP, suggesting that there need not be a negative trade-off between slowing the growth of emissions and maintaining high growth rates of the economy. Countries that were particularly successful in achieving high offsetting could well serve as case studies for how this might be achieved. However, the experience of several countries also makes it clear that, without active policies to curb the emissions intensity of the economy, emissions can actually increase faster than GDP, even when GDP has reached a high level. More detailed analysis could shed further light on the factors determining aggregate energy intensity for an economy, because this factor appears to have accounted for the largest differences in performance between economies, once the growth of GDP is allowed for. In particular, the distinction between changes resulting from sectoral composition and changes resulting from improvements in energy efficiency may be helpful in giving clues about the future course of emissions, and the possibilities of finding policies that could make a substantial difference to global CO_2 emissions.

1 Background

The recent Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report (2007) has deepened understanding of the magnitude of climate change, its consequences, and possible policies to reduce and mitigate its effects. The combustion of fossil fuels is the largest single contributor to carbon dioxide (CO_2) and total greenhouse gas (GHG) emissions and, of all major sources, has grown the most rapidly over the period 1970 to the present. Furthermore, the IPCC 2007 report shows that a long-observed trend in declining global CO_2 emission intensity per unit of gross domestic product (GDP) reversed around 2000, meaning that, with the strongest economic growth of the world economy in decades, global CO_2 emissions are growing faster than at any time since 1970.

The growth of CO_2 emissions over time has shown substantial variation among countries, and there is considerable interest about which countries have recently experienced rapid growth of emissions. The relationship between this growth and changes in various factors, such as the energy intensity and the share of fossil fuels in total energy consumption, as well as the growth of the economy itself, has been the focus of a number of studies. The primary purpose of this report is to provide a comparative baseline analysis of the change in fossil fuel emissions of a large number of countries that can serve as a starting point for detailed country-by-country investigation, and to provide focus on the key factors that are amenable to policy interventions.

The principal tool for describing the relationship between the growth of emissions and changes in various related factors is "decomposition analysis." Although there is substantial literature that applies this technique to fossil fuel emissions of CO_2, much of it concentrates on high-income countries, with one or two large developing countries also being covered. Studies covering a slightly wider range of countries used data from 2002 or earlier, so recent important developments are not reflected in these studies.

This report is designed to serve several purposes:

- It provides a statistical decomposition, or breakdown, of fossil fuel CO_2 emissions into five factors: the average emissions per unit of fossil fuel consumed (the carbon intensity of fossil fuel); the share of fossil fuel consumption in total energy consumption (including fossil fuel consumption and non–fossil fuel power production, but not solar heating of water and the like); total energy consumption per unit of GDP (energy intensity); GDP per capita; and population. This analysis excludes the use of biomass, for which there is no comparable data available.

- The decomposition is carried out for the top 70 countries measured by 2004 emissions of CO_2 from fossil fuels. Half of these are developing countries. This provides a much wider coverage of emissions and their decomposition than has been analyzed in previous studies.

- The decomposition is based on changes in emissions and the related factors between 1994 and 2004, providing a more up-to-date study than others currently available. This update is important because of significant changes observed in the growth of CO_2 emissions for a number of countries around 2000, which is explored through splitting the decomposition into two five-year subperiods. The analysis compares annual emissions at these two points in time and relates the change in these emissions to changes in a number of variables over the same period.

The report begins with an account of the technique of statistical decomposition analysis and briefly mentions some other studies that have used it. This is followed by a discussion of the model used in this report and the data sources. Countries in the study are then ranked by various measures of emissions including total CO_2 fossil fuel emissions, emissions per capita, and emissions per unit of GDP. This is followed by the five-factor decomposition and discussion of the results.

2 The Technique of Decomposition Analysis

The decomposition of fossil fuel CO_2 emissions into related factors dates back to a series of studies undertaken in the 1980s, mainly at the industry level for a single industrialized country. Kaya (1990) was influential in proposing an identity around which a decomposition of emissions related to four factors could be based:

$$\begin{aligned} CO_2 \text{ emissions from energy} \equiv\ & CO_2 \text{ emissions per unit of energy consumed} \\ & \times \text{ energy consumed per unit of GDP} \\ & \times \text{ GDP per capita} \\ & \times \text{ population} \end{aligned} \tag{1}$$

This has subsequently been expanded:

$$\begin{aligned} CO_2 \text{ emissions from energy} \equiv\ & CO_2 \text{ emissions per unit of fossil fuel consumed} \\ & \times \text{ fossil fuel consumed per unit of energy consumed} \\ & \times \text{ energy consumed per unit of GDP} \\ & \times \text{ GDP per capita} \\ & \times \text{ population} \end{aligned} \tag{2}$$

These identities focus on CO_2 emissions from the combustion of fossil fuels (oil, gas, and coal). Although these are identities that must always be satisfied by the data, and are not based on an estimated model of causal links between the variables, the movements of the components provide an important guide to changes in factors influencing CO_2 emissions from energy use.

Because the variable of interest—emissions from the consumption of energy—is related to the product of several factors, the change in emissions cannot simply be expressed as the sum of absolute changes in the five factors. Various solutions to providing a satisfactory and complete decomposition of the changes in emissions, related to the sum of a measure of changes of the factors, have been reviewed by Ang (2004) and a widely used solution is based on the so called logarithmic mean Divisia index (LMDI 1) as explained by Ang (2005).

According to Lee and Oh (2006), equation (2) can be rewritten as follows:

E = the amount of CO_2 emissions from the consumption of fossil fuel
FEC = the amount of fossil fuel consumption
TEC = the total primary energy consumption
GDP = gross domestic product
POP = population.

Hence, emissions in country i can be expressed as

$$E_i \equiv (E_i / FEC_i) \times (FEC_i / TEC_i) \times (TEC_i / GDP_i) \times (GDP_i / POP_i) \times (POP_i) \quad (3)$$
$$\equiv C_i S_i I_i G_i P_i \quad (4)$$

The change in a country's emissions (ΔE_i) between a base year 0 and an end year T can be decomposed into the effects of (a) the change in C (the emissions per unit of fossil fuel, termed the coefficient effect, C_{eff}) ; (b) the change in S (the share of fossil fuels in total energy, termed the substitution effect, S_{eff}); (c) the change in E (the energy intensity effect, I_{eff}); (d) the change in GDP per capita (G_{eff}); and (e) the change in population (P_{eff}).

$$\Delta E_i \equiv E_i(T) - E_i(0) \equiv C_{eff} + S_{eff} + I_{eff} + G_{eff} + P_{eff} \quad (5)$$

The effects, in turn, can be calculated from the following formula using LMDI[1]:

$$C_{eff} = [E_i(T) - E_i(0)] \times \{ \ln [C_i(T) / C_i(0)] / \ln [E_i(T) / E_i(0)] \} \quad (6)$$

Other effects (S_{eff}, I_{eff}, G_{eff}, P_{eff}) can also be derived from similar formulae.

With data on all the variables for a common base year and terminal year, the decomposition of the change in emissions can be calculated according to equation (6).

The change in emissions will reflect changes in the five factors because of the nature of the identity linking them. To interpret these links, it is necessary to consider the circumstances under which the factors that can be directly influenced by emissions-related policies will change.

The carbon emissions per unit of total fossil fuel consumption will rise if there is a relative shift to higher-emitting fuels (for example, the share of coal rising relative to the share of gas). This could occur even if the total quantity of fossil fuels consumed stayed constant.

The ratio of fossil fuels consumed to total energy consumed will rise if the share of non–fossil fuels (hydro, nuclear, and renewables) falls relative to the share of fossil fuels consumed. The energy intensity of the economy will fall if the use of energy increases more slowly than the level of GDP. This can occur for two main reasons. First, if the sector structure of GDP changes toward sectors that are less energy intensive, without any other changes, the average use of energy in total GDP would fall. Second, if energy efficiency increased in one or more sectors, without any structural shifts, the overall energy intensity would fall. The aggregate form of decomposition analysis used in this paper does not distinguish between these two effects.

The exclusion of the use of biomass fuel outside the power sector limits the generality of analysis, especially because its use varies greatly among countries. However, its omission is unlikely to have a large effect on the current level of total CO_2 emissions because the use of biomass is generally, but not always, carbon neutral. Including biomass consumption outside the power sector would produce an increase in measured energy intensity and decrease the share of fossil fuels in total energy use relative to what is reported in this paper. The differences between the results obtained with and without full inclusion of biomass would obviously depend on the amount of biomass consumed outside the power sector. In the future, if households and small establishments switch from biomass, commercial or otherwise, to fossil fuels and electricity—and households are most certain to do so with increasing income—fossil fuel intensity and CO_2 emissions may both rise more than what might be projected based on past trends.

Note

1. For small changes in the factors, this formula apportions the total change in emissions according to the ratio of the growth rate of each factor to the growth rate of emissions.

3 Previous Studies on the Decomposition of CO_2 Emissions from Fossil Fuels

A large number of studies using decomposition analysis now exist. Those of the greatest interest in relation to this report are ones that make a comparative analysis using several countries, especially those that include a wide range of income levels. Some of the most recent and related studies are briefly mentioned below. These studies do not all use the logarithmic mean Divisia index (LMDI) decomposition but, because the principles are similar in each case, this aspect is not reported.

Ang and Zhang (1999) used the five-factor decomposition for groupings of countries in 1993 to decompose the differences between regions of the emissions from fossil fuel use. The regions included three Organisation for Economic Co-operation and Development groupings, the former Soviet Union and Central and Eastern Europe, and the rest of the world. Differences in GDP and energy intensity were the dominant factors in explaining the large differences found between regions.

Viguier (1999) used a four-factor decomposition for the periods 1980–90 and 1990–94 for six countries (France, Hungary, Poland, the former Soviet Union, the United Kingdom, and the United States). The study covered emissions of NOx (nitrogen oxides) and SO_2 (sulfur dioxide) as well as CO_2. The reduction of emissions intensity in Western countries was accompanied by a reduction in energy intensity, while in the other countries the energy intensity rose. However, changes in fuel mix, especially in the Russian Federation, provided some offset to the increase in energy intensity.

Paul and Bhattacharya (2004) used a four-factor decomposition for the four major sectors (agriculture, industry, residential, and other) for India between 1980 and 1996. They separated the energy intensity effect from a structural effect by analyzing the emissions of each sector and the GDP of each sector. Allowing for this refinement, they showed that the GDP effect was dominant, but that the structural effect was associated with an increase in emissions, as the economy shifted relatively into sectors with higher emissions per unit of GDP. Changes in energy intensity for each sector were of relatively low importance once structural changes had been factored into the decomposition.

Nag and Parikh (2005) analyzed the decomposition of total emissions from the Indian power sector between 1974 and 1998 using a sector-based identity similar to that based at an economy level as explained above in Paul and Bhattacharya (2004). They produced scenarios of emissions until 2015 based on assumptions about changes in the various coefficients identified in the decomposition.

