Understanding Global CO_2 Emissions Dynamics

A Sectoral and Structural Decomposition Analysis

Despite decades of climate policy efforts, global CO_2 emissions continue to rise. What are the fundamental structural drivers of this trajectory, and how have sectoral dynamics, economic scale effects, and technological intensity shaped the evolution of emissions over the long run?

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1 Introduction

Global climate change is fundamentally driven by anthropogenic carbon dioxide emissions. While international agreements and national policies have increasingly targeted emission reductions, aggregate global emissions continue to follow an upward trajectory.

Understanding why emissions rise is as important as understanding how to reduce them. This report adopts a long-run, data-driven perspective to analyze the structural forces behind global CO_2 emissions, focusing on sectoral composition and macro-level drivers.

Using historical data from the **Our World in Data (OWID)** repository, we analyze emissions since the onset of industrialization and decompose observed changes using a Kaya–LMDI framework. This approach allows us to disentangle the roles of population growth, economic activity, and carbon intensity, while simultaneously identifying the sectors that have contributed most to emission growth.

2 Data and Methodology

2.1 Data Source

The analysis relies exclusively on the OWID CO_2 dataset, which provides consistent global time series of fossil fuel emissions disaggregated by source: coal, oil, gas, cement, flaring, and other industrial processes.

The dataset spans more than two centuries, enabling a unified analysis of pre-industrial, industrial, and modern emission regimes.

2.2 Methodological Framework

Two complementary analytical tools are employed.

First, a **sectoral decomposition** tracks the evolution of emissions by fuel and industry, highlighting long-term structural shifts in the global energy system.

Second, a **Logarithmic Mean Divisia Index (LMDI)** decomposition is used to attribute changes in total emissions to three fundamental drivers: population growth, economic affluence, and emissions intensity.

Unlike attribution based on correlations, LMDI provides an exact and additive decomposition, making it particularly well-suited for climate-economic analysis.

3 Global Emissions Trajectory

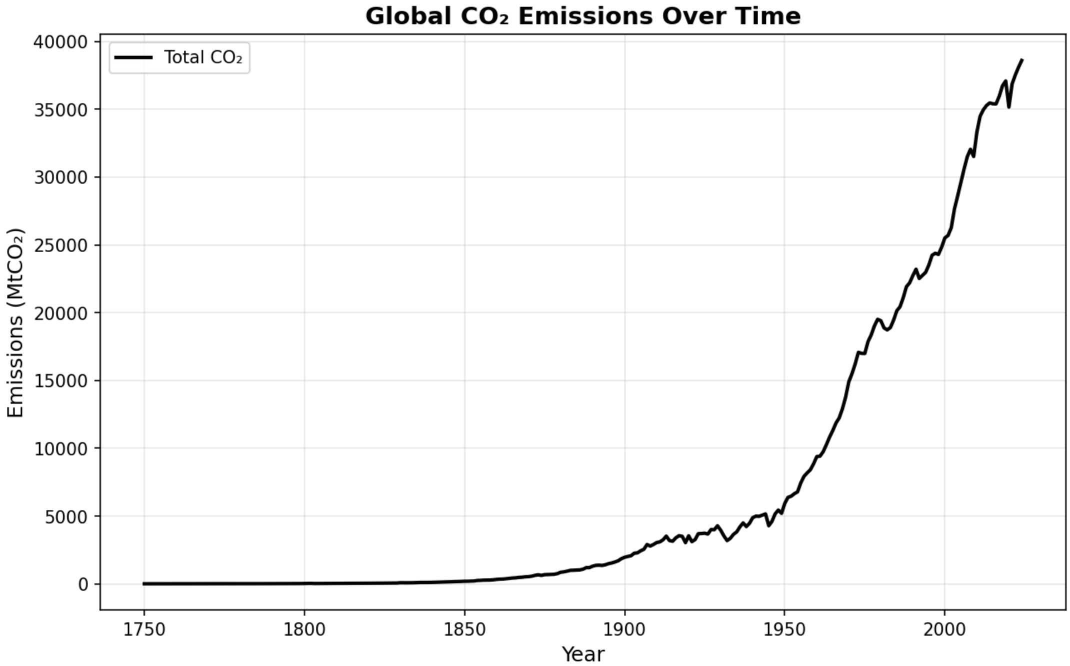

Figure 1: Evolution of global CO_2 emissions since 1750.

The figure illustrates the sharp acceleration following industrialization, with particularly rapid growth after World War II.

