Computational Mathematics of the National Impact Velocity (NIV) Engine v6

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Appendix A. Full Construction of the NIV Engine

This appendix explains every variable and computation used in the NIV Engine. All data are taken from the Federal Reserve Bank of St. Louis (FRED) and processed monthly. The purpose is to show, step by step, how the economy's throughput velocity is measured and interpreted.

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1. The Core Equation

The National Impact Velocity is defined as:

$$NIV_t = \frac{u_t\, P_t^2}{(X_t + F_t)^\eta}$$

It captures the speed at which capital regenerates within an economy after accounting for idle capacity and friction.

Where:

- u_t: Activation intensity - the strength of fiscal and monetary impulse.
- P_t: Regeneration share - proportion of GDP reinvested in productive activity.
- X_t: Idle capacity - unused share of productive potential.
- F_t: Aggregate friction - financial and structural resistance.
- η: Friction sensitivity (default = 1.0).

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2. Activation Intensity (u_t)

Purpose: Measures the combined push from fiscal spending, liquidity expansion, and interest rate movement.

Formula:

$$u_t = \tanh(\alpha_1 dG_t + \alpha_2 dA_t - \alpha_3 dr_t)$$

Components:

- dG_t: Monthly change in investment, from FRED ID `GPDIC1`.
- dA_t: 12-month change in broad money (M2), from FRED ID `M2SL`.
- dr_t: Monthly change in policy rate, from `FEDFUNDS`.

Interpretation:

- $u_t > 0$ indicates expansionary impulse (stimulus or easing).
- $u_t < 0$ indicates contractionary impulse (tightening or drag).

Parameter	Symbol	Typical Value	Meaning
Fiscal Sensitivity	α_1	1.0	Responsiveness to changes in investment growth (dG_t).
Monetary Sensitivity	α_2	1.0	Responsiveness to liquidity growth (dA_t).
Interest Resistance	α_3	0.5–1.0	Damping factor for tightening; higher values imply stronger slowdown effect.

Interpretive Logic:

- α_1 amplifies the fiscal transmission channel - more public or private investment produces stronger kinetic activation.
- α_2 amplifies the liquidity channel - rapid M2 expansion directly boosts throughput velocity.
- α_3 imposes monetary braking - higher policy rates proportionally suppress activation.

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3. Regeneration Share (P_t)

Purpose. Represents how much of total output is continuously recycled into productive activity.

Formula.

$$P_t = \frac{I_t + R_t + E_t}{GDP_t}$$

Data Sources.

- I_t: Private investment (`GPDIC1`).
- R_t: R&D proxy (10% of I_t if unavailable).
- E_t: Education proxy (5% of I_t if unavailable).
- GDP_t: Real GDP (`GDPMC1`).

A higher P_t implies more of the economy's output is being regenerated into future capacity.

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4. Idle Capacity (X_t)

Purpose. Captures how much productive capacity remains unused.

Formula.

$$X_t = 1 - \frac{TCU_t}{100}$$

Where `TCU` (Total Capacity Utilization) is from FRED ID `TCU`. If $TCU = 80$, then $X_t = 0.20$ (20% of capacity idle).

A lower X_t means higher utilization and tighter resource conditions.

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5. Aggregate Friction (F_t)

Purpose: Represents combined resistance in the financial system - spreads, real rates, and volatility.

Formula:

$$F_t = \beta_1 s_t + \beta_2 (r_t - \pi_t) + \beta_3 \sigma_{r,t}$$

Components:

- s_t: Yield spread = `DGS10 - TB3MS`.
- r_t: Policy rate (`FEDFUNDS`).
- π_t: Year-over-year inflation from CPI (`CPIAUCSL`).
- $\sigma_{r,t}$: Rolling 12-month volatility of the policy rate.

Interpretation: Higher F_t means rising frictions - tighter credit, higher real borrowing costs, or volatility shocks.

Parameter	Symbol	Typical Value	Meaning
Spread Friction Weight	β_1	0.4	Sensitivity to term spreads (yield curve slope).
Real Rate Friction Weight	β_2	0.4	Sensitivity to real interest burdens ($r_t - \pi_t$).
Volatility Friction Weight	β_3	0.2	Sensitivity to policy uncertainty or rate instability.

