The Self-Limiting Dynamics of AI Automation: A Chessboard Model of Economic Collapse

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Abstract

Artificial intelligence disrupts labor markets at an unprecedented pace, raising concerns about long-term economic stability. This paper introduces a novel computational framework — the *chessboard economy* — designed to simulate the cascading effects of AI-driven job displacement on macroeconomic indicators. Using a multi-agent system composed of workers, AI firms, non-AI firms, and a government entity, we demonstrate how excessive automation leads to employment collapse, reduced consumer demand, and ultimately self-limiting profitability for AI firms. Our model incorporates stochastic wage distributions, spatial visualization via a 2D grid, and dynamic feedback mechanisms between automation and consumption. The results reveal a critical threshold beyond which AI adoption becomes economically unsustainable due to collapsing market demand. We further explore potential mitigation strategies such as taxation policies, stimulus programs, and Universal Basic Income (UBI). By integrating mathematical modeling, simulation, and visual analytics, this work provides a multidimensional lens through which to understand and anticipate the socio-economic implications of AI advancement.

1 Introduction

Artificial Intelligence has been hailed as the engine of the Fourth Industrial Revolution, promising unparalleled productivity gains [6]. However, its impact on labor markets remains a contentious issue [2].

We identify a Schrödinger's Cat-like paradox: AI simultaneously boosts productivity and erodes the economic system sustaining it. As jobs disappear due to automation, consumer spending collapses, eventually harming the very industries driving automation [9].

To study this effect, we introduce a new modeling framework — the *chessboard economy* — in which agents are arranged on a 2D grid resembling a chessboard, allowing spatial visualization of wage distribution and job loss over time.

Our simulation reveals how unchecked AI adoption can lead to systemic instability rather than infinite efficiency [15]. This insight contributes to ongoing debates in AI ethics, labor economics, and public policy.

2 Literature Review

A growing body of literature has explored the impact of automation on labor markets and economic systems. [1] demonstrated that robots displace jobs but do not necessarily increase productivity at the national level. [6] highlighted the potential benefits of AI, but also warned of increasing inequality. [14] examined Universal Basic Income as a buffer against technological unemployment.

[4] argued that technology complements labor more often than it replaces it, while [2] emphasized the polarization of labor markets under automation. [13] warned of rising capital concentration, and [8] advocated for complexity economics to better model nonlinear interactions.

Our work builds upon these foundations by introducing a new modeling framework — the *chessboard economy* — which visualizes the spatial dynamics of AI-induced disruption and demonstrates how automation can lead to its own economic limits [7].

3 Mathematical Framework

We define the core variables governing the economic system:

Symbol	Meaning
L_t	Number of employed workers at time t
C_t	Total consumption at time t
T_t	Tax revenue collected by government at time t
S_t	Stimulus injected into economy at time t
P_t^{AI}	Profit earned by AI firm at time t
R_t^{nonAI}	Revenue of non-AI firms at time t
α	Job automation rate (fraction automated per step)
β	Propensity to consume
γ	Demand elasticity factor
τ	Tax rate applied to wages and firm revenues
ϵ	Sensitivity of AI profit to market demand drop

3.1 Employment Evolution (Eq. 1)

At each time step, a fraction α of currently employed workers are replaced by AI:

$$L_{t+1} = L_t - \lfloor \alpha L_t \rfloor$$

3.2 Consumption Function (Eq. 2)

Each worker consumes a fixed proportion β of their wage if employed:

$$C_t = \sum_{i=1}^{N} c_i, \quad \text{where } c_i = \begin{cases} \beta w_i & \text{if employed} \\ 0 & \text{otherwise} \end{cases}$$

If stimulus S_t is provided:

$$C_t = \sum_{i=1}^{N} c_i + S_t$$

3.3 Non-AI Firm Revenue (Eq. 4)

Revenue depends linearly on total consumption:

$$R_t^{nonAI} = \gamma C_t$$

3.4 Tax Revenue (Eq. 5)

Taxes are collected from wages and firm revenues:

$$T_t = \tau \left(\sum_{i=1}^{N} w_i \cdot \mathbb{1}_{\text{employed}} + R_t^{nonAI} \right)$$

