

Zooming into Inequality: A Fractal Exploration

Abstract

Fractals, found in nature as endlessly repeating patterns, offer a powerful lens through which the idea of inequality can be understood. Just as a fractal coastline retains its jagged shape no matter how closely one zooms in, inequality in the economy too replicates itself across scales, among individuals, within nations, and across the globe. This article attempts to explore economic inequality as a fractal phenomenon, with a particular focus on India while drawing comparisons with other developed, developing, and underdeveloped countries. Using mathematical tools, simple data analysis and visualizations, it attempts to demonstrate how wealth and income concentrations reveal self-similar patterns at every level. By presenting evidence from both national and global perspectives, the article attempts to highlight the persistence of inequality as a structural feature of economies. The central message underscores that inequality, much like fractals, is self-replicating and requires conscious policy interventions to disrupt its enduring cycle.

Introduction: Patterns in Nature, Patterns in Society

A coastline is a fractal signature of the sea- the closer we trace it, the more details appear, never ending in smoothness. This natural phenomenon illustrates a deeper principle: repetition with complexity.

Inequality shows a similar behaviour. Globally, a few developed countries dominate wealth; again, within these nations there is a disproportionate number of resources concentrated within the hands of the elite; and even these communities, families or companies reappear showing imbalances. This self- repetitive pattern resembles a fractal and these structures keep on occurring no matter how much we zoom in.

Mathematics offers laws like the Power Rule or the Pareto principle that can be used to study these features of the economy on how the resources are distributed and why such disparities occur.

Fractals: The Mathematics of Self-Similarity

Fractals are infinitely complex patterns that are self-similar across different scales. They get created by repetition of a simple process over and over again in a never-ending loop. Fractals, being driven by recursion, are pictures of chaos. Approximate fractals that are found in nature display self-similarity over extended but finite scale ranges. Phenomena that are known to exhibit fractal properties in nature include ocean waves, snowflakes, lightning bolts, coastlines, craters, etc.

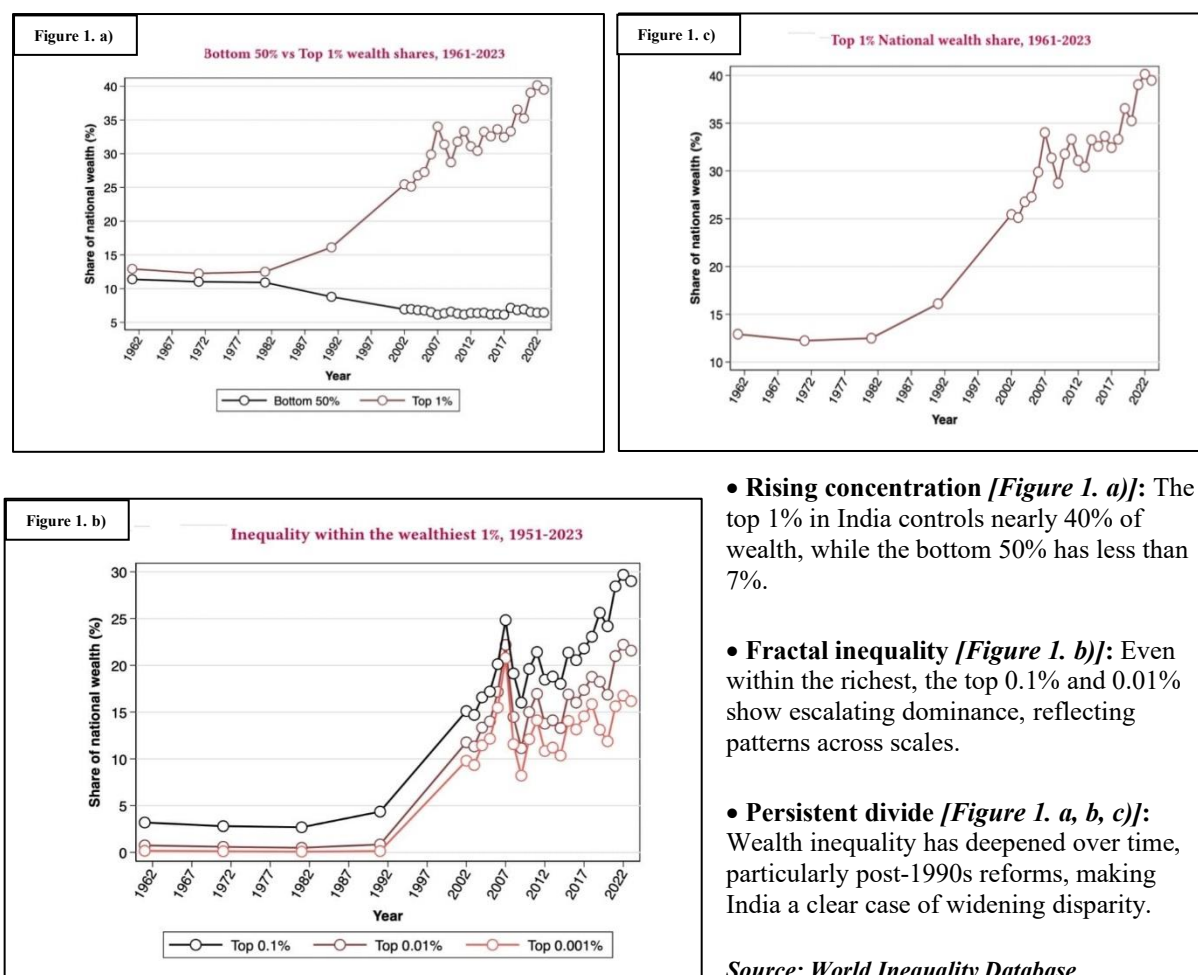
Economists and mathematicians such as Pareto and Mandelbrot have shown that income and wealth distributions often display **fractal-like properties**, repeating patterns at multiple scales. The fractal theory of income distribution applies the mathematical principles of fractals to understand how income is unevenly distributed in any nation. It gives an idea that income inequality exhibits a Pareto-like structure, i.e., a few individuals hold a disproportionately large share of the total income and throws light on the existence of a stochastic fractal relationship between a nation's output and income inequality.