Wang, Chen, and Zou (2005) carried out a five-factor decomposition analysis for China for the periods 1957–79 and 1979–2000. They showed that the change in economic policy in 1979 was associated with a large change in the importance of the different factors, with the reduction in energy intensity after 1979 playing a large role in holding back the growth in emissions.

Lise (2006) used a four-factor decomposition for Turkey for the period 1980–2003. Again this study identified a structural (composition) effect for the changing shares of sectors in GDP. The GDP (scale) effect, structure effect, and carbon-intensity effect (the coefficient effect plus substitution effect) were all associated with substantial increases in emissions, while energy intensity was associated with a small reduction in emissions.

Ebohon and Ikeme (2006) derived a three-factor decomposition for nine non-oil-producing and six oil-producing countries in Africa between 1971 and 1981. The results were very different for oil producers and non–oil producers, with much larger effects observed for non–oil producers. The aggregate results were dominated by Nigeria in the oil-producing group and South Africa in the non-oil-producing group. In both groups several countries experienced a decrease in energy intensity during this period.

Lee and Oh (2006) produced a five-factor decomposition for 15 countries in the Asia Pacific Economic Cooperation region between 1980 and 1998. This group includes high-, middle-, and lower-income representatives. Although GDP and population were strong factors associated with increases in emissions in all cases, in the high-income countries decreases in energy intensity and the share of fossil fuels, and a change in the fossil fuel mix, all contributed to partially offsetting the impacts of growth in the economies. The group of lower income countries was dominated by China, which, in this period, experienced a large drop in energy intensity, offsetting nearly half the impacts of the increase in income and population.

Herzog, Baumert, and Pershing (2006) produced a four-factor decomposition for a selection of eight countries (Brazil, China, France, the Republic of Korea, Thailand, Ukraine, the United Kingdom, and the United States) between 1990 and 2002. In most countries, the changing fuel mix was associated with a reduction in emissions, as was the decline in energy intensity, but GDP and population effects outweighed these in all cases except for the United Kingdom and Ukraine.

Liu and Ang (2007) reviewed a large number of studies using various approaches to decomposition analysis and discussed their strengths and weaknesses. They concluded that recently the LMDI 1 methodology has become the most widely accepted approach.

4 Variables and Data Sources

To undertake a comparative analysis of a large number of countries it is important to work with a common data source for each series that covers all the countries in the sample to ensure that a common methodology has been followed in compiling the data. This may minimize the chance that larger variations between observations are introduced solely because of the use of different assumptions in compiling the data. The period 1994 to 2004 was chosen to permit wide coverage of countries (data coverage is not as full for earlier years) while focusing on the most recent data available for a sufficiently lengthy period to identify important changes in the relationship between emissions and the various factors used. The definitions and sources are explained below.

The Emission of CO_2 from Fossil Fuel Consumption (million metric tons)

The data source for emissions of fossil fuel consumption was the US Department of Energy Web site,[1] produced by the Energy Information Administration (EIA). To arrive at the total emissions from all fossil fuels, it is necessary to aggregate the emissions from the three fuels involved (coal, oil, and natural gas) into common units. This is provided by the EIA through a two stage calculation. First, consumption of each fuel measured in physical units is converted into British thermal units (Btu) as a common energy unit that can be aggregated to provide a measure of total fossil fuel consumption.[2] The second step is to derive emissions of CO_2 for each fossil fuel. Different fuels require an individual conversion factor from energy available to emissions produced, and the conversion factor for coal further depends on the quality of coal consumed. Details of these conversion factors are not provided on the US Department of Energy Web site. Data in million metric tons of CO_2 emitted are provided for a list of 163 countries for every year in our data period and from these, the 70 countries with the largest CO_2 emissions in 2004 were selected for further study.

The Consumption of Fossil Fuels (quadrillion Btu)

The EIA Web site provides consumption data for the three fossil fuels measured in Btu, and these are aggregated to provide total fossil fuel consumption. The ratio of fossil fuel emissions to the consumption of fossil fuels provides the value of C (the fossil fuel coefficient of emissions; see chapter 2).

The Consumption of Primary Commercial Energy (quadrillion Btu)

The EIA figures for the consumption of primary commercial energy includes oil, dry gas, coal, net hydro production, net nuclear production, and renewable sources of electricity supplied to the grid (net geothermal, solar, wind, and wood and waste). It does not include biomass or solar consumed outside of the power sector. The ratio of the consumption of fossil fuels to the total consumption of primary energy provides the value of S (the share of fossil fuels in total energy).

The Level of GDP (2000 US$ at purchasing power parity)

Data on the level of GDP is taken from the World Development Indicators (World Bank various years). The data chosen was in constant 2000 US dollars, valued according to purchasing power parity (PPP). Data valued at market exchange rates (MER) in constant US$ was also investigated. Data valued at MER showed, in virtually every case, the same percentage increase between 1994 and 2004 as the data in PPP. This indicated that for each country, the ratio between exchange rate-based and PPP-based figures was constant throughout this period because of the lack of updating of the PPP calculations. The ranking of countries by energy intensity (energy consumption per unit of GDP) does change markedly when the calculation is shifted from PPP to MER, but this does not affect the decomposition analysis, which focuses on changes in emissions during the period. The ratio of total energy consumption to GDP (I) provides the measure of energy intensity.

The Population of the Country (millions)

Data on population is taken from the UN Population Fund and is based on extrapolations from the most recent census data available. The ratio of GDP to population (G) provides the measure of GDP per capita.

Although the data are taken from well-established sources, where updating and regular publication are observed, there are clearly possibilities of differences between the common source and government statistics. Differences in definition, differences in assumptions about conversion factors to energy equivalents and CO_2 emissions, and lags in publication can all lead to divergences in figures given for the decomposition and in the basic data used. Inferences made about individual country results are limited by the accuracy of the data available. Although it was not possible to undertake a country-by-country cross check on data, this was possible for India as part of the World Bank's India Low Carbon Growth Study, and the results are discussed in appendix 1.

Notes

1. http://www.eia.doe.gov/emeu/international/contents.html
2. For coal, which comes in various qualities ranging from lignite to hard coal, the conversion factor depends strongly on the type and quality of the coal consumed and can be a source of differences among various estimates of emissions.

5 Emissions Levels and Decomposition of Emissions Changes Between 1994 and 2004

This chapter begins with a description of the level of emissions in each country, measured as total emissions, emissions per unit of GDP, and emissions per capita. This is followed by the decomposition of changes in emissions between 1994 and 2004, and then a breakdown of the decomposition into two subperiods, 1994–99 and 1999–2004.

The Level of Emissions

Table 1 shows the level of CO_2 emissions from fossil fuel combustion in 2004 by country, ranked by total emissions. The absolute and percentage changes compared with emissions in 1994 are also shown.

Several features are immediately apparent:

- The majority of countries with the highest levels of emissions in 2004 are high-income, developed countries, but several large developing economies are also in the top 20.
- A notable group of countries that appear in the top 30 emitters are large oil producers, some of which have small populations or relatively low per capita incomes.
- Fifteen countries experienced absolute decreases in emissions during the period; these include several Eastern European and Central Asian countries, whose economies underwent major transformations during the period.
- The percentage growth of emissions between 1994 and 2004 showed considerable variation among countries. Some large emitters saw their total emissions remain essentially the same (the Russian Federation, Germany, and the United Kingdom) while other large emitters experienced substantial growth in emissions (China and India). The group of oil producers also included several with very rapid increases in the level of emissions, with the exception of Nigeria, where emissions actually fell. The top 20 countries ranked by percentage growth in emissions are shown in figure 1. Although this group includes some countries with very low levels of emissions, it also includes several whose levels of emissions are substantial, so that continuation of this trend could move them rapidly up the rankings of emitters. The group of mid-level emitters with rapid growth (such as the Republic of Korea, the Islamic Republic of Iran, Australia, and Saudi Arabia) is of particular interest in this respect.
- The top 70 emitters accounted for 95 percent of global CO_2 emissions from fossil fuels, while the top 30 accounted for 86 percent, and the top 10 accounted for 68 percent. Emissions by country are extremely unequal, with the Gini coefficient for the country level of inequality of CO_2 emissions among the 70 countries being 0.72.[1]
- The selection of a cutoff point at the 70th largest emitter has the effect of omitting countries with less than 20 million metric tons of CO_2 emitted per year. The largest emitter in 2004, the United States, emitted nearly 300 times this level.

To place the country data on the emissions of CO_2 from the commercial use of fossil fuels in the wider context of total GHG emissions, data measured in million tons of CO_2 equivalent in 2000 is available

Table 1. CO_2 Emissions, 2004 (million metric tons)

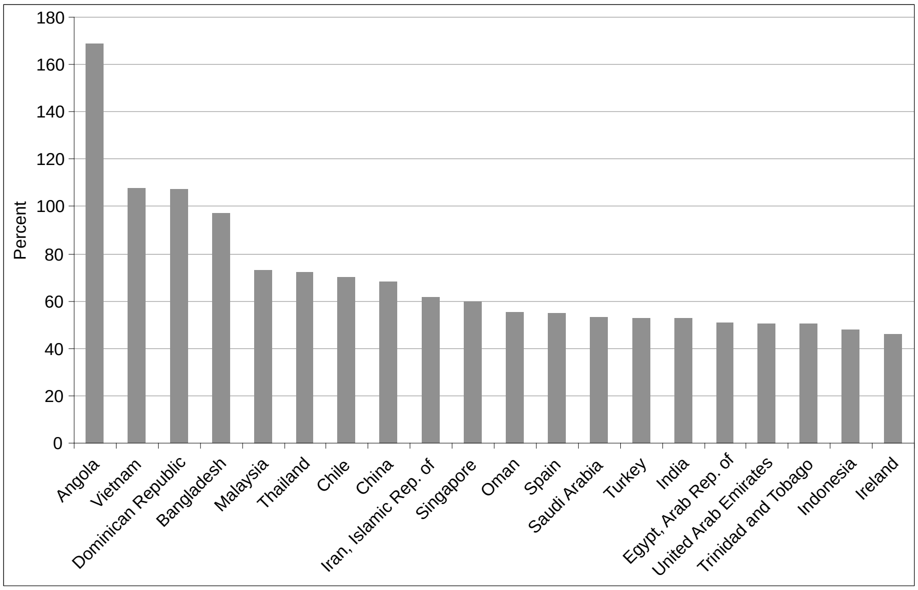
Country	Rank	Emissions in 2004	Increase since 1994	Percent increase since 1994	Country	Rank	Emissions in 2004	Increase since 1994	Percent increase since 1994
United States	1	5,912	674	13	Greece	36	106	22	26
China	2	4,707	1,911	68	Romania	37	95	-21	-18
Russian Fed.	3	1,685	-5	0	Nigeria	38	94	-1	-1
Japan	4	1,262	174	16	Algeria	39	77	-7	-8
India	5	1,113	384	53	Philippines	40	75	22	42
Germany	6	862	-5	-1	Austria	41	70	13	23
Canada	7	588	95	19	Israel	42	66	18	38
United Kingdom	8	580	12	2	Portugal	43	63	17	38
Korea, Rep. of	9	497	143	40	Chile	44	62	26	70
Italy	10	485	85	21	Finland	45	61	4	7
South Africa	11	430	86	25	Sweden	46	59	0	0
France	12	406	46	13	Vietnam	47	57	30	108
Iran, Islamic Rep. of	13	402	153	62	Hungary	48	56	-2	-4
Australia	14	386	107	38	Denmark	49	56	-9	-13
Mexico	15	385	52	15	Belarus	50	55	-10	-16
Saudi Arabia	16	365	127	53	Colombia	51	55	2	4
Ukraine	17	364	-76	-17	Syrian Arab Rep.	52	53	12	29
Spain	18	362	128	55	Norway	53	51	15	43
Brazil	19	337	69	26	Bulgaria	54	47	-3	-7
Indonesia	20	308	99	48	Switzerland	55	45	3	6
Poland	21	288	-32	-10	Ireland	56	42	13	46
Netherlands	22	267	46	21	Slovak Rep.	57	38	-2	-5
Thailand	23	219	92	72	Bangladesh	58	38	19	97
Turkey	24	212	73	53	New Zealand	59	38	7	22
Kazakhstan	25	172	18	12	Azerbaijan	60	37	-9	-20
Malaysia	26	154	65	73	Trinidad and Tobago	61	33	11	50
Belgium	27	148	20	16	Morocco	62	29	2	7
Egypt, Arab Rep. of	28	147	50	51	Peru	63	27	4	19
Venezuela, R. B. de	29	143	24	20	Oman	64	23	8	56
Argentina	30	142	27	23	Bahrain	65	23	7	44
United Arab Emirates	31	141	47	51	Ecuador	66	23	5	27
Singapore	32	129	48	60	Croatia	67	22	4	23
Uzbekistan	33	121	23	24	Tunisia	68	21	5	30
Czech Rep.	34	112	-7	-6	Dominican Rep.	69	20	11	107
Pakistan	35	106	22	26	Angola	70	20	12	169