3.5 Government Stimulus (Eq. 6)

A portion σ of tax revenue is reinvested:

$$S_t = \sigma T_t$$

3.6 AI Firm Profit (Eq. 7)

Each job automated generates profit π_{job}, but this is reduced due to declining market demand:

$$P_t^{AI} = \lfloor \alpha L_t \rfloor \cdot \pi_{job} \cdot \left[1 - \epsilon \left(1 - \frac{C_t}{C_0} \right) \right]$$

Where C_0 is initial consumption (at $t = 0$).

The term $\epsilon \left(1 - \frac{C_t}{C_0} \right)$ captures how AI profits decay as consumption falls below initial levels. When demand drops significantly, even highly profitable AI operations suffer.

4 Stochastic Processes

To reflect real-world variability, we introduce stochastic elements: - Wages sampled from $\mathcal{N}(100, 10)$ - Automation rate drawn from $\mathcal{N}(0.05, 0.01)$

These choices are grounded in empirical data: - Historical automation rates fall within 3–7% annually [1]. - Wage distributions across sectors follow approximately normal patterns [11].

5 Computational Model and Simulation Design

We implement a stochastic version of the above dynamics in Python. Workers are represented on a 2D grid resembling a chessboard, allowing visualization of wage distribution and job loss over time.

Key components: - **Worker**: Consumes a fraction β of income if employed. - **AI Firm**: Automates jobs probabilistically and adjusts profit based on demand. - **Non-AI Firms**: Revenue tied directly to aggregate consumption. - **Government**: Taxes wages and firm profits, reinvests part as stimulus.

The full code is available at `https://github.com/MOON11kr/ai_chessboard_economy`, and the animated heatmap is included as supplementary material.

6 Simulation Results

Figure 1 shows normalized trends in key indicators over 50 simulation steps.

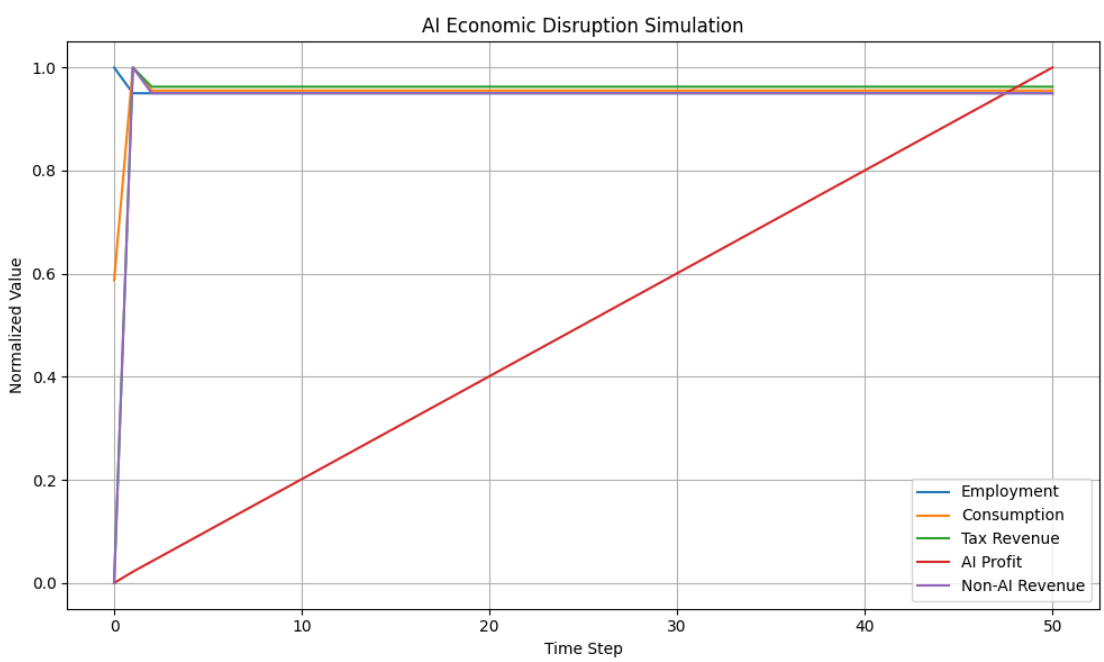

Figure 1: Normalized trends in employment, consumption, tax revenue, and AI profit over 50 steps.