Inequality: The Fractal of Economics

The Pareto principle, or the 80/20 rule, by Vilfredo Pareto, has shown how a small share of the population (20%) holds a large share of resources (80%). Yet this imbalance is not limited to one layer, it repeats fractally! Within the top 10% lies the top 1%, and within them an even smaller fraction, each possessing a disproportionate share of wealth. This self-similar structure reflects the very nature of fractals, where patterns echo at every scale. Economically, it reveals why inequality is so persistent and difficult to reverse as it throws light on how the imbalance is deeply embedded across levels.

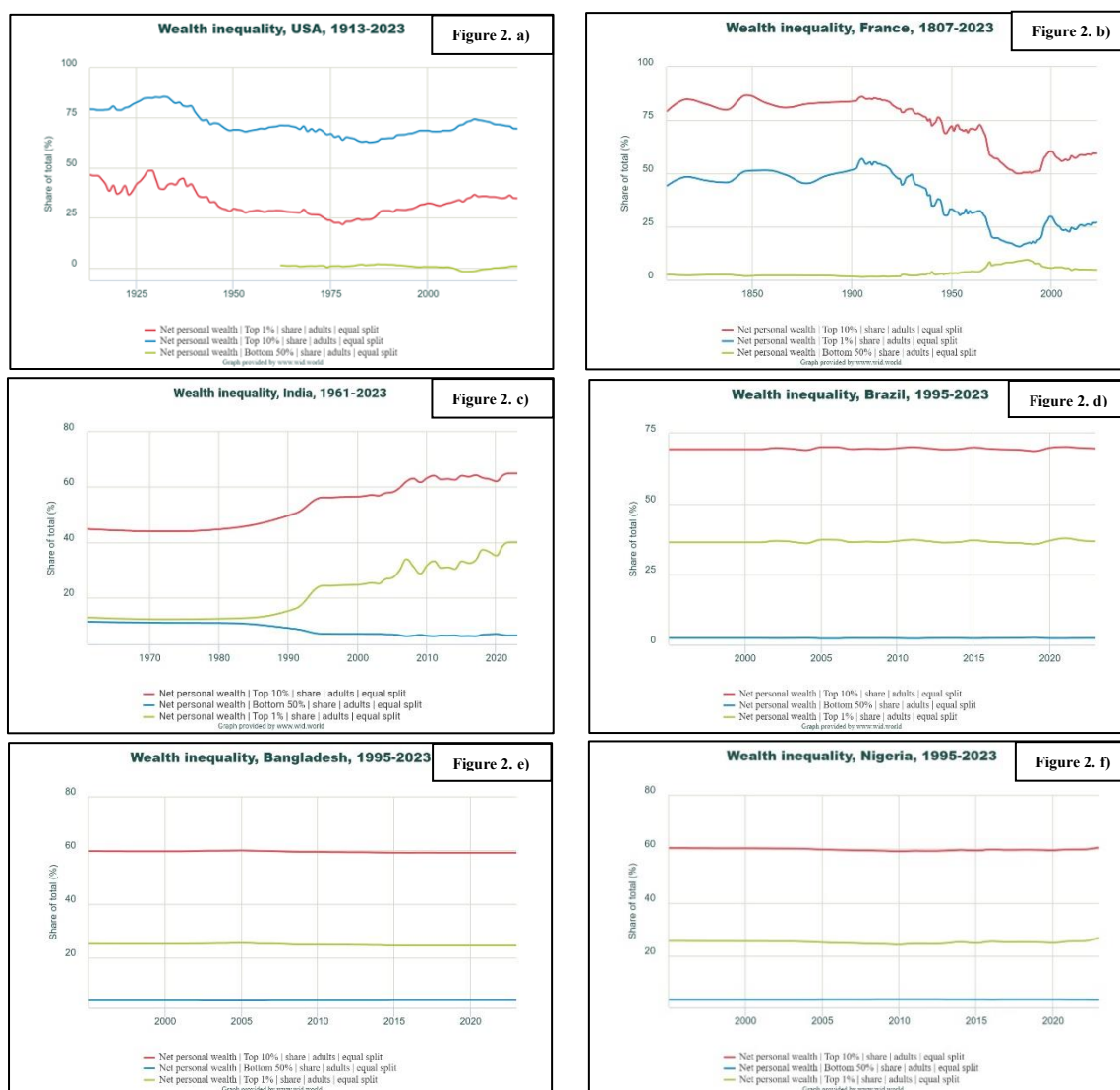
Inequality in India: A Fractal within a Nation

In the context of the Indian Economy, trends and studies over the years provide a striking example of how inequality manifests in a fractal-like pattern. The wealth share of the top **1%** has surged dramatically since the 1980s, rising from about **12–15%** to nearly **40%** in 2023, while the bottom **50%** has seen its share shrink steadily below **7%**. Within the wealthiest, the top 0.1% and 0.01% have also captured increasing proportions, showing that concentration persists even among the elite. These plots underscore two critical points: Inequality in India is widening not just between the rich and poor but also within the rich themselves and this self-replicating concentration mirrors the fractal structure of inequality. India, therefore, if considered to be a microcosm of global patterns, reveals significantly about the world inequality as a whole. These trends can be further used for comparing India with other countries to understand inequality as a global, persistent phenomenon.



Inequality Across Nations: A Comparative Lens

