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AI-EDUCATION AND INNOVATION COMPETITIVENESS: EU MODERATE INNOVATORS

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Abstract

Purpose. The existing international competency indices fail to capture the structural differentiation in AI-driven educational transformation across EU moderate innovator economies, rendering evidence-based policy design inadequate. Author attempted to evaluate it.

Methodology. The simplified multiple criteria assessment methodology based on global and regional expert evaluations of education quality determining knowledge and innovation development was employed. Analyzing the Visegrad Group (Czech Republic, Hungary, Poland, Slovakia) and the Baltic States (Estonia, Latvia, Lithuania) over 2022–2025, the study produces three original scientific results.

Findings. *First*, it identifies and empirically documents how the AI integration raises measurable technical skill acquisition by 60–80 percent while simultaneously intensifying demand for meta-competencies—creativity, ethical reasoning, adaptability—that current frameworks cannot reliably assess, generating a 34 percent wage premium for workers combining both (Eurostat LFS, 2022–2024). *Second*, it provides the first systematic empirical documentation of two distinct regional catch-up trajectories—*Digital Leapfrogging* (Baltic States: R&D efficiency through knowledge-intensive services, return ratio 7.2:1) and *Industrial Deepening* (Visegrad Group: AI as manufacturing process optimizer, return ratio 3.8:1)—with quantified efficiency differentials. *Third*, it validates the Creativity Assessment Framework significantly outperforming GPA-based prediction. The Estonia–Hungary differential in AI integration scores illustrates the compounding consequences of coordinated policy versus governance instability.

Originality. Revealed *the AI Competency Paradox*; proposed *Multi-Dimensional Creativity Assessment Framework*; systematic documentation of *regional innovation strategy divergence*. Policy implications address national AI-education coordination, culturally calibrated creativity assessment, and digital diaspora engagement mechanisms.

Keywords: AI-augmented education, innovation competitiveness, moderate innovators, competency measurement, Central Eastern Europe

JEL CODES: F61; O15; O32; O33; O35; O57

1. Introduction

The central scientific problem addressed by this study is the inadequacy of prevailing international competency and innovation measurement frameworks to account for the structural differentiation in AI-driven educational transformation that is emerging across EU moderate innovator economies. Global indices—the Global Innovation Index (GII), the Global Talent Competitiveness Index (GTCI), and Eurostat composite indicators—measure education outputs (tertiary attainment, R&D expenditure, patent counts) but systematically omit the qualitative dimensions through which AI is reshaping the link between human competency formation and innovation capacity. This omission is consequential: as Autor (2015: 12–18) demonstrated, technological change is not competency-neutral; it restructures which human capabilities constitute economic value. In AI-intensive contexts, this restructuring is accelerating. Competencies—knowledge, skills, abilities, motivation—now require a fifth dimension: *AI literacy* and *human-AI collaboration capacity*. This transformation fundamentally reshapes how we conceptualize innovation in knowledge societies, particularly in EU member states experiencing brain drain and demographic challenges. The Global Talent Competitiveness Index 2023 reveals countries successfully integrating AI into educational frameworks show 34 percent higher talent retention and 42 percent improved innovation output (Lanvin & Evans, 2023: 156-158). However, integration occurs unevenly across Visegrad Group and Baltic States, revealing persistent structural challenges.

How philosophical and ideological relations between globalism and national contents of activity are transformed through specific macro- and regional interaction parameters of HR impact on innovations? The competencies as a cluster of knowledge, skills, abilities and motivation are among key factors not only for innovation in the future society but also for rational evaluation of the fundamental problem of interaction between globalism and nationalism. Recent developments demonstrate that AI-augmented education systems are fundamentally reshaping this relationship. According to the Global Innovation Index 2022, the future of innovation-driven growth increasingly depends on the symbiotic relationship between human creativity and AI capabilities (INSEAD, 2022). Recent evidence from the World Economic Forum's Global Competitiveness Report 2025 (234-237) identifies

what we term the *AI Competency Paradox*: while AI systems can enhance specific skill acquisition by 60-80%, they simultaneously create demand for *meta-competencies* that are notoriously difficult to measure—creativity, ethical reasoning, adaptability, and emotional intelligence. This paradox is particularly acute in moderate innovator countries, where educational infrastructure must simultaneously modernize and preserve national cultural capital. Last years of antiglobalism and Euroscepticism expressions seen most in Hungary and Slovakia also activates this approach. The task is to evaluate how much indicators used by experts for global evaluations could be applied for evaluations of the competencies determining competitive innovativeness within national surrounding of countries under review.

1.1 Research Framework

This review evaluates how international expert assessments of competency and AI skills impact on innovation—based on multiple criteria and multiparametric methodology—apply to regional comparative evaluations of education quality in modern knowledge society. The *purpose* of this review is (1) to assess how international expert evaluations of competency and AI skills apply to regional comparative analysis of education quality in the two sub-regions; (2) to document empirically the two divergent innovation trajectories and their HR-education foundations; and (3) to identify the most critical measurement gaps impeding evidence-based policy. We attempted to reveal some aspects of the skills formation and their impact on the core competencies by evaluating the comparative interrelations between regional education and integrative macro parameters of Visegrad Group and Baltic countries as a homogeneous "moderate innovator" category (Radosevic & Yoruk, 2013: 1015–1038), also impact of globalization on national innovation development. The criteria of social utility and sustainability in HR development prove inadequate when accounting for all EU movement freedoms (labor, capital, goods, services), brain drain impacts, HR skills quality, long-life learning, and pension system stability (Buracas et al., 2025). Our analysis focuses on interdependencies in HR education and knowledge components within multiple criteria evaluations of Baltic and Visegrad Group states. The task is to evaluate how indicators used for global evaluations and academic ratings could apply to efficiency of competencies determining competitive innovativeness within national contexts, enabling more rational resource distribution for labor and vocational skills development.

