Cognitive Capital Multiplier (CCM):

An Open-Source Scenario Calculator for Preliminary Assessment of Cognitive Capital Impact on National Innovation Dynamics

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Abstract

Using an empirically estimated elasticity $\beta \approx 0.69$ (95% CI: 0.62–0.78) from a panel of 85 countries over 2001–2024 ($n \approx 2,040$; DOI: 10.5281/zenodo.17454336), we present the Cognitive Capital Multiplier (CCM) — a deliberately simple, fully open-source scenario tool designed exclusively for exploratory "what-if" analysis by policymakers and analysts.

The calculator combines a quality-adjusted measure of cognitive capital with the log-linear regression result to produce transparent, bounded estimates of potential long-term innovation growth. All assumptions and limitations are stated explicitly.

1 Introduction

Numerous economies in the late 20th and early 21st centuries — Singapore, South Korea, Israel, Estonia, Finland — exhibited sharp accelerations in patenting and high-technology exports only after reaching high levels of educational attainment and quality. A recent panel study of 85 countries over 2001–2024 confirmed a robust and statistically significant elasticity of innovation output with respect to cognitive capital of approximately 0.69 in natural logs.

The purpose of this paper is to transform that empirical finding into a transparent, mathematically consistent, and deliberately simplified scenario calculator that can be used by government officials, think-tank analysts, and researchers without specialised econometric training.

2 Cognitive Capital Metric

We construct a composite index of cognitive capital that uses exactly the same data and methodology as the underlying panel regression while remaining simple enough for scenario analysis. Two variants are provided, both standardised in standard deviations from the 2024 global mean:

- **Basic metric** (C_{basic}) = 0.6× (mean years of schooling) + 0.4× (tertiary attainment rate, ages 25–64).
- **Quality-adjusted metric** (recommended) $C_{\text{quality}} = C_{\text{basic}} \times \big(1 + 0.004 \times (\text{average PISA score} - 490)\big)$.

The 0.6/0.4 weights were subjected to sensitivity analysis in the range 0.5–0.7/0.3–0.5; the resulting elasticity β changes by less than ± 0.03 — well within the confidence interval of the original estimate.

3 Empirical Foundation

The core relationship was estimated via dynamic panel techniques on annual data for 85 countries (2001–2024):

$$\ln(\text{Innovation}_t) = \cdots + \beta \cdot C_{t-5\cdots-8} + \text{country \& year FE} + \text{controls} + \varepsilon_t \tag{1}$$

yielding $\beta \approx 0.69$ (95% CI: 0.62–0.78), robust to mixed-effects models, Newey-West standard errors, and Arellano-Bond GMM estimation. While the correlation is strong and survives extensive controls, it remains a controlled correlation rather than proven causation.

4 CCM Formula

The only mathematically consistent long-run extrapolation from a log-linear specification is the exponential form:

$$\text{Innovation}_{2040} \approx \text{Innovation}_{2024} \times \exp(\beta \times \Delta C) \tag{2}$$

With $\beta = 0.69$, a sustained $+1$ SD increase in quality-adjusted cognitive capital is associated with an approximate doubling of innovation output after the historical 5–8-year lag (95% CI: 1.86–2.19×).

5 Open-Source Toolkit

The complete package is publicly available under permissive licences:

- Repository (this exact version):
  `https://github.com/Evoluit-M/Evoluism-S/tree/ccm-v1.0`
- Interactive online calculator:
  `https://cognitive-capital-multiplier.streamlit.app` (live as of 18 November 2025)
- Permanent archive with DOI:
  https://doi.org/10.5281/zenodo.17635565
- Licence: MIT (code) + CC-BY-4.0 (text and data)

6 Illustrative Country Scenarios 2024–2040

Table 1 shows what the corrected exponential formula implies for selected countries under an ambitious but historically precedented trajectory of $+1.2$ SD over 16 years, alongside more realistic Japanese and Brazilian cases.

7 Policy Illustrations (15-year horizon)

Table 2 presents four policy levers that have repeatedly delivered substantial cognitive-capital gains in real-world settings, together with rough cost estimates and country examples.

8 Limitations

The tool intentionally trades sophistication for transparency and accessibility. Key limitations are:

1. Highly simplified cognitive capital metric with tested but ultimately arbitrary weights.

Country	C_{quality} 2024 (SD)	Ambitious ΔC (16 years)	Expected multiplier (95% CI)	Patents 2040 ($\times$ baseline)	High-tech export 2040 (bn USD, approx.)
United States	+2.05	+1.20	2.00$\times$ (1.86–2.19)	$\approx 2\times$	1 800–2 000
Israel	+2.18	+1.20	2.00$\times$	$\approx 2\times$	360–400
UAE	+0.75	+1.20	2.00$\times$	$\approx 2\times$	410–450
Singapore	+2.70	+1.20	2.00$\times$	$\approx 2\times$	1 200–1 300
South Korea	+2.55	+1.20	2.00$\times$	$\approx 2\times$	1 300–1 400
Estonia	+1.95	+1.20	2.00$\times$	$\approx 2\times$	90–100
Japan (realistic)	+2.65	+0.40	1.32$\times$	$\approx 1.3\times$	900–1 000
Brazil (realistic)	+0.55	+1.00	1.99$\times$	$\approx 2\times$	280–310

Table 1: Illustrative scenarios using the mathematically correct $\exp(\beta\Delta C)$ form.

Policy	Expected $\Delta C_{\text{quality}}$	Approx. annual cost (bn USD)	Feasibility examples
Attract 80–120 000 highly educated immigrants per year	+0.3–0.5 SD	2–4	UAE, Canada, Singapore
Increase tertiary attainment by 15 percentage points	+0.3–0.4 SD	0.5–1	Medium (demography-dependent)
Reallocate education spending toward STEM and critical thinking	+0.2–0.3 SD	≈ 0 (reallocation)	Estonia, Finland
Create special zones with research and tax autonomy	+0.1–0.2 SD	0.1–0.2	Context-dependent

Table 2: Indicative policy levers and their historical contribution to cognitive capital growth.

2. Correlation rather than proven causation; risk of endogeneity and omitted-variable bias.
3. Assumption of constant elasticity over long horizons, ignoring possible saturation effects and major shocks.
4. No explicit modelling of R&D expenditure, institutional quality, culture, or geopolitics.
5. Selective country examples (partially mitigated by contrasting cases).

9 Conclusion

The Cognitive Capital Multiplier is not a forecast and makes no claim to precision. It is a transparent, open, and rigorously bounded scenario instrument intended to help policymakers and analysts quickly understand the potential scale of innovation gains from sustained investment in human capital — and to serve as a starting point for more detailed modelling. Contributions, extensions, and constructive criticism are warmly welcomed.

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Permanent archive and reproducible version (code, data, LaTeX source, calculator): https://doi.org/10.5281/zenodo.17635565
Repository (this exact version): `https://github.com/Evoluit-M/Evoluism-S/tree/ccm-v1.0`

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