Interpretive Logic:

- β_1 measures how yield-curve inversion or steepening alters transmission friction.
- β_2 defines how painful real interest burdens become for capital throughput.
- β_3 captures turbulence - when volatility itself becomes a form of drag.

Default Calibration:

$$(\beta_1, \beta_2, \beta_3) = (0.4, 0.4, 0.2)$$

This configuration balances structural and cyclical frictions, tuned to historical U.S. data (1960–present).

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6. National Impact Velocity (NIV_t)

Purpose. The combined measure of economic motion - how efficiently capital flows through the system.

Formula.

$$NIV_t = \frac{u_t\, P_t^2}{(X_t + F_t)^\eta}$$

Interpretation:

- High u_t, high P_t, low X_t, low F_t -> fast, regenerative economy.
- Low u_t, low P_t, high X_t, high F_t -> sluggish, friction-heavy economy.

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7. Liquidity Stress Intensity (LSI_t)

Purpose. Shows how volatile or turbulent liquidity flow is relative to its baseline.

Formula.

$$LSI_t = \frac{\sigma_{12}(NIV)}{|\mu_{12}(NIV)| + \varepsilon}$$

Where σ_{12} and μ_{12} are 12-month rolling standard deviation and mean.

High LSI_t means unstable liquidity and possible market turbulence.

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8. Structural Drag ($Drag_t$)

Purpose. Indicates how far throughput has diverged from its longer-term equilibrium.

Formula.

$$Drag_t = 1 - \frac{NIV_t}{\mu_{24}(NIV)}$$

If $Drag_t > 0.15$, it implies growing structural slowdown; if $Drag_t < -0.05$, the economy is overextended.

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9. Spectral Ranges (Ideal Zones)

Metric	**Ideal Range**	**Interpretation**
NIV_t	0 to +1 (z-score)	Efficient regeneration without overheating.
LSI_t	0.20-0.30	Active liquidity without stress.
$Drag_t$	-0.05 to +0.05	Balanced long-term throughput.
u_t	0.2-0.5	Sustainable activation.
F_t	0.00-0.02	Smooth transmission, minimal friction.

When all variables lie in their optimal range, the system reaches the **Optimal Throughput Zone** - a state of high capital mobility, regenerative efficiency, and stable liquidity.

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10. Computational Summary

Each month, the NIV Engine performs the following steps:

1. Calculate dG_t, dA_t, dr_t.
2. Compute u_t, P_t, X_t, F_t.
3. Evaluate NIV_t.
4. Derive $LSI_t, Drag_t$.
5. Export $NIV, LSI, Drag$ visualizations.

All calculations are performed using:

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Python 3.11
Libraries: pandas, numpy, matplotlib, fredapi
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11. Interpretive View

- High NIV with stable LSI -> expansion without overheating.
- Rising LSI with falling NIV -> liquidity turbulence (financial stress).
- High $Drag$ -> structural slowdown; economy losing kinetic efficiency.
- Sustained optimal zone -> regenerative, high-mobility economy.

This framework allows policymakers and analysts to see not just static growth, but the living metabolism of the economy - its speed, friction, and regenerative depth.

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12. Calibration Notes

The sensitivity coefficients α_i and β_i are adaptive parameters that can be tuned according to macroeconomic phase:

Regime	**Recommended Adjustment**	**Rationale**
Quantitative Easing (QE)	$\alpha_2 > 1.2$	Monetary expansion amplifies liquidity
Fiscal Stimulus	$\alpha_1 > 1.5$	Investment-driven regimes heighten kineti
Tightening Cycle	$\alpha_3 > 1.0$ and $\beta_2 > 0.5$	Real-rate drag and credit friction do
Volatile Periods	$\beta_3 > 0.3$	System becomes more sensitive to rate u
Secular Expansion	$\beta_1 < 0.3$ and $\beta_2 < 0.3$	Friction coefficients relaxed during long st

Dynamic calibration allows the NIV Engine to remain sensitive yet stable across macro environments, ensuring that throughput velocity reflects real systemic momentum rather than noise.