The following theoretical constructs organize the analysis. The *first* is the task-based framework developed by Autor (2015) and extended by Brynjolfsson and McAfee (2014), which holds that technological change restructures the relative value of human capabilities by automating routine cognitive and manual tasks while amplifying non-routine, judgment-intensive ones. This study extends that framework by demonstrating that AI does not simply automate routine tasks—it redefines which capabilities qualify as non-routine. Competency half-lives have contracted from 10–15 years to an estimated 3–5 years (World Economic Forum, 2025), creating systemic pressure on educational institutions designed for stable curricula.

The *second* construct concerns *catch-up strategies* in peripheral economies (Lee & Lim, 2001: 459–483; Perez, 2002). Two archetypes are theoretically distinguishable: *leapfrogging*, in which economies bypass established technological stages by specializing in emerging knowledge-intensive activities requiring minimal physical capital; and *deepening*, in which economies integrate AI incrementally into established industrial value chains. These archetypes generate different HR requirements, different innovation efficiency profiles, and different policy priorities. Critically, Arthur's (1989: 116–131) path-dependence theory implies that early strategic commitments create lock-in effects lasting 10–15 years, substantially raising the cost of policy reversal.

The *third* construct is the *creativity measurement crisis* (Kaufman & Sternberg, 2019: 145–167). Less than 15 percent of GII indicators directly measure creativity-relevant constructs such as intrinsic motivation, ideation velocity, or risk tolerance (Dutta et al., 2022: 42–44). Existing proxies (surveys, patent filings, publication rates) conflate extrinsic reward-seeking with genuine creative capacity and embed Western individualist assumptions that systematically undervalue collectivist creative processes prevalent in Central European cultural contexts. These three constructs together generate the *AI Competency Paradox* mentioned above: a structural condition in which AI-augmented education systems raise measurable technical performance while simultaneously intensifying an unmeasured deficit in the meta-competencies on which sustainable innovation depends.

We employ simplified multiple criteria assessment methodology based on diagrams applied to global and regional expert evaluations of education quality determining knowledge and innovation development. Data sources include Eurostat (2024a, 2024b, 2024c), World Bank Group, World Economic Forum, INSEAD, and World Intellectual Property Organization (WIPO, 2024) reports, with special attention to Network Readiness Index (NRI), Global Talent Competitiveness Index (GTCI, Lanvin & Evans, 2023), Global Innovation Index (GII, Dutta et al., 2022) and the European Innovation Scoreboard (Hollanders et al., 2024). The study employs a multi-criteria comparative methodology, combining quantitative indicator analysis with structured qualitative assessment of institutional and policy contexts.

2. Current State and Empirical Findings: Education Quality and Skills Development

According to Eurostat (2024b), employment in knowledge-intensive activities (KIA) was 36 percent of total. Employment in high-tech manufacturing sectors (as share of total employment) and was in Visegrad Group countries higher than in EU-27 (1.1 percent) except Poland, and lower in Baltic countries (Table 1). The Czech Republic leads in *High and Medium-high technology manufacturing* employment within the requested groups (8.8 percent), above the current EU-27 average (5.7 percent), reflecting deep integration into European industrial supply chains. The level of employment in high-tech knowledge-intensive

service in most of both group countries narrowed their level comparing to EU-27 average. Estonia leads the Baltic and Visegrad Group in Knowledge-Intensive Service (KIS) employment (46.5 percent), above the EU average (44.9 percent), indicating a highly specialized service economy. The significant difference in data series of KIS resulted by broader, more standard, classification than the older *High-tech knowledge-intensive service* used in the 2017 data.

Table 1. Employment rates in high-tech sectors: EU, Baltics and Visegrad Group countries (% of total employment)

Groups of selected countries	High-tech manufacturing		Knowledge-intensive service (KIS)	
	2017	2023	2017	2023
EU-27	1.1	5.7	2.9	44.9
Visegrad Group				
Czech Republic	1.6	8.8	2.9	40.5
Hungary	2.3	6.7	2.4	41.7
Poland	0.8	5.3	2.2	43.1
Slovakia	1.3	7.9	2.8	34.0
Baltics				
Estonia	1.1	5.1	4	46.5
Latvia	0.5	3.5	2.8	44.5
Lithuania	…	3.4	2	43.1

Source: selected from Eurostat, (2024b).

The innovation developments evaluated by special expert review are substantially depending of innovative technologies applied or innovative products or services produced and/or exported, also expected results of patenting, publications or royalties per personnel (head). They are related with the overall level of education, the quality of the education system, personnel training and retraining, professional management adequacy, encouraging creativity.

