Global and regional drivers of accelerating CO₂ emissions

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Supporting Information

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Fig. 6. Regional and temporal distributions of (a) fossil-fuel CO₂ emissions $F_i$ (MtC y⁻¹); (b) commercial energy consumption $E_i$ (EJ y⁻¹); (c) population $P_i$ (millions); (d) GDP (MER) $G_{Mi}$; and (e) GDP (PPP) $G_{Pi}$. GDP is in G$ y^{-1}$ (billions of constant-price 2000 U.S. dollars per year). Sources are as in Table 1.

SI Figure 7

Fig. 7. Regional and temporal distributions of fossil-fuel CO₂ emissions (MtC y⁻¹) from (a) solid fuels; (b) liquid fuels; and (c) gas fuels. Data source: EIA.

SI Figure 8

Fig. 8. Factors in the Kaya identity, $F = Pgef = Pgh$, for nine regions. All quantities are normalized to 1 at 1990. Intensities are calculated with $G_{Mi}$ (MER). Other details are as for Fig. 2.

SI Figure 9

Fig. 9. Per-capita emission $F_i/P_i$ (Upper) and per-capita primary commercial energy consumption $E_i/P_i$ (Lower). Note the vertical axes are logarithmic. Sources are as in Table 1.
**SI Figure 10**

**Fig. 10.** (Upper) Observed CO$_2$ emissions: from EIA data summed over all countries (red), from CDIAC data summed over all countries (green), and the global total from the CDIAC data set (blue). (Lower) Emissions from China and from EIA (red) and CDIAC (blue) data.

**SI Text**

**Primary Energy**

Total primary energy consumption includes (i) energy from solid, liquid, and gas fossil fuels; (ii) energy used in nuclear electricity generation; (iii) electricity from renewables (hydroelectric, wind, solar, geothermal, and biomass); and (iv) nonelectrical energy from renewables, mainly as heat from biomass. Commercial primary energy includes contributions i, ii, and iii but excludes iv. Contribution iv can be difficult to measure, especially in developing regions. Its fractional contribution to total primary energy is often large in developing regions (>50%) but is smaller in developed regions. Contribution iv is included in EIA primary-energy data only for the U.S., where it represented a share of total U.S. primary energy of 3.7% (early 1980s) declining to 2.1% (early 2000s). It is not included in the EIA data for regions other than the U.S., so the non-U.S. energy data strictly describe commercial primary energy.

Because of the nature of the energy data, the present analysis applies to commercial primary energy. The presence of contribution iv in energy data for the U.S. introduces a small inconsistency amounting to an overestimate of commercial primary energy for the U.S. averaging >3% (declining with time) and an equivalent overestimate of global commercial primary energy averaging >0.7% (likewise declining with time).

The intensities $e_i = E_i/G_i$ and $f_i = F_i/E_i$ are defined for commercial primary energy. Relative to corresponding intensities defined with total primary energy, $e_i$ as defined here is an underestimate and $f_i$ is an overestimate by the same factor. The carbon intensity of the economy, $h_i = F_i/G_i = e_i f_i$, is independent of the definition of primary energy.

**The Global Carbon Cycle**

In 2005, the cumulative global fossil-fuel emission of CO$_2$ was $C(t) = 319$ GtC and the cumulative emission from the other major CO$_2$ source, land use change (J. G. Canadell, C.L.Q., M.R.R., C.B.F., E. T. Buitenhuis, et al., unpublished data) was 156 GtC (3). Of the total cumulative emission from both sources (>480 GtC), less than half (>210 GtC) has remained in the atmosphere, the rest having been taken up by land and ocean sinks (4). For the recent period 2000-2005, emission fluxes averaged 7.2 GtC y$^{-1}$ from fossil fuels and 1.5 GtC y$^{-1}$ from land use change; through this period the fossil-fuel flux grew rapidly at >3% y$^{-1}$, and the land use change flux remained approximately steady. A time-dependent indicator of sink effectiveness is the airborne fraction, the fraction of the total emission flux from fossil fuels and land use change that accumulates in the atmosphere each year. Recent work (J. G. Canadell, C.L.Q., M.R.R., C.B.F., E. T. Buitenhuis, et al., unpublished data) shows that the airborne fraction has averaged 0.44 for the period 1959-2005, increasing slightly through those 47 years to an average of 0.48 for 2000-2005. This implies a slight weakening of land and ocean sinks relative to total emissions.

**Definition of Regions**
D1: Andorra, Australia, Bermuda, Canada, Iceland, Israel, Liechtenstein, Monaco, New Zealand, Norway, Korea (South), San Marino, Singapore, Switzerland, Taiwan

D2: Albania, Algeria, Anguilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Bahrain, Barbados, Belize, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, British Virgin Islands, Brunei Darussalam, Bulgaria, Cameroon, Cayman Islands, Chile, Colombia, Cook Islands, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Czechoslovakia (Former), Korea (North), Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, French Polynesia, Gabon, Ghana, Grenada, Guatemala, Haiti, Honduras, Indonesia, Iran, Iraq, Jamaica, Jordan, Kenya, Kuwait, Lebanon, Libyan Arab Jamahiriya, Malaysia, Marshall Islands, Mauritius, Mexico, Micronesia, Mongolia, Montserrat, Morocco, Namibia, Nauru, Netherlands Antilles, New Caledonia, Nicaragua, Nigeria, Occupied Palestine, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Puerto Rico, Qatar, Romania, Saint Kitts-Nevis, Saint Lucia, Saint Vincent and the Grenadines, Saudi Arabia, Serbia and Montenegro, Seychelles, Somalia, South Africa, Sri Lanka, Sudan, Suriname, Swaziland, Syria, Macedonia, Thailand, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turks and Caicos Islands, United Arab Emirates, Uruguay, Venezuela, Vietnam, Zanzibar, Zimbabwe

D3: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, Cape Verde, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Kinshasa), Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Guyana, Kiribati, Laos, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Timor-Leste, Togo, Tuvalu, Uganda, Tanzania, Vanuatu, Yemen, Zambia

EU: Austria, Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom

FSU: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova (Republic of), Russian Federation, Tajikistan, Turkmenistan, Ukraine, USSR (Former), Uzbekistan