Source: World Bank calculations.
Note: These numbers are taken from a table posted on the EIA Web site before September 18, 2007. The revised figures for 2004 posted on September 18 differ slightly from those shown in this table.

from the Climate Analysis Indicators Tools database (World Resources Institute 2006). The data on total GHG emissions include the six main gases—CO_2, CH_4 (methane), N_2O (nitrous oxide), PFCs (perfluorocarbons), HFCs (hydrofluorocarbons), and SF_6 (sulfur hexafluoride)—from all sources, including land use changes and international bunkers. Although the derivation of CO_2 emissions from fossil fuel combustion may not be exactly the same as that used by the EIA, and 2000 is the latest year currently available for the range of countries in this study, the ratio of CO_2 emissions from fossil fuel combustion to total GHG emissions (including those from land use change and international bunkers) shown in table 2 indicates the relative importance of fossil fuels globally and in specific countries.

The ratio of fossil fuel CO_2 emissions to total GHG emissions varies substantially among countries, but for the majority in the sample, fossil fuel CO_2 is responsible for more than 50 percent of the total. For certain countries, such as Indonesia and Brazil, where

Figure 1. Top 20 Countries Ranked by Percentage Growth in Emissions Between 1994 and 2004



Source: World Bank calculations.

other sources of GHG emissions are predominant, policies to reduce total emissions need to focus more intensively on non–fossil fuel sources.

A different perspective is provided by tabulating CO_2 emissions per unit of GDP (emissions intensity). Table 3 provides the information based on GDP measured at purchasing power parity (PPP) and at market exchange rates (MER).[2] The values of GDP per capita are also provided, and the list of countries is ranked by emissions per unit of GDP at PPP. Although the correlation between the two measures of GDP per capita is extremely high (R^2 = 0.92), most countries have rather different values on the two measures. For virtually all, the value at PPP is much higher than at MER, while just a few high-income countries have GDP at MER slightly higher than at PPP. Accordingly, emissions per unit of GDP are generally very much lower when measured at PPP. Figure 2 shows a scatter plot of emissions per unit of GDP in 2004 based on the two measures.

The data in table 3 indicate that the ranking of countries according to emissions per unit of GDP at PPP is different from that for total emissions—with some low population countries appearing at the top of the ranking. Oil producers are again well represented in the top group. Among large developing economies, China, and especially India, Brazil, and Mexico, move well down the list. Among high-income countries, the two largest contributors to global CO_2 emissions, the United States and Japan, also move down the list when ranked by emissions per unit of GDP. Higher and lower income countries are scattered throughout the table, suggesting that there is little evidence of a systematic relationship between emissions per unit of GDP and the level of GDP. The relationships between emissions intensity and the measures of GDP per capita are negative—the squared correlation at MER is statistically significant at 21 percent, but that at PPP is statistically insignificant at 4 percent.

Table 2. The Ratio of Fossil Fuel CO_2 Emissions to Total GHG Emissions, 2000

Country	Percent CO_2 from fossil fuel combustion to total GHG emissions	Country	Percent CO_2 from fossil fuel combustion to total GHG emissions
Indonesia	9.3	Oman	66.3
Peru	10.3	Iran	66.5
Malaysia	12.5	Greece	66.8
Angola	13.6	Sweden	68.5
Brazil	13.8	Croatia	68.5
Nigeria	19.1	Denmark	68.9
Ecuador	19.2	South Africa	69.4
Colombia	21.4	Syria	69.7
Bangladesh	23.4	Canada	69.7
Philippines	30.4	Spain	70.0
Pakistan	30.5	Romania	70.1
Singapore	31.5	Belgium	70.2
Venezuela	35.6	France	70.7
New Zealand	38.8	Kazakhstan	71.6
Argentina	39.1	Bulgaria	71.8
Morocco	47.0	Israel	72.0
Thailand	48.8	Hungary	73.1
Tunisia	51.8	Saudi Arabia	73.4
Vietnam	52.0	Azerbaijan	74.2
Chile	53.1	Slovak Republic	75.4
India	**53.7**	Russia	75.8
Turkey	53.8	Trinidad and Tobago	75.9
United Arab Emirates	55.4	Switzerland	76.6
Egypt	57.2	United Kingdom	76.9
Mexico	58.5	Finland	77.1
Dominican Republic	59.0	Portugal	77.2
Ukraine	59.5	Italy	77.8
China	59.5	Austria	78.5
Algeria	60.9	Poland	78.6
Ireland	61.4	Korea, Republic of	79.0
Uzbekistan	63.6	Germany	80.1
Norway	64.4	Czech Republic	82.3
Belarus	64.6	Bahrain	82.5
Netherlands	64.9	Japan	83.3
Australia	65.2	United States	86.8

Source: World Resources Institute 2006.

Table 4 shows emissions per capita for each country in the list and GDP per capita, with countries ranked by emissions per capita. The relationship between these two variables for individual countries over time is explored in the Environmental Kuznets Curve literature where some authors have found an inverted U shape between them, suggesting that initially as income per capita increases, emissions per capita rise, but then as income per capita increases further the level of

Table 3. Emissions per Unit of GDP and GDP per Capita, 2004

Country	Emissions/ GDP (metric tons per million US$, PPP)	Emissions/ GDP (metric tons per million US$, MER)	Per Capita GDP, PPP	Per Capita GDP, MER	Country	Emissions/ GDP (metric tons per million US$, PPP)	Emissions/ GDP (metric tons per million US$, MER)	Per Capita GDP, PPP	Per Capita GDP, MER
Uzbekistan	2,686	7,204	1,712	639	Israel	437	548	22,950	18,319
Trinidad and Tobago	2,054	2,938	12,181	8,516	Croatia	437	973	10,890	4,891
Kazakhstan	1,785	6,309	6,504	1,840	Indonesia	431	1,564	3,245	894
Bahrain	1,749	2,292	18,148	13,852	New Zealand	423	614	22,423	15,425
United Arab Emirates	1,488	1,470	22,135	22,405	Turkey	422	923	6,951	3,175
Ukraine	1,300	8,254	5,949	937	Finland	418	465	28,078	25,239
Russian Fed.	1,298	5,124	9,018	2,285	Germany	403	442	25,905	23,627
Azerbaijan	1,240	4,683	3,551	940	Mexico	402	624	9,061	5,847
Saudi Arabia	1,204	1,698	12,661	8,977	Algeria	392	1,161	6,058	2,046
Singapore	1,202	1,227	25,209	24,689	Chile	378	707	10,168	5,436
Venezuela, R. B. de	995	1,188	5,457	4,568	Hungary	366	1,017	15,228	5,474
South Africa	972	2,821	9,362	3,226	Japan	364	259	27,080	38,041
Belarus	877	3,308	6,425	1,704	India	362	1,887	2,831	542
Iran, Islamic Rep. of	867	3,163	6,738	1,847	Spain	357	552	23,782	15,372
Syrian Arab Rep.	861	2,484	3,304	1,145	Denmark	350	334	29,338	30,685
Bulgaria	799	3,101	7,577	1,953	Pakistan	349	1,235	1,969	556
Nigeria	762	1,663	959	439	Dominican Rep.	341	948	6,786	2,442
Angola	719	1,594	1,772	799	Portugal	332	548	18,278	11,096
Australia	690	848	28,049	22,846	United Kingdom	331	364	29,406	26,741
Oman	663	1,027	13,881	8,961	Italy	326	428	25,641	19,527
China	661	2,745	5,441	1,311	Argentina	316	495	11,750	7,486
Malaysia	658	1,437	9,374	4,296	Ireland	314	359	33,102	28,981
Czech Rep.	638	1,758	17,233	6,251	Norway	307	283	36,234	39,302
Poland	632	1,497	11,797	4,983	Tunisia	290	897	7,170	2,322
Canada	631	747	29,164	24,618	Austria	288	340	29,675	25,087
Netherlands	569	670	28,918	24,560	Vietnam	274	1,394	2,520	496
Romania	569	2,030	7,688	2,154	France	249	287	26,989	23,456
United States	552	552	36,234	36,234	Brazil	247	514	7,406	3,564
Korea, Rep. of	546	810	19,108	12,879	Morocco	243	727	3,875	1,297
Egypt, Arab Rep. of	541	1,286	3,747	1,577	Sweden	232	224	28,226	29,219
Slovak Rep.	536	1,589	13,282	4,479	Philippines	207	836	4,431	1,094
Belgium	499	599	28,437	23,681	Colombia	196	586	6,275	2,099
Greece	476	774	20,077	12,354	Switzerland	194	177	31,958	35,060
Ecuador	463	1,154	3,740	1,501	Peru	194	445	5,122	2,227
Thailand	460	1,457	7,453	2,356	Bangladesh	155	655	1,756	416