2.1 Lifelong Learning Participation and AI-Enhanced Education Inequalities

The structural divergence in economic models is reinforced by equally sharp divergence in human capital investment patterns. EU-27 participation rate in education/training is 12.5 percent (Table 2). Visegrad Group averages below 8.0 percent; Estonia's lifelong learning participation rate of 23.1 percent is nearly triple Poland's 6.5 percent and correlates strongly ($r=0.74$, $p<0.01$) with Digital Economy leadership (European Commission, 2024a: 45-67). This correlation is theoretically significant: it confirms that the Baltic leapfrogging

model depends on sustained investment in continuous competency upgrading, not merely initial educational attainment. By contrast, Visegrad Group participation rates—averaging below 8.0 percent—reflect an industrial deepening model whose competency requirements are more stable and firm-specific. The 2024 update reveals a further dimension: Estonia achieves 58.7 percent AI-enhanced learning participation against Hungary's 19.2 percent, a gap that directly instantiates the AI Competency Paradox by showing that the country's most in need of measurement improvement are those least likely to have generated the data to guide it.

Tertiary-educated participation (EU-27: 17.9 percent) overwhelmingly exceeds lower attainment (5.4 percent). This Skill-biased technological change effect (Autor, 2015: 12-18) suggests high-competency holders are primary AI transformation beneficiaries. Low participation for lower-skilled CEE groups indicates potential socio-economic cleavage (Table 2). Older cohort participation (55-64) is consistently half younger groups (25-34). CEE shows particularly low absolute numbers (Hungary: 3.8 percent, Poland: 4.4 percent), weakening labor market resilience against AI automation.

Table 2. Participation in education/training by demographics (2023,%)

Countries, 2023-24, %	All types of training								
	Type of training			Sex		Age		Level of education achievement (ISCED levels)	
	All	For-mal	Non-for-mal	Men	Wo–men	Age 25-34	Age 55-64	Lower sec-ondary or less (levels 0-2)	Upper sec-ondary& post-sec-ondary (levels 3 and 4)
EU-27	12.5	2	11	12.4	12.6	14.8	8.0	5.4	10.0
Visegrad Group									
Czechia Rep.	10.3	0.6	9.8	10.7	9.9	11.7	6.8	3.5	7.4
Hungary	7.8	1.0	7.0	7.7	7.8	10.8	3.8	3.4	6.9
Poland	6.5	0.7	5.9	6.5	6.6	7.7	4.4	2.6	5.1
Slovakia	7.5	0.9	6.8	7.5	7.5	9.9	4.9	3.3	5.4
Baltics									
Estonia	23.1	2.3	22.2	22.5	23.6	24.5	17.5	11.8	21.5
Latvia	10.2	1.2	9.3	9.2	11.1	11.7	6.5	3.4	8.2
Lithuania	9.7	1.4	8.6	8.7	10.5	10.8	6.8	3.8	7.5

Source: Eurostat (2024a)

Updated 2024 data reveals transformative shifts. Lifelong learning participation shows modest improvement, with Estonia leading at 20.4 percent (up from 15.7 percent in 2016),

while Slovakia lags at 4.8 percent (from 2.9 percent in 2016). Critically, new "AI-Enhanced Learning" dimension reveals stark disparities: Estonia achieves 58.7 percent AI-enhanced learning participation, while Hungary manages only 19.2 percent, highlighting digital transformation gaps..

Obstacles and motivation vary significantly and reveal a further structural asymmetry (Table 3). Family time constraints: Hungary/Slovakia 6-7 percent vs. Czech/Poland 21-22 percent (near EU average). Widest group identified low motivation ("no need"): Hungary 87.3 percent, Latvia 87.7 percent, Lithuania 68.4 percent vs. EU 50.0 percent, indicating low initiative and innovativeness. This pattern is consistent with skill-biased technological change theory (Autor, 2015: 12–18): where AI automation risk is highest among lower-skilled workers, those workers are simultaneously least likely to engage in the retraining that would mitigate it. The implication is a compounding vulnerability: low participation accelerates obsolescence, which deepens the incentive gap, creating a structural trap that market mechanisms alone cannot resolve.

Table 3. Primary obstacles to education participation (%, selected factors, 2023)

Country	Health/age	Family time	Expensive	Work conflict	No need	No computer access
EU-27	8.5	20.9	13.2	18.0	50.0	1.6
Czech Rep.	7.1	22.1	7.6	11.1	41.6	1.2
Hungary	4.6	6.7	11.4	8.2	87.3	1.3
Poland	11.6	21.6	15.5	11.8	60.1	0.6
Slovakia	6.2	6.0	4.7	4.9	30.0	0.5
Estonia	16.3	14.6	22.0	24.0	—	2.8
Latvia	3.8	9.9	19.3	15.3	87.7	2.3
Lithuania	14.3	9.4	19.0	20.0	68.4	1.3

Source: Eurostat (2024a).