While India illustrates the fractal nature of inequality within a single country, a cross-country perspective reveals how this phenomenon plays out even across diverse economic contexts. The **United States** and **France**, despite being developed economies, highlight how advanced financial systems and policy frameworks still grapple with persistent wealth concentration. **Brazil** and **India**, representing developing nations, exhibit stark divides where rapid growth has been coexisting with rising inequality. Meanwhile, **Nigeria** and **Bangladesh**, as underdeveloped economies, show fragile wealth structures where inequality is deeply tied to limited resources and institutional challenges. Comparing the **bottom 50%**, **top 10%**, and **top 1% wealth shares** across these countries gives interesting insights, as it highlights both the universal and context-specific patterns of inequality. This broader view underscores how inequality, like a fractal, repeats across nations with different levels of development.



Figures 2a)-2f): Wealth inequality trends across six representative countries: USA, France, India, Brazil, Nigeria, and Bangladesh [Source: World Inequality Database]

The above graphs, obtained from the World Inequality Database, highlight how wealth inequality reproduces itself in a fractal-like manner. In India and Brazil, the steep rise of the top 1% within the top 10% illustrates nested concentration of wealth. Although Nigeria and

Bangladesh show more stability, the top shares remain disproportionately high. France and the USA, with longer historical data, demonstrate how inequality levels fluctuate across centuries but never dissolve the hierarchical layering of wealth. This cross-country comparison reveals a common structural property: inequality scales recursively, much like fractals, regardless of geography or stage of development, emphasizing both its mathematical significance and real-world consequence.