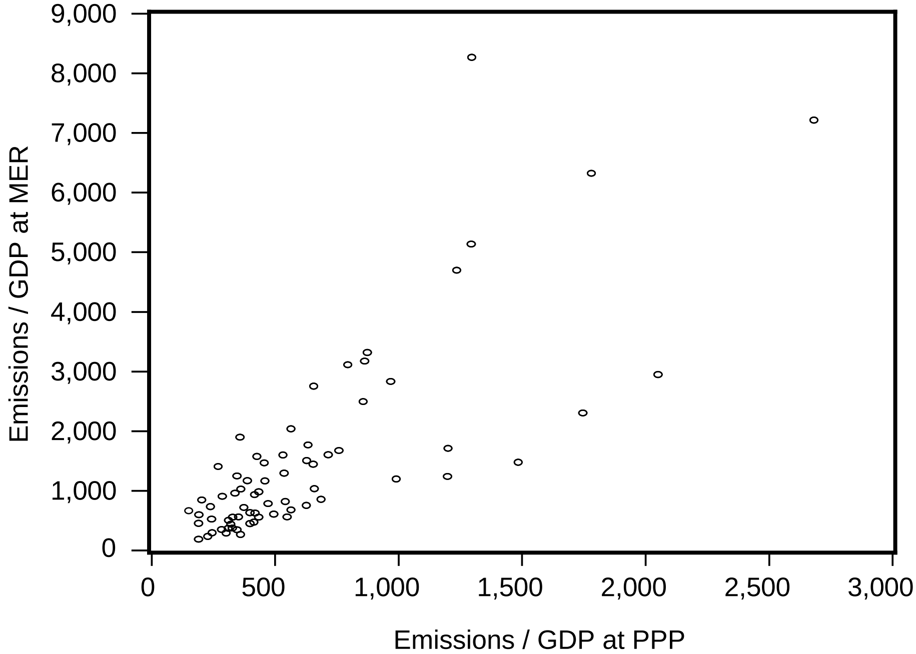
Source: World Bank calculations.

emissions per capita declines. This literature has been reviewed by Stern (2003).

On a per capita basis, a group of low population countries heads the ranking, but the United States also has a high value. China, and especially India and Indonesia, all with very large populations, move toward the bottom of the list. Higher income countries are found predominantly in the top half of the rankings, and lower income countries in the bottom half. The global Gini coefficient for emissions per capita, where all individuals within a country are assumed to share emissions equally, is 0.53. This is almost identical to the measure of inequality of per capita incomes for the same group of countries.

Plots of emissions per capita against income per capita for both PPP and MER measures are shown in figures 3 and 4. The former shows a modest squared correlation of 34 percent between the two series and

Figure 2. Emissions per unit of GDP Measured at PPP and at MER, 2004 (tons per million 2000 US$)



Source: World Bank calculations.

the latter 30 percent, indicating that there is a tendency for CO_2 emissions per capita to increase as GDP per capita increases. From this cross-section data there is little evidence for the downturn of an Environmental Kuznets Curve at higher income levels.

The Decomposition of Emissions Between 1994 and 2004

The decomposition of the change in CO_2 emissions between 1994 and 2004 is presented in table 5, where countries are ranked by decreasing GDP per capita. The decomposition is based on GDP measured in PPP and, as mentioned above, the results are identical for virtually all countries when GDP in MER is used. The table also includes the decomposition for the aggregate of the 70 countries; this can be taken as a close approximation of the decomposition for the global economy.

The pattern of results is fairly consistent across countries during this period:

- At the global level, increases in GDP per capita (Geff) were the largest single factor associated with growth of emissions. Population increases (Peff) were associated with an effect almost half as large as GDP per capita. A large decrease in energy intensity (Ieff) offset 40 percent of the combined effects of these two factors. The effect of the fossil fuel mix (Ceff) was associated with a small decline in aggregate emissions, and the share of fossil fuels in total energy (Seff) with a small increase in total emissions.

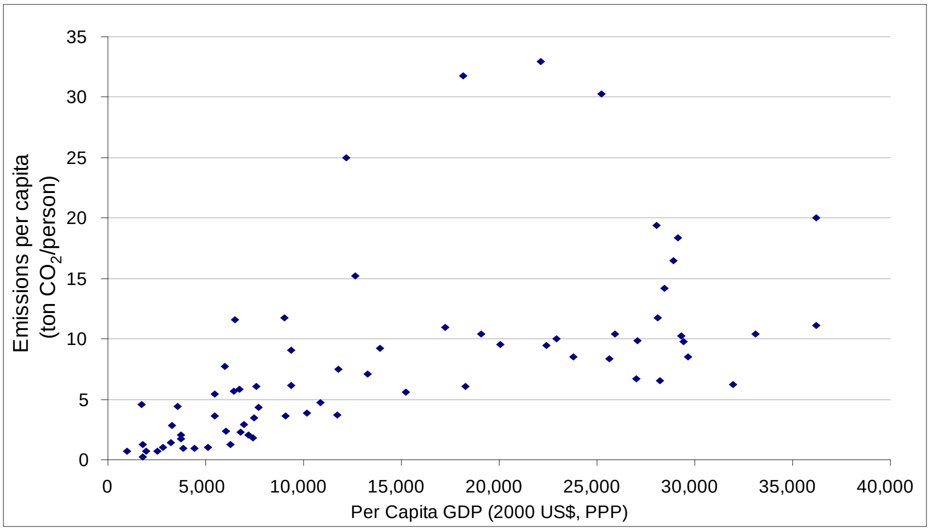
Table 4. Emissions per Capita and GDP per Capita, 2004

Country	Emissions per capita (tons per person)	GDP per capita (2000 US$, PPP)	Country	Emissions per capita (tons per person)	GDP per capita (2000 US$, PPP)
United Arab Emirates	32.94	22,135	Malaysia	6.17	9,374
Bahrain	31.75	18,148	Portugal	6.08	18,278
Singapore	30.30	25,209	Bulgaria	6.06	7,577
Trinidad and Tobago	25.02	12,181	Iran, Islamic Rep. of	5.84	6,738
United States	20.01	36,234	Belarus	5.64	6,425
Australia	19.36	28,049	Hungary	5.57	15,228
Canada	18.40	29,164	Venezuela, R. B. de	5.43	5,457
Netherlands	16.45	28,918	Croatia	4.76	10,890
Saudi Arabia	15.24	12,661	Uzbekistan	4.60	1,712
Belgium	14.20	28,437	Azerbaijan	4.40	3,551
Finland	11.74	28,078	Romania	4.37	7,688
Russian Fed.	11.71	9,018	Chile	3.84	10,168
Kazakhstan	11.61	6,504	Argentina	3.71	11,750
Norway	11.12	36,234	Mexico	3.65	9,061
Czech Rep.	10.99	17,233	China	3.60	5,441
Germany	10.43	25,905	Thailand	3.43	7,453
Korea, Rep. of	10.43	19,108	Turkey	2.93	6,951
Ireland	10.41	33,102	Syrian Arab Rep.	2.85	3,304
Denmark	10.26	29,338	Algeria	2.38	6,058
Israel	10.04	22,950	Dominican Rep.	2.32	6,786
Japan	9.87	27,080	Tunisia	2.08	7,170
United Kingdom	9.75	29,406	Egypt, Arab Rep. of	2.03	3,747
Greece	9.56	20,077	Brazil	1.83	7,406
New Zealand	9.47	22,423	Ecuador	1.73	3,740
Oman	9.20	13,881	Indonesia	1.40	3,245
South Africa	9.10	9,362	Angola	1.27	1,772
Austria	8.54	29,675	Colombia	1.23	6,275
Spain	8.49	23,782	India	1.02	2,831
Italy	8.36	25,641	Peru	0.99	5,122
Ukraine	7.74	5,949	Morocco	0.94	3,875
Poland	7.46	11,797	Philippines	0.92	4,431
Slovak Rep.	7.12	13,282	Nigeria	0.73	959
France	6.73	26,989	Vietnam	0.69	2,520
Sweden	6.56	28,226	Pakistan	0.69	1,969
Switzerland	6.20	31,958	Bangladesh	0.27	1,756

Source: World Bank calculations.

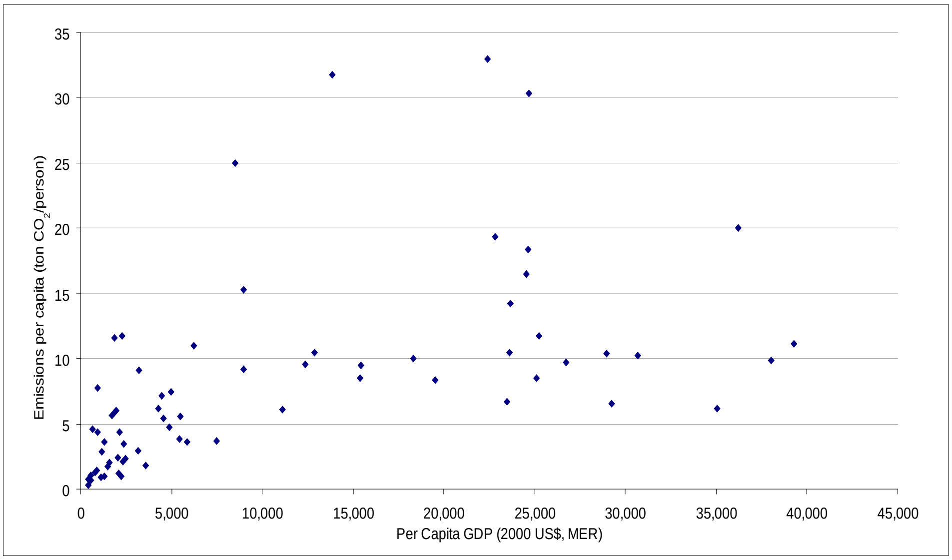
- Fifteen countries experienced an overall decrease in emissions. These countries were predominantly in Eastern Europe and the former Soviet Union.
- Fifty-six countries experienced a negative value for the coefficient effect—that is, the emissions per unit of fossil fuel used declined. This was probably due to a faster increase in the use of gas (especially) and oil than of coal. Nigeria and Brazil are examples where this effect was dominant in the total change of emissions, while Japan was one of the few countries where an increase in this factor was a major contributor to the overall growth in emissions.
- In the majority of countries, the substitution effect (the change in the share of fossil fuels in total energy consumption), whether positive or negative, was small. Norway and Canada experienced increases in the share of fossil fuels in total energy consumed, which made a large contribution to the overall increase of emissions, while Germany and Ukraine experienced declines in the share of fossil fuel that were substantial in relation to the total change in emissions.
- Forty-nine countries experienced a reduction in energy intensity, and in several cases this made a significant contribution in relation to the size

Figure 3. Emissions per Capita and GDP per Capita, PPP, 2004



Source: World Bank calculations.

Figure 4. Emissions per Capita and GDP per Capita, MER, 2004



Source: World Bank calculations.