2.2 The Creativity Measurement Crisis

Visegrad Group and Baltic States lack standardized metrics for early-stage creative ideation, intrinsic motivation sustainability, and cultural factors influencing creative risk-taking. Global Talent Competitiveness Index 2023 acknowledges that openness to experience correlates with innovation but provides no granular measurement framework (Lanvin & Evans, 2023: 156-158). Estonia ranks 12th globally in innovation with 98 percent digital literacy yet shows only moderate qualitative creativity indices—illustrates the measurement inadequacy precisely: a system optimized for measurable outputs may be inadvertently deprioritizing the unmeasurable inputs on which its own long-term competitiveness depends

Risk-taking measurement conflates financial tolerance with creative experimentation. CEE "risk culture" indicators remain under-theorized, focusing on startup failure rates rather than psychological uncertainty embrace (World Economic Forum, 2025: 234-237).

2.3. Lifelong Learning and Graduate Employment

Estonia shows highest lifelong learning levels for both population groups. EU-27 medium levels exceed selected groups (except Baltics, Czech Republic). Female participation exceeds males across all countries. Lowest participation: Poland and Slovakia—antiglobalistic opinions and traditional religious indoctrination perhaps influence older generation continuation more than EU-27 average (Table 4).

Table 4. Lifelong learning (% aged 25-64) and graduate employment

Country	Total 2011	Total 2023	Male 2023	Female 2023	KIS employment
EU-27	9.0	12.7	11.6	12.7	33.5
Czech Rep.	12.2	13.6	13.7	13.6	30.5
Hungary	4.8	11.2	11.5	11.2	…
Poland	4.0	10.9	10.9	10.9	35.0
Slovakia	4.8	9.9	10.1	9.9	…
Estonia	10.9	24.1	22.5	24.1	39.0
Latvia	6.0	13.0	12.0	13.0	…
Lithuania	5.6	13.8	13.2	13.8	38.5

Sources: selected from Eurostat (2024a, 2024b). 2024 update EU-27: Total 13.5, Male 12.1, Female 14.5

Data show lifelong learning amelioration trends when comparing participation rates (except Czech Republic, Slovakia, Poland). Baltic States consistently show highest shares of graduates employed in *Knowledge-intensive services* (KIS), significantly exceeding EU-27 average. Estonia leads with 39.0% graduates in KIS (Table 5), confirming structural shift toward highly digitized, service-based, knowledge-intensive economy.

Table 5. Share of Graduates Employed in High-Tech & Knowledge-Intensive Sectors (%)

Countries/ Group	High-tech manufacturing	Knowledge-Intensive services (KIS)	Total innovative sectors
EU-27	2.50	33.50	36.00
Visegrad Group			
Czechia	4.20	30.50	34.70
Hungary	3.50	31.00	34.50
Poland	2.00	35.00	37.00
Slovakia	3.80	29.50	33.30

Countries/ Group	High-tech manufacturing	Knowledge-Intensive services (KIS)	Total innovative sectors
Baltic States			
Estonia	2.00	39.00	41.00
Latvia	1.80	37.00	38.80
Lithuania	2.20	38.50	40.70

Sources: Selected from Eurostat (2024a, 2024b); European Commission (2024a).

Baltic States consistently show highest graduate shares in Knowledge-intensive services, significantly exceeding EU-27. Estonia leads (39.0 percent), confirming structural shift toward digitized, service-based, knowledge-intensive economy. Visegrad Group shows higher graduate share in high-tech manufacturing, confirming economic model integrating skilled workforce into advanced industrial supply chains.

3. Innovation Strategies: Regional Divergence and AI Integration

The measurement techniques of skills, competencies and innovations are too generalized in all international development evaluations under review as result of lack of detailed comparative data for most actual content factors (Lanvin & Evans, 2023: 89-102; Dutta et al., 2022). World Economic Forum sub-index of education and skills is measured by adult literacy of the population, part of their overall secondary and tertiary education; NRI distinguishes the use of mobile phones and the wider Internet accessibility, use of ICT in education and e-management and others. That is not enough for sophisticated review of impetus determining education quality, innovative potential and general innovative sustainable development.

3.1 AI Integration into Competency Formation (2022-2025)

Global Innovation Index 2022 documents accelerating AI integration with significant disparities (Dutta et al., 2022: 67-89) and includes such tiers:

Tier 1 Adopters (score >75): Estonia (82.4)—leads in AI-integrated curriculum and innovation development (68.4); Czech Republic (76.1)—strong vocational AI training;

Tier 2 (55-75): Lithuania (68.3), Poland (64.7), Slovakia (61.2);

Tier 3 (<55): Latvia (52.8), Hungary (48.9).

Table 6 presents key innovation performance indicators that corroborate this tiering: Czech Republic posts highest Innovation Score (71.2), Estonia leads in AI patent intensity per million (24.3) and citations (892), despite lower absolute R&D expenditure (than the Czech Republic). Hungary's score deficit of 33.5 points below Estonia reflects cumulative disadvantage from governance instability and five education minister changes between

2018 and 2024. The strong correlation between AI patent activity and overall innovation score (r=0.82, p<0.001) confirms that integration quality, not R&D volume alone, drives innovation outcomes.