Global emissions remained negligible for over a century before increasing rapidly in the late nineteenth century. The post-1950 period marks a structural break, characterized by unprecedented growth rates and persistent increases despite episodic shocks.

Beyond its long-run upward trend, the emissions trajectory reveals several structurally distinct phases reflecting major transformations in the global economic and energy system.

Prior to industrialization, emissions remained negligible, as production relied primarily on biomass and low-energy technologies. The diffusion of coal-powered industrial processes in the nineteenth century initiated a first sustained rise in emissions, coupling economic growth to fossil fuel use.

A decisive structural break occurs after World War II. Rapid population growth, mass industrialization, urbanization, and the globalization of production chains combine to generate unprecedented emission growth rates. The transition from coal to oil and later natural gas diversified the fossil energy mix, but did not reduce aggregate emissions.

Temporary declines associated with major economic shocks are visible, yet these effects are short-lived. Emissions rebound quickly as activity resumes, indicating strong structural inertia in the global energy–economy system.

This persistence suggests that long-run emissions growth is driven not by cyclical fluctuations, but by deep structural forces embedded in economic scale and energy infrastructure.

4 Sectoral Dynamics

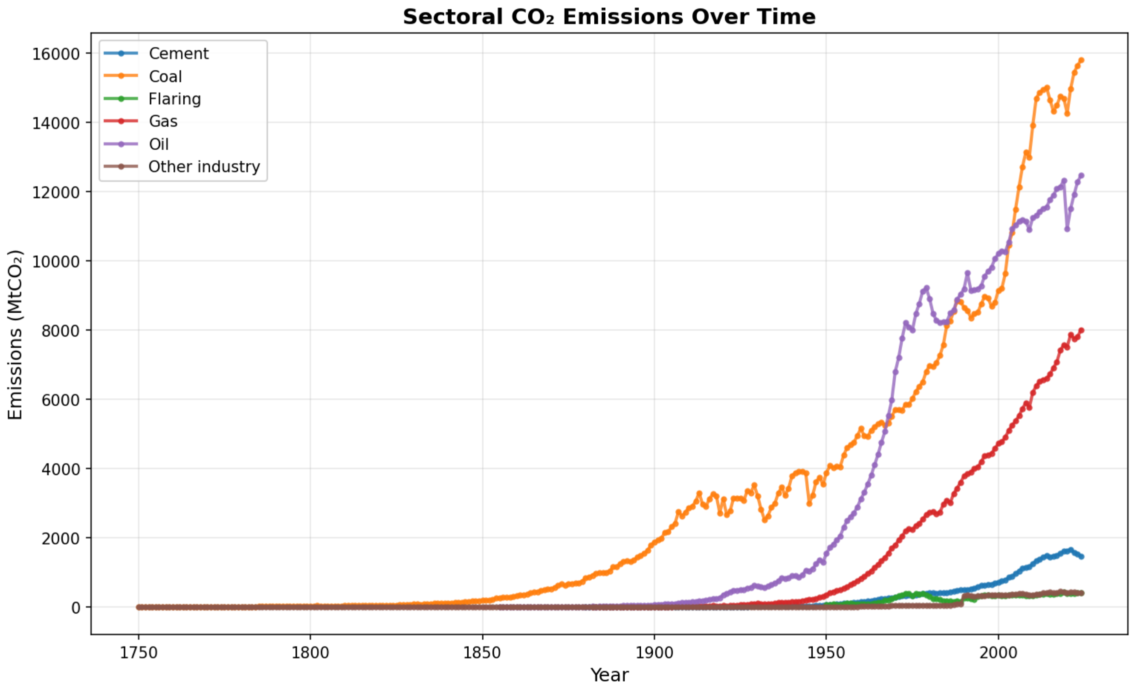

Figure 2: Sectoral CO_2 emissions over time.

Coal dominates early industrialization, while oil and gas drive post-war growth.Coal was the primary driver of emissions throughout the nineteenth century.However, the second half of the twentieth century saw a diversification of emission sources, with oil and natural gas becoming dominant contributors.

The sectoral trajectories reveal that the long-run growth of global emissions is driven by a small number of dominant fossil fuel sources. Coal underpins early industrialization, reflecting its central role in power generation and heavy industry during the nineteenth and early twentieth centuries.

The post-war period marks a clear transition toward oil and natural gas, closely linked to the expansion of transport systems, petrochemicals, and electricity generation. While gas exhibits a smoother growth path, oil displays pronounced volatility, mirroring geopolitical shocks and price fluctuations.