Table 5. Decomposition of the Change in CO2 Emissions Between 1994 and 2004
(million metric tons)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E	2004 GDP per capita (2000 US$, PPP)
Norway	-2.4	11.6	-6.7	10.3	2.6	15.4	36,234
United States	6.1	14.6	-1,126.1	1,210.7	569.0	674.5	36,234
Ireland	-0.9	-0.2	-12.3	22.3	4.6	13.4	33,102
Switzerland	-0.2	1.3	-4.4	4.2	1.6	2.6	31,958
Austria	0.2	2.0	-3.1	12.5	1.3	13.0	29,675
United Kingdom	-25.5	8.3	-133.7	143.7	19.6	12.4	29,406
Denmark	-1.3	-6.2	-13.5	10.1	2.3	-8.6	29,338
Canada	-9.4	38.6	-109.9	124.1	52.2	95.5	29,164
Netherlands	11.1	-2.9	-21.1	46.0	13.3	46.4	28,918
Belgium	-6.8	-0.2	-2.5	25.6	4.0	20.1	28,437
Sweden	-1.1	-2.3	-13.3	15.2	1.5	-0.1	28,226
Finland	-1.2	-2.5	-13.3	19.3	1.7	4.0	28,078
Australia	6.3	3.3	-22.0	80.7	38.8	107.2	28,049
Japan	41.8	-0.4	0.6	106.1	26.0	174.1	27,080
France	-2.5	-4.1	-32.0	69.9	15.0	46.3	26,989
Germany	-22.2	-23.7	-84.7	111.6	14.1	-4.9	25,905
Italy	-6.6	3.2	20.0	61.6	6.5	84.8	25,641
Singapore	-4.1	0.0	-0.5	28.6	24.4	48.4	25,209
Spain	-4.9	8.7	22.3	82.3	20.2	128.5	23,782
Israel	-1.6	0.2	0.7	5.3	13.5	18.1	22,950
New Zealand	1.7	1.3	-7.2	7.7	3.4	6.9	22,423
United Arab Emirates	-4.6	0.0	-21.6	2.0	71.7	47.4	22,135
Greece	-2.9	-1.8	-8.1	30.3	4.7	22.2	20,077
Korea, Rep. of.	-11.0	-21.9	-28.0	175.9	27.9	142.8	19,108
Portugal	-1.1	1.3	2.6	12.4	2.3	17.4	18,278
Bahrain	-0.3	0.0	-1.7	4.4	4.5	7.0	18,148
Czech Rep.	-6.9	-6.1	-23.2	30.3	-1.2	-7.1	17,233
Hungary	-4.1	0.0	-20.0	23.2	-1.2	-2.1	15,228
Oman	-0.3	0.0	2.0	3.1	3.4	8.3	13,881
Slovak Rep.	-2.8	-1.4	-14.5	16.1	0.4	-2.2	13,282
Saudi Arabia	-6.6	0.0	70.9	-18.7	81.2	126.8	12,661
Trinidad and Tobago	-6.3	0.0	1.5	14.7	1.0	10.9	12,181
Poland	-20.0	1.0	-148.0	134.8	0.2	-31.9	11,797
Argentina	-4.6	2.8	14.4	0.0	14.1	26.6	11,750
Croatia	0.8	0.5	-5.5	8.7	-0.5	4.0	10,890

of the total change in emissions. This group included some high-income countries (notably the United States, the United Kingdom, Canada, and Germany); Russia, Ukraine, and Eastern European countries (Hungary, Poland) benefiting from the restructuring of their economies; and China[3] and India, where substantial contributions from a reduction in energy intensity in relation to the size of the total change in emissions were experienced.

- In several of the oil-producing countries, energy intensity increased during the period, adding to the effects of growth in income and population.
- To understand the decomposition for an individual country, it would be necessary to undertake a more detailed analysis of policy and structural changes during the period. However, the broad patterns established give a guide to the relative importance of the five factors used in the decomposition.

Table 5. Decomposition of the Change in CO_2 Emissions Between 1994 and 2004 (million metric tons) (continued)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E	2004 GDP per capita (2000 US$, PPP)
Chile	-3.5	3.4	3.7	15.8	6.2	25.6	10,168
Malaysia	-5.2	2.7	8.6	31.9	26.8	64.9	9,374
South Africa	-0.3	-1.0	-30.1	62.2	55.0	85.8	9,362
Mexico	-9.5	-4.0	-28.9	40.1	54.1	51.7	9,061
Russian Fed.	-34.5	-17.7	-414.3	514.2	-52.4	-4.6	9,018
Romania	0.3	-7.8	-39.3	30.4	-4.9	-21.3	7,688
Bulgaria	-2.4	-1.6	-8.0	12.1	-3.6	-3.4	7,577
Thailand	-9.7	-0.8	49.7	35.7	16.8	91.8	7,453
Brazil	-27.2	2.0	22.3	27.6	43.9	68.6	7,406
Tunisia	-1.3	-0.1	-2.5	6.4	2.2	4.9	7,170
Turkey	-8.4	2.1	9.7	41.9	27.7	73.0	6,951
Dominican Rep.	0.3	-0.2	3.2	5.1	2.1	10.5	6,786
Iran, Islamic Rep. of	-27.3	1.3	35.2	107.5	36.6	153.1	6,738
Kazakhstan	3.3	2.9	-59.9	84.3	-12.8	17.8	6,504
Belarus	-3.8	-0.1	-34.6	31.0	-2.8	-10.3	6,425
Colombia	-2.1	-0.5	-7.1	2.3	9.3	1.9	6,275
Algeria	-6.7	-0.3	-30.4	18.2	12.4	-6.9	6,058
Ukraine	-11.3	-16.6	-93.0	84.0	-38.8	-75.7	5,949
Venezuela, R. B. de	2.2	-0.2	8.9	-12.3	25.4	24.1	5,457
China	-108.3	-35.8	-1,155.4	2,917.7	293.0	1,911.2	5,441
Peru	-0.1	-1.7	-2.6	4.6	4.1	4.3	5,122
Philippines	-0.3	-1.2	-2.1	13.2	12.5	22.0	4,431
Morocco	-0.9	-0.9	-4.6	3.9	4.4	1.9	3,875
Egypt, Arab Rep. of	-11.4	2.6	5.8	29.8	22.9	49.7	3,747
Ecuador	0.6	0.2	-1.4	2.3	3.1	4.7	3,740
Azerbaijan	-1.7	-1.1	-31.4	21.8	3.4	-9.0	3,551
Syrian Arab Rep.	-1.2	0.7	-2.3	2.6	12.0	11.9	3,304
Indonesia	-1.6	-3.3	30.1	40.6	33.6	99.4	3,245
India	-31.7	20.0	-152.4	394.4	153.2	383.6	2,831
Vietnam	-5.9	1.4	5.5	22.9	5.9	29.8	2,520
Pakistan	-3.7	1.0	-10.4	13.3	21.7	22.0	1,969
Angola	5.4	0.2	-2.2	5.7	3.3	12.4	1,772
Bangladesh	0.2	0.2	4.2	8.5	5.5	18.7	1,756
Uzbekistan	-3.9	1.2	-14.7	24.1	16.7	23.3	1,712
Nigeria	-29.8	-0.5	-6.6	13.3	22.7	-1.0	959
Aggregate	**-156.4**	**150.4**	**-3,389.3**	**5,735.0**	**2,664.6**	**5,004.3**	**9,099**

Source: World Bank calculations.
Note: See the discussion of equation (5) in chapter 2 for definitions of the decomposition factors.

One useful way to summarize the decomposition analysis is to compare the impacts from income and population growth, which are virtually always positive,[4] and are outside direct interventions that might have been expected to moderate emissions, and the three other factors, which had the potential through policy interventions to reduce emissions. To this end, an "offsetting" coefficient is defined:

Offsetting coefficient = - [sum of changes from emissions per unit of fossil fuel, fossil fuel consumption relative to total energy consumption, and energy intensity of GDP] / [changes from GDP per capita and population] (7)

A score of 100 percent indicates that the total increase in emissions attributed to GDP per capita growth and population growth was exactly offset by improvements in the three other factors. A negative score indicates that emissions increased faster than would have been accounted for by the growth of GDP and population.

For the aggregate of 70 countries, 40 percent of the potential growth in emissions from GDP and population growth was offset by the three factors. For individual countries, the offsetting coefficients, ranked by size of coefficient, are shown in table 6.

Table 6. Offsetting Coefficients for Decomposition of Emissions, 1994–2004

Country	Offsetting coefficient	Country	Offsetting coefficient
Ukraine	267.4	Belgium	32.0
Romania	183.6	Trinidad and Tobago	30.4
Denmark	169.1	India	30.0
Bulgaria	140.3	Korea, Rep. of	29.9
Belarus	136.4	South Africa	26.8
Azerbaijan	135.5	Netherlands	21.7
Czech Republic	124.4	Bahrain	21.5
Poland	123.7	Syrian Arab Rep.	19.0
Algeria	122.6	Philippines	14.2
Slovak Republic	113.5	Ecuador	12.4
Hungary	109.5	Australia	10.3
Germany	103.9	Singapore	8.8
Nigeria	102.7	Austria	6.0
Russian Fed.	101.0	Egypt, Arab Rep. of	5.7
Sweden	100.4	Brazil	4.0
United Kingdom	92.4	Israel	3.5
Colombia	83.6	Vietnam	-3.3
Finland	80.7	Turkey	-4.9
Morocco	77.3	Iran, Islamic Rep. of	-6.3
Kazakhstan	75.0	Malaysia	-10.5
United States	62.1	Chile	-16.2
Switzerland	56.7	Portugal	-18.6
Croatia	51.5	Norway	-19.5
Peru	50.6	Italy	-24.4
Ireland	50.2	Spain	-25.4
Canada	45.8	Oman	-26.9
France	45.5	Japan	-31.9
Mexico	45.1	Bangladesh	-33.2
Tunisia	43.8	Indonesia	-33.9
Uzbekistan	42.8	Angola	-38.6
China	40.5	Dominican Republic	-45.6
New Zealand	37.9	Thailand	-74.6
Pakistan	37.1	Venezuela, R. B. de	-83.8
Greece	36.5	Argentina	-89.8
United Arab Emirates	35.7	Saudi Arabia	-102.8

Source: World Bank calculations.