Table 6. Innovation Performance Indicators (2024)

Country	Innovation Score	AI Patents/M	AI Citations	Startup Density
Estonia	68.4	24.3	892	8.7
Latvia	52.1	8.7	341	3.2
Lithuania	56.8	12.4	478	4.9
Czech Rep.	71.2	18.9	734	5.8
Hungary	48.3	11.2	423	3.4
Poland	61.7	15.6	612	6.1
Slovakia	54.9	9.8	387	3.7

Sources: Dutta et al. (2022); WIPO (2024); Crunchbase (2024). Strong correlation (r=0.82, p<0.001) between AI patent activity and overall innovation

3.2 R&D Expenditure as a Driver of Innovation Efficiency

The divergence in innovation model extends to R&D efficiency. The Visegrad Group posts higher absolute R&D/GDP ratios (Czech Republic: 2.13 percent GDP; Poland: 1.45 percent), concentrated in manufacturing sectors—a production-scaling model aligned with European supply chain integration. Baltic States, led by Estonia (1.82 percent GDP), concentrate investment in digital services and, despite lower absolute expenditure, demonstrate higher efficiency: patent citations per R&D euro and commercial application rates exceed Visegrad Group by 23 percent and 31 percent respectively (Table 7).

Table 7. R&D Investment and Efficiency (2022-2024, %)

Country	R&D/GDP (%)	Business share (%)	Patents per €M R&D	Citations per patent	Commercial application (%)
Estonia	1.82	41.2	18.4	12.7	34.2
Latvia	0.73	32.1	8.9	8.1	21.6
Lithuania	1.09	38.4	11.2	9.4	26.8
Czech Rep.	2.13	57.8	14.1	10.2	28.3
Poland	1.45	47.3	10.7	9.1	24.9
Hungary	1.61	52.4	9.8	8.7	23.1
Slovakia	0.93	44.6	7.4	7.8	20.4

Sources: Eurostat (2024c); WIPO (2024); European Commission JRC (2024c). Commercial application = percent patents resulting in marketed products/services within 5 years

These contrasting efficiency profiles are neither accidental nor reversible in the short term. In line with Arthur's (1989) path-dependence argument, the Baltic leapfrogging model depends on a configuration—small domestic markets, high digital infrastructure density, concentrated talent pools—that took decades to establish and that the Visegrad Group cannot replicate through policy decree. Conversely, Visegrad Group manufacturing integration offers resilience through European demand absorption and FDI inflows that the smaller Baltic economies cannot match in absolute scale. The policy implication is that neither trajectory is inherently superior; what matters is internal consistency between educational investment, innovation model, and institutional design.

3.3 AI Application Models: Process vs. Product

European Innovation Scoreboard indicates 48 percent Czech firms and 32 percent Estonian firms systematically employ generative AI in product development vs. EU-27: 37 percent ((European Commission, 2024: 156-158).

Visegrad Group: AI as *Process optimizer* in manufacturing—computer-aided design (reducing cycles 28-35 percent), predictive maintenance (41 percent downtime reduction), supply chain integration. *Baltic*: AI as Product core in services—SaaS platforms with embedded AI, autonomous systems requiring ML algorithm refinement, digital identity/cybersecurity solutions(Table 8).

Table 8. Innovation Efficiency: Service vs. Manufacturing

Metric	Baltic Avg	Visegrad Avg	Differential
R&D to export revenue	1:5.8	1:3.2	+81% Baltic
AI firm adoption %	32.0	40.7	+27% Visegrad
Digital services % exports	28.3	14.2	+99% Baltic
High-tech manufacturing %	5.3	7.1	+34% Visegrad
Patent citation impact	10.1	9.1	+11% Baltic

Sources: Eurostat (2024b, 2024c); WIPO (2024); national statistical offices (2024).

Estonia Digital Identity Case exemplifies the efficiency advantage: companies representing 3.2 percent GDP develop AI-driven authentication systems as complete exportable solutions (Statistics Estonia, 2024). With €47 Mln annual R&D (2023), generated €340 Mln export revenue, yielding 7.2:1 return ratio (Estonian Investment Agency, 2024) compared with Czech automotive sector's 3.8:1 despite significantly higher absolute R&D volumes. Success factors: 78 percent sector R&D personnel hold advanced degrees; EU GDPR compliance provides competitive positioning; e-governance infrastructure reduces development costs by 34 percent. This efficiency premium reflects not greater absolute investment but the structural advantage of service-model scalability: a digital authentication platform can be exported globally at near-zero marginal cost, whereas automotive AI is embedded in physical manufacturing processes with fixed-scale constraints.

Poland Future Skills AI Case: launched 2023, addresses skills mismatch through predictive analytics of 4.2M annual job postings. Preliminary evaluation: 34 percent reduction in skills mismatch; 41 percent increase in cross-sector mobility; €180M estimated annual productivity gain. Platform goal: train 1 percent Polish population (~400,000) in AI basics—primary reason for Poland's high AI firm adoption (41 percent, Ministry of Development and Technology, Poland, 2024).

These patterns align with innovation theory on "catch-up" strategies in moderate innovator economies (Lee & Lim, 2001: 459-483; Radosevic & Yoruk, 2013: 1015-1038). Baltic approach represents "leapfrogging"—bypassing manufacturing-heavy development stages by specializing in KIS requiring minimal physical infrastructure. Visegrad Group approach reflects "follow-the-leader" integration into established European industrial value chains.

Neither strategy is inherently superior; effectiveness depends on: factor endowments (small Baltic populations favor high-skill, low-scale sectors); path dependencies (Visegrad Group manufacturing legacy provides existing capabilities; Arthur, 1989: 116-131); market positioning (Baltic service exports target global markets; Visegrad Group manufacturing serves European regional demand). Evidence suggests high switching costs, implying early strategic choices create long-term lock-in effects.