Importantly, no major emitting sector exhibits a sustained absolute decline over the full sample period. Even sectors with lower growth rates continue to expand in absolute terms, reinforcing the conclusion that observed changes reflect a recomposition of fossil fuel use rather than a structural decarbonization of the energy system.

This transition reflects not decarbonization, but a shift in fossil fuel composition.

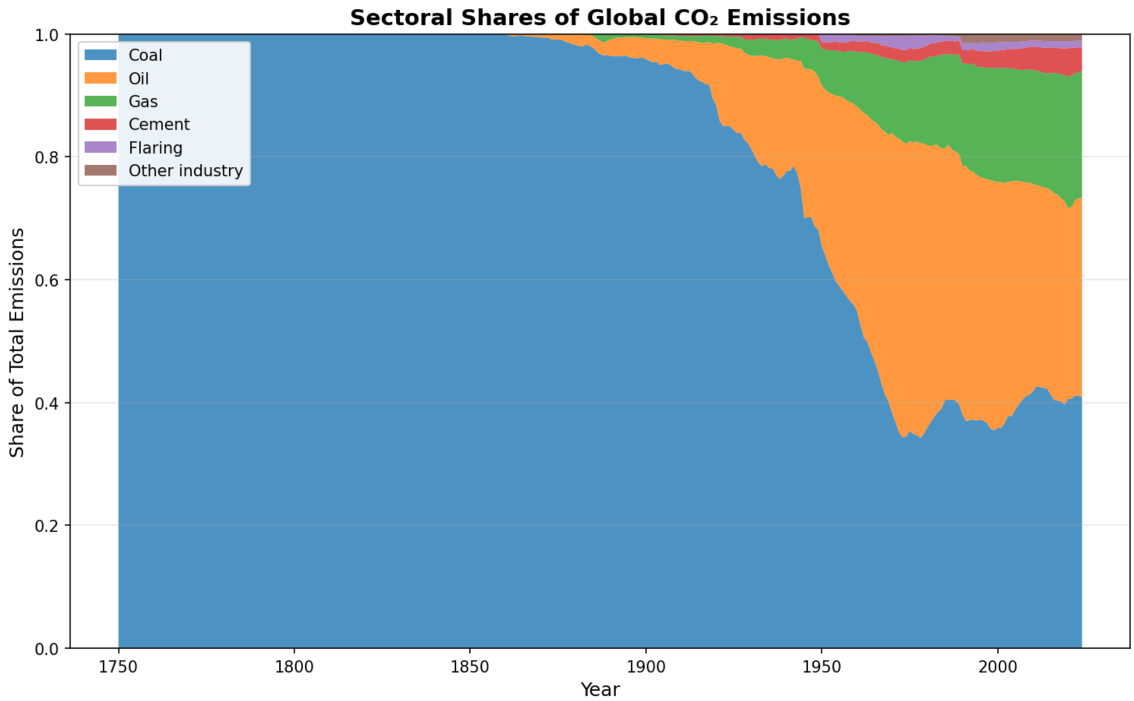

Figure 3: Sectoral shares of total global CO_2 emissions.

The decline of coal's dominance coincides with the rise of oil and gas. While coal's relative share has declined, absolute emissions from all major fossil fuels have continued to rise, underscoring the scale of the challenge.