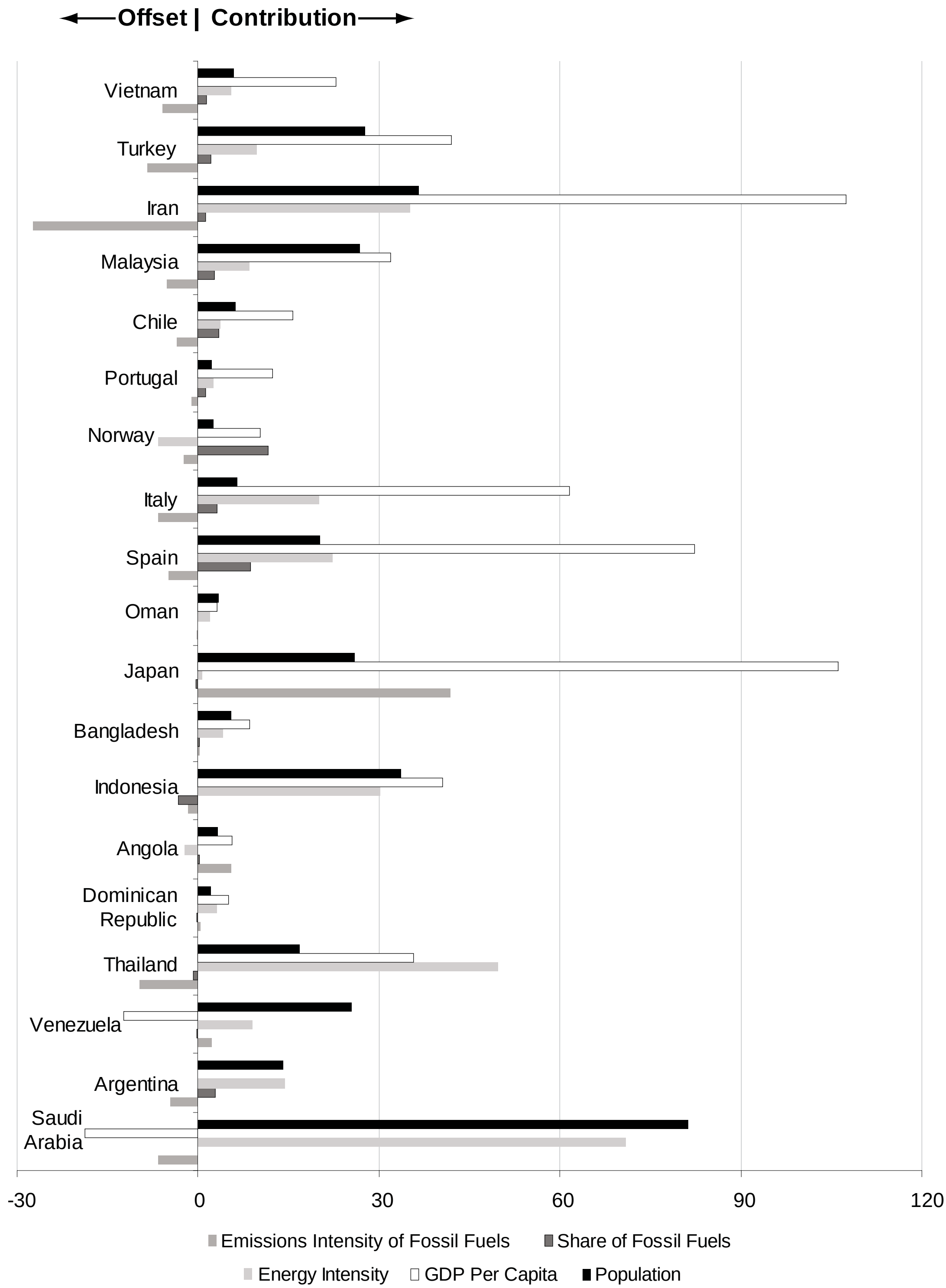
The table of offsetting coefficients highlights a number of features:

- The range of offsetting experienced during the period was wide, with 15 countries more than fully offsetting the potential increase in emissions from income and population growth. A group of 19 countries experienced "negative offsetting" in that movements in the three factors (emissions per unit of fossil fuel, fossil fuel consumption relative to total energy consumption, and energy intensity of GDP) added to the increase in emissions from income and population growth.
- The group of countries with full offsetting included several Eastern European and former Soviet Union countries, where massive changes in sector structure may have been responsible for shifting the economies to lower energy intensity. However, it also included Denmark and Sweden, where market forces alone would have been unlikely to bring about large-scale sectoral adjustment and improvements in energy efficiency. The detailed routes by which Denmark and Sweden achieved this performance may be instructive for other high-income countries considering how to reduce the total level of their CO_2 emissions. The group also included Algeria and Nigeria, both of which are major hydrocarbon producers. Algeria experienced a major decline in energy intensity, while Nigeria experienced a large drop in emissions per unit of fossil fuel consumed.
- The group of countries with negative offsetting are mixed in type, including high-income developed countries such as Japan, Italy, and Spain; several oil producers (including Saudi Arabia, Indonesia, and República Bolivariana de Venezuela) that may have adopted very energy-intensive growth strategies; and some low-income countries (Dominican Republic, Bangladesh). There does not appear to be a common link between these countries, except for the group of oil producers, and country-level studies would be needed to understand the causes of their performance. The components of the decomposition for the group of countries with negative offsetting are shown in figure 5.
- Among countries with the largest absolute emissions, the United States was able to offset a sizeable fraction of its growth in emissions but, given the size of the economy, the increment was still large. By contrast, Japan, with relatively low income and population growth, experienced negative offsetting, but the total increment was relatively small. Russia fully offset the growth in emissions related to income and population but, given that population decline and massive changes in sectoral structure and energy efficiency were stimulated by the political changes during this period, a similar performance may be difficult to maintain in the coming decade. China and India, while enjoying rapid growth during the decade, were also able to offset significant portions of the potential growth in emissions.
- Looking across the list of countries as a whole, it is noticeable that the offsetting coefficient is not correlated with income levels. Although high-income countries may have been best able to carry out policies that would have reduced emissions growth, it does not appear that during the decade studied there was a systematic worldwide link between the degree of offsetting and the level of per capita income.

The Changing Pattern of Decomposition Between 1994 and 2004

Many economies experienced important changes during the decade analyzed, particularly those of Eastern Europe and the former Soviet Union where the first years overlapped or immediately succeeded important political changes. In addition, the increasing price of oil and other fossil fuels, as well as heightened awareness of global warming, may have led more recently to intensification of policies to slow the growth of emissions. By splitting the data into two subperiods of equal duration, some important shifts in behavior can be detected. The offsetting coefficient and changes

Figure 5. Decomposition for "Negative Offsetting" Countries, 1994–2004



Source: World Bank calculations.

in emissions for the two subperiods, ranked by the magnitude of offsetting coefficients for the whole period, are shown in table 7. The detailed tables for the decompositions during the two subperiods are given in appendix 2.

Table 7. Offsetting Coefficients and Changes in Emissions, 1994–99 and 1999–2004

Country	Δ E (1994-99)	Offsetting coefficient (1994–99)	Δ E (1999-2004)	Offsetting coefficient (1999–2004)
Ukraine	-115.4	-6.1	39.7	71.1
Romania	-25.3	-1,461.9	4.0	83.5
Denmark	-7.0	185.2	-1.6	138.7
Bulgaria	-6.3	-101.4	2.9	73.6
Belarus	-7.8	191.0	-2.4	113.1
Azerbaijan	2.8	46.0	-11.8	155.2
Czech Rep.	-15.9	249.5	8.8	47.5
Poland	4.7	94.9	-36.7	177.1
Algeria	0.3	97.6	-7.2	142.7
Slovak Rep.	-2.9	133.4	0.6	91.8
Hungary	-0.9	109.4	-1.2	109.5
Germany	-35.6	148.5	30.7	38.4
Nigeria	-10.4	194.5	9.5	58.9
Russian Fed.	-153.1	-65.1	148.4	72.2
Sweden	-1.1	111.8	1.0	86.4
United Kingdom	-17.1	120.6	29.5	61.9
Colombia	3.9	-3.3	-1.9	123.5
Finland	-9.9	188.9	13.9	-83.4
Morocco	3.0	-6.1	-1.1	118.6
Kazakhstan	-23.3	-190.9	41.2	44.8
United States	419.2	59.8	255.2	65.5
Switzerland	3.2	-7.4	-0.7	122.7
Croatia	2.3	40.3	1.7	62.2
Peru	3.4	22.4	0.9	79.7
Ireland	9.1	41.4	4.3	64.1
Canada	65.9	30.0	29.5	65.1
France	41.5	9.2	4.8	88.4
Mexico	26.7	43.9	25.0	46.3
Tunisia	3.0	31.3	1.9	57.9
Uzbekistan	5.2	63.6	18.1	30.1
China	105.4	91.5	1,805.9	-10.2
New Zealand	3.2	32.8	3.7	42.0

Table 7. Offsetting Coefficients and Changes in Emissions, 1994–99 and 1999–2004 (continued)

Country	Δ E (1994-99)	Offsetting coefficients (1994–99)	Δ E (1999-2004)	Offsetting coefficients (1999–2004)
Pakistan	18.4	-18.5	3.6	83.1
Greece	10.8	17.5	11.4	49.0
United Arab Emirates	23.8	19.3	23.6	48.6
Belgium	10.5	32.2	9.6	31.7
Trinidad and Tobago	4.5	15.0	6.4	39.8
India	205.6	21.4	178.0	39.4
Korea, Rep. of	72.2	15.8	70.6	41.7
South Africa	24.7	45.4	61.1	13.4
Netherlands	15.8	61.5	30.6	-88.5
Bahrain	4.4	-24.2	2.6	55.1
Syrian Arab Rep.	9.4	-45.3	2.4	72.3
Philippines	16.0	-47.2	6.0	63.2
Ecuador	1.6	-128.7	3.2	34.7
Australia	71.8	-7.9	35.4	36.1
Singapore	22.8	14.2	25.6	1.8
Austria	6.7	14.8	6.3	-6.9
Egypt, Arab Rep. of	16.8	35.5	32.9	-32.9
Brazil	65.5	-100.1	3.1	92.9
Israel	11.4	-0.6	6.7	10.9
Vietnam	13.4	-9.2	16.4	2.8
Turkey	41.3	-35.7	31.8	23.0
Iran, Islamic Rep. of	66.1	-35.3	87.0	11.9
Malaysia	16.9	28.3	48.0	-47.6
Chile	22.5	-84.6	3.0	74.4
Portugal	16.8	-52.6	0.6	85.3
Norway	7.9	-4.0	7.5	-46.9
Italy	36.7	-0.7	48.1	-55.2
Spain	62.5	-32.4	66.0	-18.1
Oman	5.4	-91.3	2.9	29.2
Japan	61.4	-44.2	112.7	-25.5
Bangladesh	7.5	-34.6	11.2	-31.9
Indonesia	55.1	-248.1	44.3	30.5
Angola	6.1	-59.3	6.3	-15.1
Dominican Rep	4.4	-8.9	6.1	-125.4
Thailand	43.2	-355.2	48.6	-1.6
Venezuela, R. B. de	13.7	-174.6	10.4	-24.2
Argentina	23.5	-73.8	3.1	-704.4
Saudi Arabia	23.7	-61.7	103.1	-118.6

For a number of countries, the degree of offsetting is substantially different between the two periods indicating that significant structural changes took place between the two subperiods:

- For a small group of countries (Ukraine, Romania, Bulgaria, Russia, and Kazakhstan) the apparent negative offsetting in the first subperiod occurred because the net effect of GDP and population changes reduced emissions, and the three policy-related factors were making a further contribution to reducing emissions in that period. In the second subperiod, no country experienced negative GDP growth. The very large offsetting coefficient for Romania in the second subperiod was caused by the very small size of the denominator, indicating the slight decrease in emissions that could be related to the change in GDP.
- For a large number of countries, similar offsetting coefficients were experienced, indicating that

the balance of factors did not change markedly between the two periods.