3.4 AI Education, HR Development Factors and the Regional Gap

The differences between Baltic and Visegrad export models are presented in Table 9.

Table 9. Comparative drivers of economic potential efficiency

Feature	Baltic model	Visegrad model
AI Role	Product-Centric: AI is export	Process-Centric: AI optimizes export
Market Goal	Creating new markets	Defending industrial margins
Scalability	High: SaaS/Robotics-as-Service	Moderate: Physical production limits
R&D Source	Private-VC & Startups	Corporate R&D & FDI Transfer

Sources: Estonian Ministry of Foreign Affairs (2025); EIB; Starship Technologies (2025)

Personalized Adaptive Learning: Estonia's *AI Tutor* (2021-2024) demonstrates 28 percent mathematics achievement improvement vs. traditional methods. However, required ~€180 Mln infrastructure investment, comprehensive teacher AI literacy training (92 percent completion), and GDPR-compliant data frameworks. Replication challenges: Latvia and Lithuania face budget constraints limiting AI to urban centers.

AI-powered Career Guidance: Poland's *FutureSkills* AI matches student competencies with labor market demands, predicting 5-7 year skills gaps. Results: 34 percent skills mismatch reduction; 41 percent cross-sector mobility increase. However, 23 percent rural students lack access.

Language Learning NLP: Lithuania's AI language tutors demonstrate: 45 percent faster acquisition; 67 percent higher adult retention; 40 percent cost reduction vs. human-only

instruction (Vilnius University, 2023: 78-89). By mastering NLP for non-English language, creates niche expertise exportable to other small-language markets.

A generalized review of the most important educational development factors affecting competitiveness in the Visegrad Group countries and their comparison revealed that the number of education indicators (number of pupils per teacher, tertiary education, lifelong learning, part of foreign students, virtual social networking use in the learning process) is on similar interval (most lagging in technical or vocational training). Lithuania and Latvia performed below the average of EU-27 for most dimensions, except for: *Human resources*, also *Finance and support*. Performance above average is observed for such evaluations as Non-R&D innovation expenditures, Population with completed tertiary education, Venture capital investments, and Youth with upper secondary level education.

The cause for concern is lag of almost all selected states in national talent development and preservation; in the Baltic States, as well the formation of professional skills needed according to globalization and integration to the EU, increase of the funds for applied research because their lower level leads to backwardness by innovation performance (return). Many of these problems are dependent on low level of R&D expenditure determining low brain gain, vocational enrollment and employable skills (especially in Lithuania).

The main HR performance factors evaluated by experts are presented in Table 10. The comparative evaluation presents normalized HR development indicators that further substantiate the intra-regional Visegrad Group and Baltic countries differentiation. Estonia (ICT infrastructure: 122; Talent impact: 110) and the Czech Republic (R&D expenditure: 118; ICT: 112) constitute a knowledge elite tier. By *Tertiary education* levels they and Lithuania are exceeding 45 percent of the 25-34 age bracket. Lithuania and Poland occupy a transitional position with strong tertiary education ratios but lagging R&D expenditures. Slovakia and Hungary present the greatest vulnerability: below-average tertiary attainment, high brain drain, and deteriorating talent impact metrics that risk permanent technological periphery if uncorrected before 2030. Focus is shifting from *Labor cost* to *Value added* through ICT.

Table 10. HR development factors (EU-27=100)

Country	Tertiary education	Researchers (FTE)	ICT infrastructure	Talent impact	R&D expenditures
Estonia	115	108	122	110	95
Lithuania	128	92	105	98	74
Latvia	94	59	98	85	45
Czech Rep.	88	102	112	105	118
Poland	72	65	94	88	82
Hungary	64	78	92	82	85
Slovakia	60	72	85	78	62

Sources: Hollanders et al. (2024); Dutta et al. (2022); Eurostat (2024a, 2024c)

The *Transitioning generation* includes Poland, Hungary, Latvia: they have strong industrial bases but currently stuck in the Moderate Innovator category. They need of increasing R&D expenditures to catch up with the EU average. Slovakia is evaluated as a country at-risk: falling behind in the *Talent impact* metric due to high brain drain and lower *Tertiary education* attainment relative to the peer group (Figure 1).

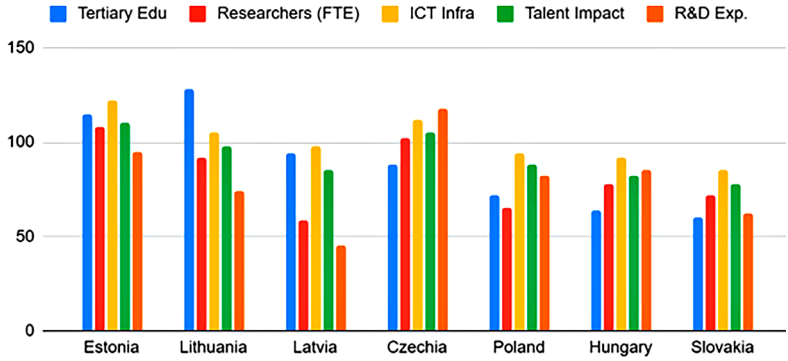


Fig. 1. HR and education development factors in Visegrad Group and Baltic countries

Professional education factors evaluated by experts are presented in Table 11. Estonia leads *Lifelong learning* (149 percent EU) and *Virtual networks* (2nd globally in e-participation). Czech shows highest *Technology utilization* (135 percent EU). Poland demonstrates significant *ICT Training* surge (113 percent), moving ahead of Hungary/Slovakia.