5 Year-on-Year Contributions

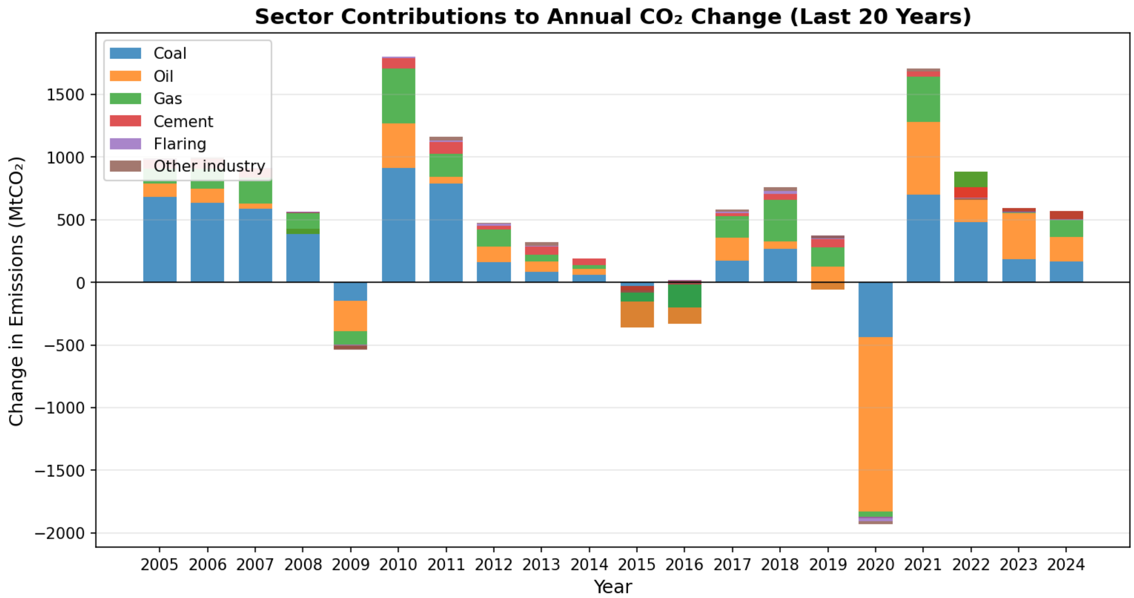

Figure 4: Sectoral contributions to annual changes in global emissions over the last 20 years.

Negative contributions during economic shocks are short-lived. Short-term declines in emissions, such as those observed during financial crises or the COVID-19 pandemic, are primarily driven by reductions in oil and coal consumption. However, these effects are rapidly reversed as economic activity resumes.

6 Structural Decomposition Analysis

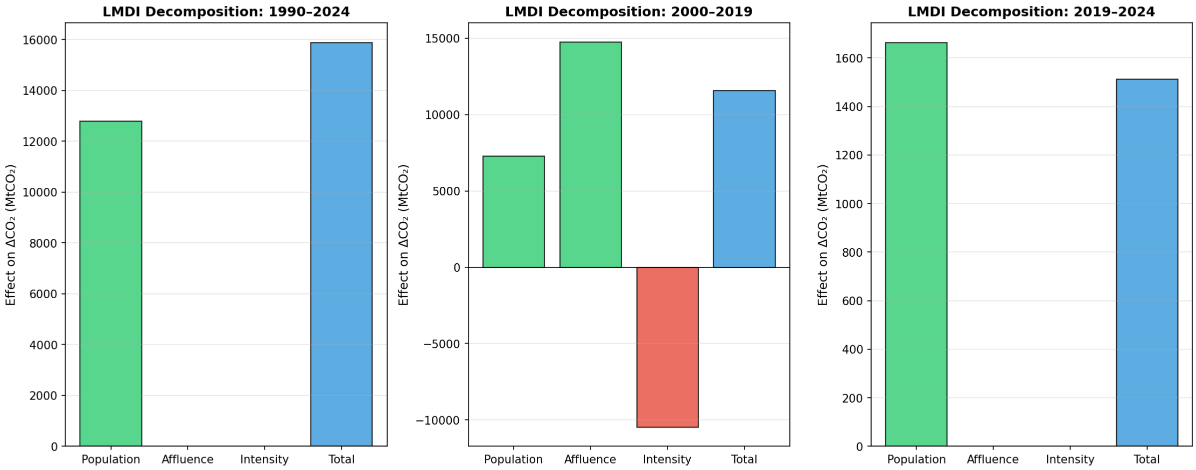

Figure 5: LMDI decomposition of changes in global CO_2 emissions across periods.

Population and affluence effects dominate, while intensity improvements partially offset growth. The decomposition reveals a clear and robust pattern. Population growth and rising affluence exert strong upward pressure on emissions, while improvements in emissions intensity consistently act as a mitigating force.

Critically, intensity improvements have never been sufficient to counterbalance scale effects.

This finding highlights the structural nature of the climate challenge: technological efficiency alone cannot deliver absolute emission reductions without accompanying changes in economic scale or energy systems.

7 Conclusion

This report demonstrates that global CO_2 emissions are driven by deep, structural forces embedded in population growth, economic expansion, and sectoral energy use.

While technological progress has reduced emissions intensity, these gains have been overwhelmed by scale effects. Sectoral analysis further shows that fossil fuel diversification has not translated into meaningful decarbonization.

Effective climate mitigation therefore requires structural transformation, not merely incremental efficiency improvements.

Future research may extend this framework to regional analyses or scenario-based projections, providing further insight into transition pathways.