- For a third group of countries, the offsetting coefficient increased substantially, indicating a move toward slowing down the growth or even reducing the level of emissions relative to the growth of GDP and population. This group of countries includes a number of lower income countries that experienced negative offsetting during the first subperiod, but moved to partial positive offsetting in the second period. This latter group consists of Pakistan, Syria, the Philippines, Ecuador, Australia, Brazil, Turkey, the Islamic Republic of Iran, and Indonesia.
- A group of 13 countries experienced negative offsetting in both subperiods. In addition to some large oil producers (Norway, Angola, República Bolivariana de Venezuela, and Saudi Arabia), the group includes some high-income, non-oil producers (Italy, Spain, and Japan).
- Six countries moved from partial positive offsetting in the first subperiod to negative offsetting in the second subperiod, indicating that the policy-related factors had ameliorated the effects of growth earlier, but added to it in the latter period. This group includes Colombia, China, the Netherlands, Austria, Egypt, and Malaysia.

The experience of countries with the largest absolute emissions during the two subperiods was quite different. The United States experienced growth in emissions during both periods, but in both offset a substantial fraction of the effects of the growth in income. China experienced little growth in emissions in the first subperiod, partly thanks to high offsetting, but in the second subperiod experienced a very large growth in emissions, when the effects of very rapid growth were slightly compounded by negative offsetting. Japan experienced modest increases in emissions during both periods, partly related to negative offsetting in both. Russia experienced a substantial decline in emissions during the first period, but then experienced a sizeable growth in emissions during the second period, despite a high degree of offsetting. Finally, India experienced similar growth of emissions during the two subperiods, with the slightly lower increase in the second period being associated with higher offsetting.

Notes

1. More detailed analysis of the inequality of CO_2 emissions among countries is given by Heil and Wodon (2000) and Duro and Padilla (2006).
2. The choice between using GDP at MER and PPP to calculate emissions intensity is discussed by Stern (2006) and by Holtsmark and Alfsen (2004).
3. The very large fluctuation in China's energy intensity, which declined until 2002 but then started to increase, has been the stimulus for a detailed analysis of changes in the country's economic structure. See Ma and Stern (2006); Liao, Fan, and Wei (2007); and Hoffman and Labar (2007).
4. The exceptions are Saudi Arabia, where per capita income fell during the period, and Russia and other countries in the former Soviet Union and Eastern Europe, where changed political boundaries led to declines in population.

6 Conclusions

The report focuses on the 70 top ranking countries based on CO_2 emissions from fossil fuels in 2004, covering 95 percent of the global total CO_2 emissions. The top 20 contributors to global CO_2 emissions from fossil fuels were mainly drawn from higher income developed countries, but they also included several large developing economies. In addition, several large oil-producing countries were in the top 30. During the period 1994–2004, some 15 countries experienced a decline in emissions; this group comprised mainly former Soviet Union and Eastern European countries that had undergone major structural change during the period. The percentage growth in emissions during the decade showed considerable variation among countries, with some large emitters experiencing significant growth, and others relatively low growth. The degree of inequality between countries with respect to total CO_2 emissions is extremely high, with a Gini coefficient of 0.72.

The intercountry distribution of emissions per unit of GDP (emissions intensity) was measured using GDP at purchasing power parity and at market exchange rates. The emissions intensity for most countries was very much lower using the former measure. The ranking of countries by emissions intensity also changed substantially relative to the ranking by total emissions. Emissions intensity was not systematically related to GDP per capita.

The ranking of countries by emissions intensity changed substantially relative to the ranking by total CO_2 emissions. Among large developing economies, Brazil, India, and Mexico ranked much lower on emissions intensity than on total emissions among the group of 70 countries studied. Several middle-income countries were among those with the highest rankings of emissions intensity.

Emissions per capita were positively but only moderately correlated with GDP per capita and showed no evidence of an eventual decline in emissions per capita at higher per capita income (the Environmental Kuznets Curve phenomenon). The global per capita measure of inequality of emissions was much lower than that for the country level inequality, and was very similar to the measure of income inequality. Some countries with large populations, such as India and Indonesia, moved almost to the bottom of the ranking based on this measure.

The decomposition analysis related the change in emissions during the decade to changes in five factors (emissions per unit of fossil fuel, fossil fuel consumption relative to total energy consumption, energy intensity of GDP, GDP per capita, and population). For the group of countries as a whole, GDP per capita was the dominant variable linked to the growth in total emissions, with population being only one-half as important. However, the decrease in energy intensity was so large that it offset about 40 percent of the combined influence of these two factors. The fossil fuel mix showed a small negative effect on the change in emissions, while the share of fossil fuels in total energy consumption contributed a small increase to the change in emissions.

The relative importance of the three factors that could be directly linked to policies to slow down the growth of emissions (fossil fuel mix, share of fossil fuels in total energy, and energy intensity of GDP) to the positive effects of GDP growth is measured by the "offsetting" coefficient. For the decade as a whole, 15 countries more than offset the combined impacts of GDP and population growth. This group consisted mainly of former Soviet Union and Eastern European countries, but also included two Scandinavian countries, whose policies toward emissions may give important clues for other countries wanting to slow the growth of emissions. There were also 19 countries where the potential offsetting factors actually led to a further increase in emissions beyond that which would have been expected from the growth of GDP ("negative offsetting"). The group included several oil producers, but also some non-oil-producing, high-income developed countries. Two developing countries with the largest populations and CO_2 emissions, China and India, had offsetting coefficients near the global average for the period.

When the data was split into two five-year subperiods it become apparent that for some countries large changes had taken place in the course of the decade. For one group of countries the offsetting coefficient increased substantially; this group included several developing countries. An important group of 13 countries experienced negative offsetting in both subperiods, indicating that this was a longer term trend; the group included some major oil producers, and some high-income, non-oil-producing countries. Six countries moved from positive to negative offsetting between the two subperiods, indicating that they had actually seen emissions rise faster relative to GDP. The experiences of countries with the largest absolute emissions across the two subperiods were quite different. The United States and India both experienced substantial offsetting throughout the entire period, while China and the Russian Federation both experienced high offsetting in the first period, but much reduced offsetting in the second. For the group as a whole there was no apparent correlation between the improvement in offsetting and the level of GDP, indicating that during the period studied higher income countries had not performed better in slowing the growth of emissions relative to GDP.

However, several countries did experience improved performance of emissions relative to GDP, suggesting that there need not be a negative trade-off between slowing the growth of emissions and maintaining high growth rates of the economy. Countries that were particularly successful in achieving high offsetting could well serve as case studies for how this might be achieved. However, the experience of several countries also makes it clear that, without active policies to curb the emissions intensity of the economy, emissions can actually increase faster than GDP, even when GDP has reached a high level. Additional and more detailed analysis could shed further light on the factors determining aggregate energy intensity for an economy, because this factor appears to have accounted for the largest differences in performance between economies, once the growth of GDP is allowed for. In particular, the distinction between changes resulting from sectoral composition and energy efficiency may be helpful in giving clues about the future course of emissions, and the possibilities of finding policies that could make a substantial difference to global CO_2 emissions.

The magnitude of the decline in energy intensity in many countries suggests that further work to understand why this has happened would be important. In particular, a further decomposition into changes in sector structure (the shares of agriculture, manufacturing, and services) and changes in energy intensity at sector levels would provide information on the extent to which changes in the sector mix that are related to economic growth and development have been responsible for changes in overall emissions.

Appendix 1—
Decomposition of CO_2 Emissions for India Comparing EIA and Government of India Data

As part of the India Low Carbon Growth Study, a separate exercise on CO_2 emissions data was carried out using the most recent data on fuel use and emissions provided by the government of India. These data can be taken as the most authoritative currently available, and provide a useful comparison with that published by the Energy Information Administration (EIA) in June 2006, which was based on earlier published government sources. The data from the government of India takes account of the specific quality of the fuels consumed, which is reflected in the thermal content and in the emissions per physical unit. Data on GDP at 2000 US$ in PPP continued to be taken from the World Development Indicators (WDI; World Bank various years), as the sole source for comparable PPP data; population data continued to be taken from UN Population Fund (UNFPA) as the most widely used estimate of population between censuses. Data from the two sources is shown to illustrate the sources of differences, and these are then used to provide alternative decompositions.

Consumption of Fossil Fuel Data in Physical Units

Energy source	EIA 1994	Government of India 1994	EIA 2004	Government of India 2004
Petroleum (thousand barrels a day)	1,413	1,412	2,450	2,419
Dry gas (billion cubic feet)	594	612	1,088	1,185
Coal (million short tons)	314	261	478	397

Consumption of Energy in Thermal Units (quadrillion British thermal units)

Energy source	EIA 1994	Government of India 1994	EIA 2004	Government of India 2004
Petroleum	2.94	2.88	5.02	4.92
Dry gas	0.68	0.62	1.13	1.26
Coal	5.45	5.05	8.11	7.19
All primary energy including nonfossil fuels	9.97	8.89	15.42	13.84

Emission of CO_2 from Fossil Fuel Consumption (million metric tons)

Energy source	EIA 1994	Government of India 1994	EIA 2004	Government of India 2004
Petroleum	193	200	306	342
Dry gas	36	33	64	67
Coal	497	461	741	656
All fossil fuels including gas flaring	729	693	1,113	1,064

Gross Domestic Product (billion 2000 US$ at PPP)

	WDI 1994	WDI 2004
GDP	323	590

Population (millions)

	UNFPA 1994	UNFPA 2004
Population	918	1,087

Decomposition of Changes in Emissions Between 1994 and 2004 (million metric tons)

Source	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E
EIA data	-31.7	20.0	-152.4	394.4	153.2	383.6
Government of India data	-15.9	3.9	-139.1	376.0	146.0	371.0

The comparison of the EIA data and the recent government of India data shows some important differences, particularly with respect to the consumption of coal, where the government figures show lower total consumption and lower emissions. As a result, the total levels of CO_2 emissions in 1994 and in 2004 are about 5 percent lower than those given by the EIA. Thus, the change in emissions to be used in the decomposition analysis is slightly lower. The shares of the five factors do change but the main conclusions about the relative importance of the different factors are similar.