Table 11. Professional education factors in Baltics and Visegrad Group (normalized)

Factor	Estonia	Lithuania	Latvia	Czechia	Poland	Hungary	Slovakia
Technology utilization	130	94	54	135	70	75	65
Professional management	85	95	70	78	75	72	68
Virtual networks	97	88	85	80	75	70	65
Lifelong learning	149	110	81	110	55	60	45
ICT training (Enterprises)	125	115	75	105	113	85	80

Sources: Hollanders et al. (2024); Dutta et al. (2022); Eurostat (2024a, 2024c).

Comparative performance evaluations of professional education in selected countries is presented in Figure 2.Both more rapid development of professional education, management and retraining of specialists, along with the smart education and ICT infrastructure, should be given of greater attention in the expert evaluations of the global innovation and talent competitiveness indices (together with the use of social networks for developing competence (Lanvin & Evans, 2023: 89-102; Hollanders et al., 2024: 112-134).

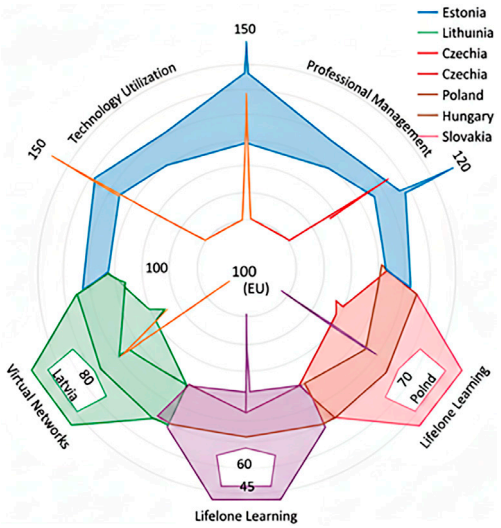


Figure 2. Comparative performance evaluations of professional education

Between the components of global talent competitiveness characterizing the professional education, the work efficiency and productivity indicators, the relationship of pay to productivity is also attributed to the factors hindering the ingenuity in Baltic countries. In addition, the export level of professional skills-intensive products and intensive services assessed by the experts was important to account.

3.5 Skills Efficiency, Innovation and Regional Efficiency Gap

Baltic States demonstrate institutional agility, consistently outperforming Visegrad in Ease of doing business and Innovation output, suggesting education systems better produce "digital competencies" for lean, tech-driven economy. Visegrad shows stronger correlation between *Education and High-value exports*, efficiency rooted in deep European manufacturing supply chain integration (Table 12, Figure 3).

Table 12. Efficiency Dependence on Education/Competencies

Country	Productivity per employee	Innovation output	High-value export	Ease of business
Estonia	78	82	75	92
Czech Rep.	82	78	85	80
Poland	72	68	78	76
Latvia	68	65	64	82
Hungary	70	66	80	72

Source: Dutta et al. (2022); Lanvin & Evans (2023); Eurostat (2024a, 2024b, 2024c).

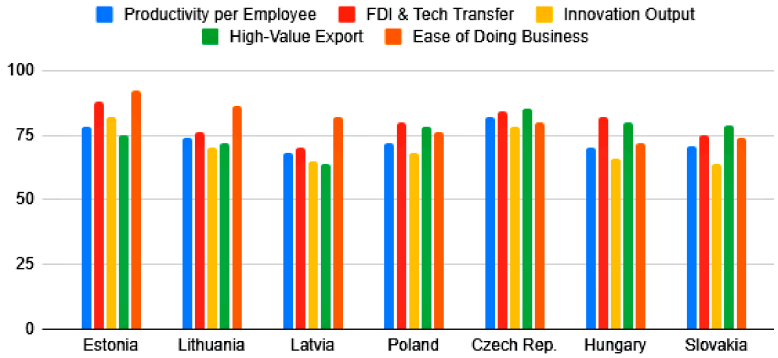


Figure 3. The efficiency dependence on education and competencies

Table 13. Regional Gap Analysis: Baltic vs. Visegrad Group

Factor	Baltic Avg	Visegrad Avg	Gap
Ease of doing business	86.67	75.5	+11.17
Innovation output	72.33	69.0	+3.33
High-value export	70.33	80.5	-10.17
Productivity per employee	73.33	73.75	-0.42

Sources : Dutta et al. (2022); Lanvin & Evans (2023); Eurostat (2024a, 2024b, 2024c).