An annotated heatmap animation (see supplementary material) illustrates the spatial spread of unemployment across a chessboard-style grid of workers. Each square represents a worker whose color reflects wage level, with black indicating unemployment. Over time, clusters of job loss expand, mimicking real-world geographic and sectoral disparities.

7 Conceptual Framework

To provide a comprehensive overview of the problem, Figure 2 illustrates the key feedback loops and consequences of excessive automation.

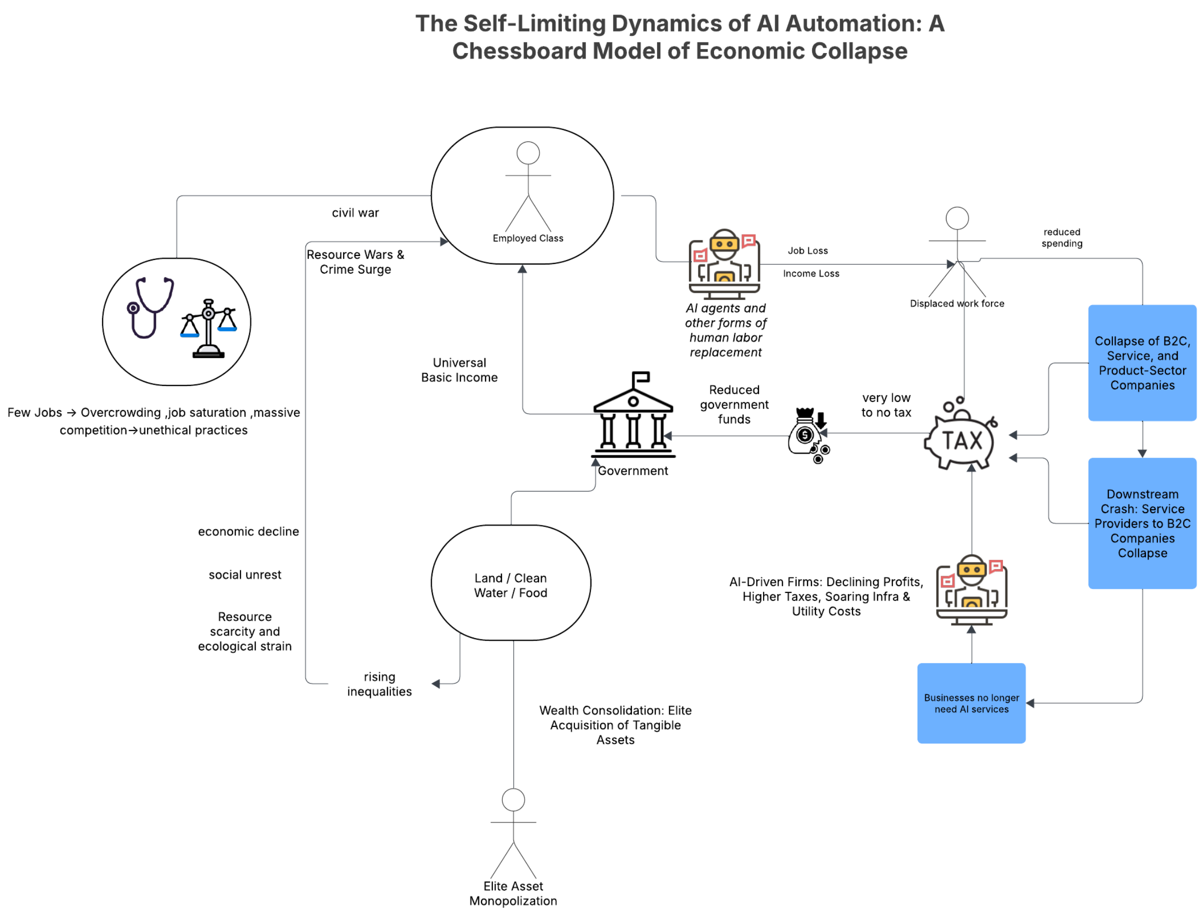

Figure 2: Conceptual Flowchart: The Fallacy of Infinite Efficiency in Post-Human Work Models

The flowchart highlights several critical pathways:

- **Employed Class**: Automation reduces employment, leading to income loss. - **AI Agents and Other Forms of Human Labor Replacement**: Jobs are automated, reducing consumption and tax revenue. - **Government**: Reduced government funds due to lower tax revenues. - **Displaced Workforce**: Unemployed workers lead to reduced spending. - **Taxes**: Very low or no taxes from displaced workers. - **Economic Instability**: Downstream impacts include: - Collapse of B2C, service, and product-sector companies. - Declining profits for AI-driven firms. - Businesses no longer needing AI services. - **Social Consequences**: Resource wars, crime surge, elite asset monopolization, etc.

This conceptual framework serves as the foundation for our simulation, which quantifies these effects dynamically.

8 Policy Implications

Our simulation highlights several important insights relevant to policymakers:

- Automation boosts productivity but must be paced to avoid destabilizing consumer demand [3]. - Taxation and redistribution policies can mitigate collapse by stabilizing consumption [13]. - Universal Basic Income (UBI) could act as a buffer against demand shocks caused by AI-driven unemployment [14]. - Sector-specific interventions may help preserve essential services and prevent cascading failures.

We ground our recommendations in recent UBI experiments: - Finland's 2017–2018 pilot showed increased well-being among recipients [12]. - GiveDirectly's UBI experiment in Kenya found sustained increases in income and mental health [5].

