Geometric Phase Transitions in Wealth Distribution: A Gravitational Accretion Model

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Empirical studies in Econophysics, notably by Yakovenko (2000), have identified a universal "Two-Class" architecture in income distribution: an exponential Boltzmann-Gibbs bulk (97%) followed by a power-law Pareto tail (3%). While stochastic models successfully reproduce these statistics via additive and multiplicative noise, they lack a geometric mechanism explaining the structural origin of this separation. This work introduces a gravitational interpretation within the EMIS (Energy-Matter-Information-Spacetime) framework. We model the economy as a dual-phase system where Money functions as conserved Energy and Capital functions as Mass. We demonstrate that the transition from the exponential to the power-law regime corresponds to a geometric phase transition: money in the thermal bulk behaves as a free gas, while money in the tail undergoes gravitational accretion due to the curvature induced by accumulated capital. This model physically derives the "poverty trap" as a maximum-entropy thermodynamic equilibrium and identifies wealth concentration as a symmetry-breaking phenomenon driven by the metric topology of the market manifold.

I. INTRODUCTION

The distribution of income and wealth follows one of the most persistent patterns in economics. While Pareto [1] identified the power-law tail and Gibrat [2] proposed proportionate growth, it was Dragulescu and Yakovenko [3] who established a comprehensive statistical mechanical framework for the entire population.

Yakovenko showed that income distribution is not uniform but splits into two distinct regimes: a thermal Boltzmann-Gibbs distribution for the lower 97% of the population, and a Pareto power-law tail for the top 3% [3]. This "Two-Class" structure implies a fundamental difference in how wealth is accumulated. The lower class operates under conservation laws (additive noise), while the upper class benefits from multiplicative growth [4].

However, a critical theoretical question remains: *What is the physical mechanism that allows an agent to cross from the thermal regime to the Pareto regime?* Current models describe the statistics well but do not explain the structural constraints that enforce this phase transition.

In this paper, we introduce the EMIS (Energy-Matter-Information-Spacetime) Framework to reframe this phenomenon through the lens of **General Relativity** and **Thermodynamics**. We propose that Capital is not merely a number in a ledger, but a form of "Structural Mass" that curves the economic metric, creating gravitational wells that naturally capture energy (money) flow.

II. THE THERMAL REGIME: THE GAS PHASE

For the majority of the population (the 97%), economic interaction is dominated by the exchange of labor for money to meet survival needs. In the EMIS framework, this corresponds to the **Gas Phase** of matter.

Individual agents behave like ideal gas molecules. Their kinetic energy (income) is subject to random collisions (transactions) where money is locally conserved. According to the Maximum Entropy Principle, the equilibrium distribution of energy E in such a system is inevitably exponential [5]:

$$P(E) \sim \exp(-E/T), \tag{1}$$

where T represents the average "economic temperature" (per capita money supply).

This reinterpretation leads to a stark conclusion: Poverty is not a moral failure or a lack of effort; it is the **MaxEnt (Maximum Entropy)** ground state of unstructured energy flow. Without "Structural Mass" (Capital), agents are thermodynamically constrained to the Boltzmann distribution.

Empirically, the probability distribution of income $P(m)$ is observed to be a superposition of two distinct regimes, approximated as [3]:

$$P(m) \approx c_1 \exp\left(-\frac{m}{T}\right) + \frac{c_2}{m^{\alpha+1}}. \tag{2}$$

The first term represents the Boltzmann-Gibbs distribution arising from conservation laws. The second term represents the Pareto tail arising from multiplicative growth.

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III. THE GRAVITATIONAL REGIME: ACCRETION

The top 3% of the distribution follows a power law: $P(E) \sim E^{-\alpha}$. Yakovenko attributes this to multiplicative dynamics ($dE \propto E$). EMIS provides a geometric explanation for this behavior.

We propose that when accumulated energy exceeds a certain threshold, it can be crystallized into **Structure** (Capital, IP, Institutional Rights). This structure acts as **Mass** (M) in the economic spacetime. Just as mass curves spacetime in General Relativity, Capital curves the economic potential field.

This curvature creates a **"Profit Potential Well"**. Energy (Money) flowing through the system follows the geodesic of least action, which naturally spirals into these wells. The dynamic equation shifts from stochastic collision to gravitational accretion:

$$\frac{\mathrm{d}M}{\mathrm{d}t} \propto M. \tag{3}$$

This is the physical basis of the "Rich-get-Richer" phenomenon. The Pareto tail is, effectively, the event horizon of these structural gravitational singularities.

IV. THE BARRIER AND PHASE TRANSITION

A key question in social mobility is: *Why can't the poor easily become rich?* The EMIS framework explains this as a **Phase Transition** problem.

Moving from the Thermal Regime (Gas) to the Gravitational Regime (Accretion) requires crossing a threshold analogous to the **Event Horizon** in General Relativity. We denote this threshold as r_c, referencing the critical radius of an accretion disk where gravitational binding energy overcomes thermal kinetic energy. In the economic context, r_c represents the minimum "Structural Mass" required to bend the local metric significantly. Below r_c, the agent is merely a particle in the thermal gas; above r_c, the agent becomes a gravitational singularity that dictates the flow of the surrounding metric.

Below this critical nucleation radius, the **Thermodynamic Dissipation** (cost of living, inflation) dominates over **Gravitational Attraction** (investment returns). The agent remains trapped in the thermal well, governed by entropy. Only by injecting sufficient external energy (innovation, leverage) can an agent cross the barrier and initiate self-sustaining accretion [6].

V. DISCUSSION

The EMIS framework offers more than a static description of wealth distribution; it provides a generative mechanism for social dynamics. By identifying Capital as "Structural Mass", we bridge the gap between stochastic economics and field theory.

A. Implications for AI and Simulation

Current Large Language Models (LLMs) often struggle with causal reasoning in social domains due to the lack of a "ground truth" physics engine. EMIS provides a candidate for a **Neuro-symbolic Constraint Layer**. By mapping social variables to conserved physical quantities, we can build AI agents that are less prone to "hallucinating" economically impossible scenarios (e.g., infinite growth without entropy production).

B. Policy Implications

If inequality is a phase transition driven by geometric constraints rather than moral failure, policy interventions must shift from purely redistributive (treating symptoms) to structural (altering the metric). Reducing the "gravitational constant" of capital—perhaps through decentralized information protocols—may be more effective than simply taxing the accretion disk.

Future work will focus on Agent-Based Modeling (ABM) to numerically simulate the phase transition point r_c under varying constraints of Information transparency. While this work focuses on the geometric aspect, future extensions may explore the connections to network topology [7], derivative pricing dynamics [8], and potentially the holographic implications of entropic gravity [9–11].

VI. CONCLUSION

By mapping money to energy and capital to mass, the EMIS framework unifies the two distinct distributions observed by Yakovenko [3] into a single physical model. We show that the economy is a dual-phase system: a thermodynamic background of maximum entropy, punctuated by localized gravitational wells of low entropy. This suggests that inequality is not an anomaly, but a geometric inevitability of systems allowing structural accumulation.

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