From Local to Global: Patterns of Inequality Across Scales

The graphs below underscore how inequality reproduces itself at multiple layers. At the **top 10% level [Figure 3a)]**, wealth concentration remains stark: the USA consistently above 70%, India rising rapidly past 60%, while Bangladesh shows relative stability near 60%. Yet, when narrowed to the **top 1% [Figure 3b)]**, the pattern repeats fractally, India's surge to nearly 40% and Bangladesh's steady 30% reveal that even within the elite, a smaller fraction commands disproportionate wealth. **Globally, the top 10% control around three-quarters of total wealth, but within them, the top 1% alone hold over a third.** This layered concentration illustrates the fractal nature of inequality, where inequities persist not only between classes but also within the wealthiest groups themselves and this goes on and on.

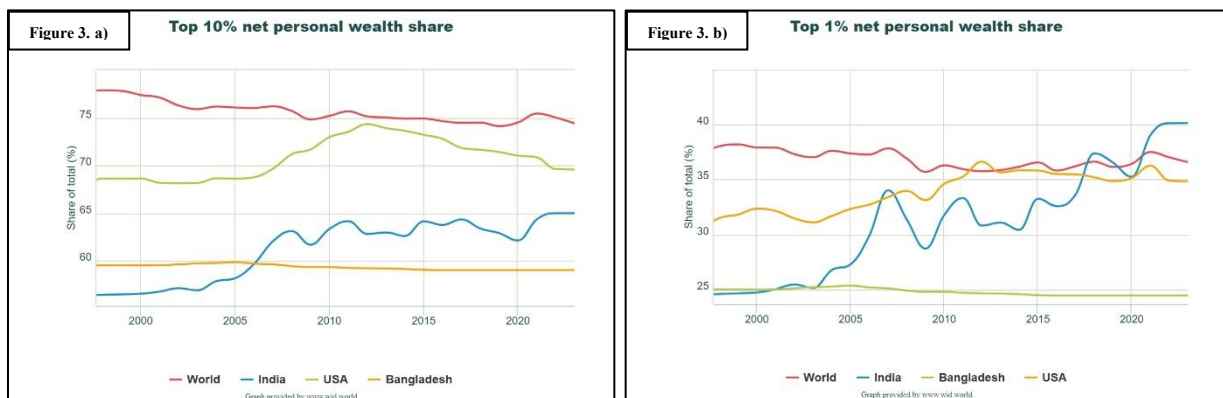


Figure 3a) - 3b): Top 10% [3(a)] and top 1% [3(b)] wealth shares over time for the USA, India, Bangladesh, and the global inequality trend (red plot) [Source: World Inequality Database]

These two graphs show world inequality and demonstrate how the fractal-like nature of wealth concentration persists across all levels. By selecting one country each from developed, developing, and underdeveloped categories, it becomes evident that the same pattern repeats regardless of context: the **top 10% consistently dominate wealth**, and within them, the **top 1% hold an outsized share**. These cases serve as representatives of broader trends, showing how inequality in individual nations aggregates to shape global inequality. The world trend lines reflect this cumulative effect, where the persistence of concentration at smaller scales within countries and within groups, aggregate and build up to the global level. Thus, inequality is not only a national phenomenon but a universal and self-replicating pattern that mirrors the fractal logic that is, inequities within parts contribute to inequities of the whole.

Wealth vs. Income: Converging Patterns of Inequality

While this analysis focuses on **wealth**, since it reflects not just a yearly flow of resources but also stock of purchasing power and long-term control over assets, it is worth noting that income distributions show a strikingly similar pattern. The two measures, though conceptually distinct, reveal parallel trajectories that is, the yearly concentration of income compounds into the cumulative concentration of wealth. In that sense, both demonstrate a **fractal-like repetition**, where the inequality visible in annual flows (income) mirrors and amplifies into the inequality of accumulated stocks (wealth).

