## 1 Variable Definitions and Parameters

Variable	Description	Unit / Scale	
Core Productive	Capacity	<u> </u>	
$X_{ m real}$	Actual productive capacity, derived from primary energy, animal power, and human labor (KWPE).	million kWh	
$X_{ m norm}$	Normalized productive capacity, relative to baseline $X_{\text{real},0}$ .	Dimensionless	
KWPE	Kilowatt Productivity Equivalent: human labor converted to energy- equivalent productivity.	million kWh	
$\begin{array}{c} \mathbf{PrimaryEnergy} \\ (PE) \end{array}$	Total primary energy supply.	million kWh	
AnimalPower $(AP)$	Animal-based mechanical power supply.	million kWh	
Population	Total population.	persons	
ArableLand	Total arable land.	hectares	
Technology and In			
$X_{ m bonus}$	Technology dividend factor, capturing the impact of STEM, education, TFP, and patent growth.	0–5	
STEM	Share of STEM workforce or education index.	Dimensionless	
EduRate	Education enrollment or attainment rate.	Dimensionless	
TFP PatDen	Total factor productivity index. Patent density per capita.	Dimensionless patents / 1000 peo- ple	
Societal Tension I	Metrics	•	
$Z_{ m raw}$	Raw social tension before scaling.	Dimensionless	
$Z_{ m scaled}$	Scaled social tension (normalized).	Dimensionless	
$Z_{ m eff} \ Zc$	Effective societal contradiction index. Societal complexity contradiction index, composite of Gini, poverty, violence, etc.	Dimensionless 0–5	
Gini	Gini coefficient of inequality.	0–1	
MurderRate	Homicide rate.	per 100k pop.	
PovertyRate	Poverty incidence rate.	0-1	
MCapGDP	Market capitalization relative to GDP.	Ratio	
Trust	Social trust index (survey-based).	0–1	
$S_{popdens}$	Population density friction factor.	0-2.5	
Resilience and Stability			
Ω	Structural resilience index (including shocks).	-5 to 5	

Variable	Description	Unit / Scale	
$\Omega_{shock}$	Exogenous shock to resilience (e.g., disasters).	Dimensionless	
Oc	Composite baseline resilience (savings, unemployment, debt, LPI).	Dimensionless	
SavingsRate	Gross savings as % of GDP.	0-1	
Unemployment	Unemployment rate.	0-1	
DebtRate	Government debt ratio.	0-1	
LPI	Logistics Performance Index (normalized).	0–10	
Demography and	,		
PopPressure	Population pressure on land and productivity.	Dimensionless	
$KWPE_{pc}$	Per capita kilowatt productivity equivalent.	kWh / capita	
UrbanRate	Urbanization rate.	0-1	
Contradiction Dyn	namics		
$Y_{base}$	Baseline social tension.	Dimensionless	
Y	Actual societal contradiction level.	Dimensionless	
$Y_{limit}$	Societal carrying capacity (max sustainable contradiction).	Dimensionless	
MilitaryRatio	Military expenditure as share of GDP.	0-1	
$k_Y$	Scaling factor for $Y$ growth.	Dimensionless	
$k_{Limit}$	Scaling factor for carrying capacity.	Dimensionless	
ZImpactK	Weight of social tension $(Z)$ in $Y$ dynamics.	Dimensionless	
YLimitDecayBeta	Decay acceleration factor during negative productivity growth.	Dimensionless	
Crisis and Collapse			
S	Crisis accumulation pool.	Dimensionless	
SDecayRate	Crisis pool decay rate when $Y \leq Y_{limit}$ .	0–1	
$I_{reset}$	Collapse trigger indicator (binary).	0/1	

## 2 Variable Definitions and Parameters

Variable	Description	Unit / Scale
Core Productive Capacity		
$X_{ m real}$	Actual productive capacity, derived	million kWh
	from primary energy, animal power,	
	and human labor (KWPE).	
$X_{ m norm}$	Normalized productive capacity, rela-	Dimensionless
	tive to baseline $X_{\text{real},0}$ .	

Variable	Description	Unit / Scale
KWPE	Kilowatt Productivity Equivalent:	million kWh
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	equivalent productivity.	
PrimaryEnergy	Total primary energy supply.	million kWh
(PE)	rotai primary energy suppry.	IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
AnimalPower $(AP)$	Animal-based mechanical power sup-	million kWh
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Population	Total population.	persons
ArableLand	Total arable land.	hectares
Technology and In	novation	
$X_{ m bonus}$	Technology dividend factor, capturing	0-5
×	the impact of STEM, education, TFP,	
	and patent growth.	
STEM	Share of STEM workforce or education	Dimensionless
	index.	
EduRate	Education enrollment or attainment	Dimensionless
	rate.	2 111011010111000
TFP	Total factor productivity index.	Dimensionless
PatDen	Patent density per capita.	patents / 1000 peo-
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Trust	Social trust index (survey-based).	0-1
$S_{popdens}$	Population density friction factor.	0-2.5
Resilience and Sta	-	
$\Omega$	Structural resilience index (including	-5 to 5
	shocks).	
$\Omega_{shock}$	Exogenous shock to resilience (e.g., dis-	Dimensionless
	asters).	
Oc	Composite baseline resilience (savings,	Dimensionless
	unemployment, debt, LPI).	
SavingsRate	Gross savings as % of GDP.	0-1
Unemployment	Unemployment rate.	0-1
DebtRate	Government debt ratio.	0-1
LPI	Logistics Performance Index (normal-	0-10
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	izou).	

Variable	Description	Unit / Scale	
Demography and Pressure			
PopPressure	Population pressure on land and pro-	Dimensionless	
	ductivity.		
$KWPE_{pc}$	Per capita kilowatt productivity equiv-	kWh / capita	
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UrbanRate	Urbanization rate.	0-1	
Contradiction Dynamics			
$Y_{base}$	Baseline social tension.	Dimensionless	
Y	Actual societal contradiction level.	Dimensionless	
$Y_{limit}$	Societal carrying capacity (max sus-	Dimensionless	
	tainable contradiction).		
MilitaryRatio	Military expenditure as share of GDP.	0-1	
$k_Y$	Scaling factor for $Y$ growth.	Dimensionless	
$k_{Limit}$	Scaling factor for carrying capacity.	Dimensionless	
ZImpactK	Weight of social tension $(Z)$ in $Y$ dy-	Dimensionless	
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	tive productivity growth.		
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S	Crisis accumulation pool.	Dimensionless	
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