Appendix 2 —
Decomposition of Emissions During Subperiods

Decomposition of Emissions Between 1994 and 1999 (million metric tons)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E
Norway	0.0	3.3	-3.1	6.3	1.3	7.9
United States	-3.2	-19.2	-601.2	753.6	289.4	419.2
Ireland	-0.6	0.1	-5.8	14.0	1.5	9.1
Switzerland	-0.3	0.9	-0.3	2.0	1.0	3.2
Austria	0.3	-0.3	-1.2	7.2	0.7	6.7
United Kingdom	-26.0	-4.1	-69.5	73.1	9.5	-17.1
Denmark	-5.4	-2.6	-7.3	7.0	1.3	-7.0
Canada	-3.4	31.5	-56.4	69.6	24.6	65.9
Netherlands	7.1	-2.5	-29.8	34.3	6.6	15.8
Belgium	-5.8	-0.9	1.7	13.3	2.2	10.5
Sweden	-0.4	-3.1	-6.6	8.6	0.5	-1.1
Finland	-6.3	-4.8	-10.0	10.3	0.8	-9.9
Australia	4.5	2.3	-1.6	47.3	19.2	71.8
Japan	-10.9	-23.7	53.5	28.0	14.5	61.4
France	-0.5	7.5	-11.2	38.4	7.3	41.5
Germany	-28.1	-13.3	-67.6	63.5	9.9	-35.6
Italy	-10.4	1.0	9.6	33.1	3.3	36.7
Singapore	0.7	0.0	-4.4	12.6	13.9	22.8
Spain	-3.4	10.3	8.4	43.1	4.1	62.5
Israel	-0.4	0.2	0.3	4.1	7.2	11.4
New Zealand	-0.2	1.7	-3.1	3.2	1.5	3.2
United Arab Emirates	0.3	0.0	-6.0	0.5	29.0	23.8
Greece	-1.6	-1.2	0.5	10.0	3.0	10.8
Korea, Rep. of	-5.8	-16.5	8.8	69.6	16.1	72.2
Portugal	-0.1	4.1	1.8	10.1	0.9	16.8
Bahrain	0.3	0.0	0.6	0.9	2.7	4.4
Czech Rep.	-6.9	-0.3	-19.3	11.2	-0.5	-15.9
Hungary	-2.3	0.3	-8.2	9.8	-0.5	-0.9
Oman	1.2	0.0	1.4	0.6	2.3	5.4
Slovak Rep.	-4.4	0.4	-7.4	8.2	0.4	-2.9
Saudi Arabia	-17.7	0.0	26.7	-19.5	34.1	23.7
Trinidad and Tobago	-1.4	0.0	0.6	4.7	0.5	4.5
Poland	-9.2	0.2	-79.5	92.2	1.0	4.7
Argentina	-2.3	6.4	5.9	5.9	7.6	23.5
Croatia	0.7	-0.3	-1.9	4.4	-0.5	2.3

Decomposition of Emissions Between 1994 and 1999 (million metric tons) (continued)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E
Chile	-0.5	6.6	4.2	8.8	3.4	22.5
Malaysia	-2.8	0.3	-4.2	11.4	12.1	16.9
South Africa	-0.6	-3.1	-16.9	11.4	33.9	24.7
Mexico	5.2	-10.1	-16.1	19.4	28.2	26.7
Russian Fed.	-8.6	-17.3	-34.5	-77.3	-15.4	-153.1
Romania	-0.1	-9.0	-14.6	1.1	-2.8	-25.3
Bulgaria	0.1	-2.7	-0.7	-1.3	-1.9	-6.3
Thailand	-0.8	0.9	33.5	1.5	8.0	43.2
Brazil	-4.7	4.2	33.3	10.3	22.4	65.5
Tunisia	-0.4	0.0	-0.9	3.2	1.2	3.0
Turkey	-3.5	2.9	11.5	16.5	13.9	41.3
Dominican Rep.	-0.1	-0.2	0.6	3.2	0.9	4.4
Iran, Islamic Rep. of	-13.2	3.0	27.4	29.8	19.1	66.1
Kazakhstan	2.0	2.1	-19.5	0.1	-8.1	-23.3
Belarus	-1.8	-0.8	-13.8	9.8	-1.2	-7.8
Colombia	-0.9	0.8	0.2	-1.3	5.0	3.9
Algeria	-0.3	-0.3	-13.3	7.6	6.7	0.3
Ukraine	-9.1	-16.1	18.5	-93.0	-15.7	-115.4
Venezuela, R. B. de	1.0	-1.6	9.3	-7.8	12.8	13.7
China	-102.7	-23.9	-1,010.1	1,111.9	130.2	105.4
Peru	0.2	0.0	-1.2	2.2	2.1	3.4
Philippines	0.7	-2.6	7.0	4.6	6.3	16.0
Morocco	0.1	0.1	0.0	0.5	2.3	3.0
Egypt, Arab Rep. of	-2.5	-1.3	-5.4	16.1	9.9	16.8
Ecuador	0.4	-0.1	0.5	-0.8	1.5	1.6
Azerbaijan	17.3	-0.3	-19.4	2.8	2.4	2.8
Syrian Arab Rep.	-0.1	0.4	2.6	0.5	6.0	9.4
Indonesia	4.0	-2.9	38.1	-0.2	16.0	55.1
India	-13.7	13.0	-55.2	187.4	74.0	205.6
Vietnam	-3.2	0.7	3.6	9.7	2.6	13.4
Pakistan	-0.1	4.9	-1.9	4.0	11.6	18.4
Angola	4.6	0.2	-2.5	2.6	1.2	6.1
Bangladesh	0.1	0.2	1.6	3.2	2.4	7.5
Uzbekistan	-2.2	1.1	-7.9	6.2	8.1	5.2
Nigeria	-19.0	0.0	-2.5	-0.3	11.3	-10.4

Source: World Bank calculations.

Decomposition of Emissions Between 1999 and 2004 (million metric tons)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E
Norway	-2.7	8.8	-3.7	3.8	1.3	7.5
United States	9.8	35.6	-531.0	457.1	283.7	255.2
Ireland	-0.3	-0.3	-7.0	8.5	3.4	4.3
Switzerland	0.1	0.4	-4.2	2.4	0.6	-0.7
Austria	-0.1	2.5	-2.0	5.3	0.7	6.3
United Kingdom	1.2	12.3	-61.4	67.7	9.7	29.5
Denmark	3.8	-3.4	-6.0	3.0	1.0	-1.6
Canada	-6.3	6.6	-55.3	55.9	28.6	29.5
Netherlands	3.7	-0.2	10.9	9.8	6.5	30.6
Belgium	-0.8	0.8	-4.4	12.2	1.7	9.6
Sweden	-0.7	0.9	-6.5	6.5	0.9	1.0
Finland	5.4	2.7	-1.8	6.9	0.7	13.9
Australia	1.8	1.0	-22.7	34.5	20.8	35.4
Japan	54.7	25.2	-57.0	78.7	11.0	112.7
France	-2.1	-12.3	-21.9	33.0	8.1	4.8
Germany	6.3	-9.9	-15.5	45.9	3.9	30.7
Italy	4.6	2.2	10.3	27.9	3.2	48.1
Singapore	-5.5	0.0	5.0	16.2	9.9	25.6
Spain	-1.2	-3.1	14.5	38.4	17.5	66.0
Israel	-1.2	0.0	0.4	1.0	6.5	6.7
New Zealand	2.0	-0.6	-4.1	4.5	1.9	3.7
United Arab Emirates	-5.6	0.0	-16.7	1.7	44.2	23.6
Greece	-1.4	-0.5	-9.1	20.8	1.6	11.4
Korea, Rep. of	-5.2	-4.3	-41.0	109.8	11.4	70.6
Portugal	-1.2	-3.3	1.0	2.6	1.6	0.6
Bahrain	-0.6	0.0	-2.5	3.9	1.8	2.6
Czech Rep.	0.3	-5.4	-2.9	17.3	-0.5	8.8
Hungary	-1.8	-0.3	-11.8	13.4	-0.7	-1.2
Oman	-1.9	0.0	0.7	2.9	1.2	2.9
Slovak Rep.	1.6	-1.8	-6.8	7.6	0.0	0.6
Saudi Arabia	15.1	0.0	40.9	4.7	42.5	103.1
Trinidad and Tobago	-5.2	0.0	0.9	10.2	0.5	6.4
Poland	-11.4	0.8	-73.7	48.4	-0.8	-36.7
Argentina	-2.5	-4.0	9.2	-6.6	7.0	3.1
Croatia	0.1	0.8	-3.7	4.4	0.0	1.7

Decomposition of Emissions Between 1999 and 2004 (million metric tons) (continued)

Country	C_{eff}	S_{eff}	I_{eff}	G_{eff}	P_{eff}	Δ E
Chile	-3.9	-4.3	-0.7	8.4	3.5	3.0
Malaysia	-1.9	2.5	14.8	19.5	13.0	48.0
South Africa	0.3	2.4	-12.2	51.6	18.9	61.1
Mexico	-15.5	6.7	-12.8	20.8	25.8	25.0
Russian Fed.	-24.3	0.4	-360.8	567.7	-34.6	148.4
Romania	0.3	1.2	-21.6	25.8	-1.8	4.0
Bulgaria	-2.4	1.1	-6.8	12.5	-1.6	2.9
Thailand	-10.1	-2.1	13.0	39.0	8.8	48.6
Brazil	-24.9	-2.5	-12.5	19.2	23.7	3.1
Tunisia	-0.9	-0.1	-1.6	3.3	1.1	1.9
Turkey	-5.2	-1.1	-3.2	27.1	14.2	31.8
Dominican Rep.	0.5	-0.1	2.9	1.4	1.3	6.1
Iran, Islamic Rep. of	-13.8	-2.4	4.5	82.2	16.6	87.0
Kazakhstan	0.9	0.4	-34.7	77.8	-3.2	41.2
Belarus	-2.0	0.7	-19.7	20.1	-1.5	-2.4
Colombia	-1.3	-1.3	-7.6	3.7	4.6	-1.9
Algeria	-6.4	-0.1	-17.7	11.0	6.0	-7.2
Ukraine	-1.5	0.3	-96.5	156.4	-19.0	39.7
Venezuela, R. B. de	1.2	1.6	-0.8	-4.4	12.8	10.4
China	24.4	-5.1	148.2	1,510.9	127.4	1,805.9
Peru	-0.4	-1.9	-1.4	2.5	2.1	0.9
Philippines	-1.2	1.7	-10.8	9.5	6.7	6.0
Morocco	-1.0	-1.1	-4.9	3.6	2.2	-1.1
Egypt, Arab Rep. of	-9.2	4.4	13.0	12.3	12.5	32.9
Ecuador	0.1	0.3	-2.1	3.4	1.5	3.2
Azerbaijan	-17.4	-0.9	-14.9	20.0	1.4	-11.8
Syrian Arab Rep.	-1.2	0.3	-5.5	2.4	6.5	2.4
Indonesia	-6.7	-0.2	-12.5	45.6	18.2	44.3
India	-18.7	6.5	-103.4	212.6	81.0	178.0
Vietnam	-2.5	0.7	1.3	13.5	3.4	16.4
Pakistan	-3.9	-4.4	-9.3	10.2	11.0	3.6
Angola	-0.3	0.0	1.1	3.2	2.3	6.3
Bangladesh	0.0	0.0	2.6	5.4	3.1	11.2
Uzbekistan	-1.6	0.0	-6.2	17.8	8.1	18.1
Nigeria	-9.3	-0.5	-3.8	12.9	10.2	9.5

Source: World Bank calculations.

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