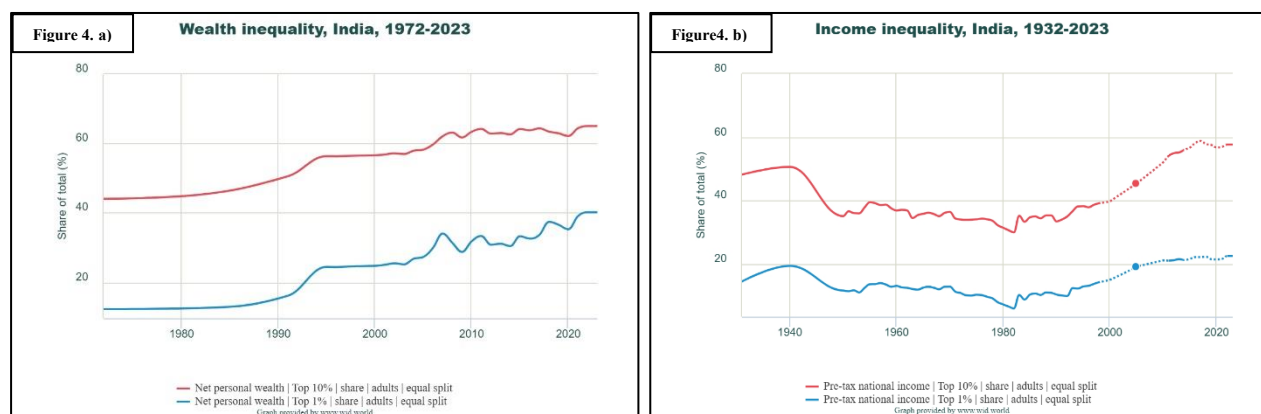


Figure 4a) - 4b): Wealth [4(a)] and income [4(b)] shares of the top 10% and top 1% in India, illustrating nearly parallel trends and reinforcing the fractal-like nature of inequality [Source: *World Inequality Database*]

Conclusion: Fractals of Inequality and the Need for Rethinking Distribution

The exploration of inequality through the lens of fractals reveals a striking truth. The concentration of wealth persists and replicates at every scale. From India's wealth distribution to cross-country comparisons and global aggregates, the same pattern emerges. The **top 10% hold a majority share**, but even within them, the **top 1% command disproportionate control**, and within them, further layers of inequality can be uncovered. This mirrors the very definition of fractals, that is, structures that repeat themselves across scales. While conventional measures such as the Lorenz curve and Gini coefficient capture the extent of inequality, the fractal perspective highlights its self-replicating nature across scales, offering a deeper lens of understanding

The comparison between wealth and income strengthens the argument, showing that inequality is not a function of one metric but a systemic reality, with yearly income accumulation reinforcing wealth concentration. Ultimately, inequality must be understood as a **self-replicating, fractal-like phenomenon** that demands policy responses beyond surface redistribution and direct benefit transfers like cash or food subsidies. Addressing it requires recognizing its persistence across scales, within countries, across nations, and globally. Only by acknowledging its fractal or symmetric nature, meaningful steps can be envisioned towards a more equitable future.

Breaking the Fractal: A Trickle-Up Approach to Equality

As observed, the fractal nature of inequality shows that disparities replicate from the smallest units of society to the global economy. Data reveal that currently, the **top 10% own**

approximately 76% of global wealth, while the **bottom half hold less than 2%**, and yet, even within the elite, wealth keeps clustering among the top 1% (World Inequality Report, 2022; World Inequality Database). This self-replicating pattern cannot be undone by traditional trickle-down strategies, which assume prosperity at the top will eventually reach the base. Instead, what is required is a **trickle-up approach** that is, strengthening the micro-level so inequalities are dismantled before they can replicate upward.

Investments strategized towards reforming household-level education, healthcare, and asset-building, coupled with local redistribution policies aimed at ensuring that opportunities and wealth accumulation begin from the ground may provide a way to address inequality from its very roots. If such opportunities are nurtured carefully at the local scale, their effects are likely to flow upward, gradually stabilizing both national and global economies. Alongside this, measures such as progressive taxation, regulation of tax havens, and coordinated wealth governance could complement the process by addressing concentration at the higher levels. Only by fixing inequities where they first emerge can the fractal pattern of inequality be broken.

References

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