Additionally, our simulations show that UBI successfully stabilizes demand when $\sigma > 0.3$. Below this threshold, stimulus is insufficient to offset demand loss.

8.1 Policy Comparison Table

Table 1: Comparison of Policy Scenarios

Policy Scenario	Employment (%)	Consumption ($)	AI Profit ($)
No Intervention	20%	$15,000	$1,200
UBI ($\sigma = 0.5$)	45%	$32,000	$2,800
Progressive Taxation	30%	$25,000	$2,100
Combined UBI + Taxation	50%	$35,000	$3,000

9 Discussion

The simulation reveals a critical phenomenon: AI-driven automation creates a negative feedback loop that eventually undermines its own profitability [10]. As jobs disappear, consumer demand falls, reducing the very markets AI firms depend on [15].

This aligns with [8], who argues that complexity economics must account for such nonlinear interactions. It also echoes [13]'s warnings about wealth concentration and rising inequality.

Our chessboard model adds a spatial dimension to this understanding, showing how job loss propagates like a virus across sectors and regions [7].

10 Conclusion

This paper demonstrates that infinite automation does not equate to infinite efficiency. Instead, excessive reliance on AI without compensatory mechanisms risks triggering economic instability [9]. Our chessboard model offers a novel visual and analytical framework for studying these effects and emphasizes the importance of designing AI systems within a broader socio-economic context [6].

10.1 Limitations

Our model assumes homogeneous firms and simplified behavioral rules. Future work should explore: - Sectoral heterogeneity (e.g., essential vs. discretionary industries) - Regional differences in automation impact - Dynamic wage adjustments

Code Availability

The Python implementation of the model is publicly available at `https://github.com/MOON11kr/ai_chessboard_economy`. The repository includes scripts for generating both the line graphs and the chessboard heatmap animation.

Supplementary Material

A full-resolution version of the animated heatmap (`ai_disruption_chessboard.gif`) is provided alongside this manuscript for dynamic visualization of the model's behavior.

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