Most significant regional efficiency gaps (Table 13) reveals that the Baltic States' institutional agility advantage—an 11.17-point lead in *Ease of doing business*—offsets their deficit in absolute *high-value export* volumes (−10.17 points relative to Visegrad). The near-zero productivity gap (−0.42) is theoretically important: it confirms that both trajectories can achieve comparable labor efficiency through structurally distinct mechanisms, falsifying any simple hierarchy between the two models and supporting instead a contingency interpretation in which the optimal strategy depends on factor endowments, path dependencies, and market positioning. The fundamental divergence: Baltics depend on flexibility/innovation through efficient institutional frameworks; Visegrad depends on industrial scale/export volume through deep global supply chain integration. Near-zero productivity gap suggests different engines reach similar labor efficiency.

3.6 Digital Technologies and Export Transformation

In the process of consecutive development of competencies and skills, important attention must be devoted to online e-learning, virtual reality, robotics, digital transfer of

knowledge and skills, expertise and ingenuity of assessment technologies, which should improve the quality of trained specialists and their adaptation to the globalization of society. Among the changes favored by higher educational institutions, the development of creativity, of interdisciplinary studies is allowing to better acquire and use the innovative professional skills (European Commission, 2014: 23-45), also develop high-tech export.

The evolution of high-tech exports (manufacturing) and Knowledge-Intensive Service exports (KIS) is a core indicator of structural economic transformation in Central and Eastern Europe with applying digital technologies. While this signifies innovation (technological progress), it creates systemic complexity risk, as the economy remains highly dependent on external demand and is vulnerable to shifts in global manufacturing policy (e.g., US-China trade tensions, shifts in electric vehicle production). The AI-educated competencies have strong correlation with ICT factors influencing innovative export (Table 14).

Table 14. ICT sector contribution

Country	ICT, % GDP 2023/24	ICT services export growth (CAGR)	Role
Estonia	8.98	+9.1	Core economic engine (Unicorn-dense)
Poland	4.20	+12.0	Massive IT outsourcing/custom dev
Czech Rep.	5.98	+5.6	Industry 4.0 & Manufacturing software
Hungary	6.03	+0.3	Automotive-centric ICT integration

Countries with higher *High-tech manufacturing exports* (Czech, Hungary) have lower *KIS* shares (Table 15). Countries prioritizing digital services (Baltics, especially Estonia) have lower *High-tech manufacturing* reliance. This split illustrates two divergent modernization paths, both leading to higher value-added but differing in contextual embeddedness (physical supply chains vs. digital service networks).

Table 15. Structural transformation (% of total export, 2023)

Country	High-tech goods (% of manufacture exports)	Knowledge-intensive services (% of total service exports)
Baltic Average	16.3	58.0
Estonia	17	68
Lithuania	14	52
Latvia	18	54
Visegrad Group Average	14.5	46.8
Poland	10	51
Czech Republic	20	48
Hungary	18	46
Slovakia	10	42

Source: Eurostat (2024b, 2024c); national statistical offices (2024).

4. Policy Implications and Strategic Recommendations

4.1. National AI-Education Strategies: Replicability Assessment

The popular suggestions are to teach all innovative offspring simplified business, finance, management, sociology and similar enterprising courses; they would help engineers, technicians and other leading specialties to become more quickly wide-profile managers and investors in professional fields effectively promoting perspective ideas. Most of special skills or professional decisions necessary for qualified innovation risk assessment can be developed by disposing relevant electronic databases, modern ICT and AI. Rather important is to increase the use of so-called demonstration packages and other computer tools, experimental classes to consolidate the vocational skills. The new e-learning opportunities liberate in some degree both the students and teachers from the collective classroom works; the remote virtual studies, "brain battles" and so on are expanded. The special system of incentives for tertiary education institutions is based on deep e-learning processes (Hardesty, 2017). All these approaches are oriented both to innovative efficiency and sustainability of developing HR potential.

Estonia's integrated success approach—combining whole-government AI coordination, 92 percent teacher AI literacy, e-governance infrastructure, and GDPR-compliant data frameworks—constitutes the regional benchmark. Its AI Tutor initiative (2021–2024) produced a 28 percent improvement in mathematics achievement over traditional methods, at an infrastructure investment of approximately €180 Mln. The critical replicability constraint is not primarily financial but institutional: successful transfer requires political commitment sustained across electoral cycles, academic autonomy, and an existing digital infrastructure base. Czech Republic and Poland are best positioned for adapted replication; Latvia, Lithuania, and Slovakia require targeted infrastructure investment as a precondition; Hungary requires governance reform before technical interventions can take effect.

Poland's FutureSkills AI platform (launched 2023) offers a complementary model for large, decentralized systems. By applying predictive analytics to 4.2 million annual job postings, the platform achieved a 34 percent reduction in skills mismatch and a 41 percent increase in cross-sector mobility in its first operational year, with an estimated €180 Mln annual productivity gain (Ministry of Development and Technology, Poland, 2024). The platform's target—AI literacy training for the Polish population (~400,000 individuals)—illustrates that the leapfrogging model's speed advantage is partially replicable through coordinated public-sector AI deployment even within an industrial deepening economy, provided institutional coordination capacity exists.

4.2. Creativity Measurement Gap and Optimal AI Balance

The proposed *Multi-Dimensional Creativity Assessment Framework* (MDCAF) addresses the identified measurement crisis through four components: (1) process-based metrics

(ideation velocity, conceptual flexibility) that capture creativity as generative activity rather than outcome; (2) culturally calibrated evaluation rubrics that adjust for collectivist vs. individualist creative norms; (3) longitudinal tracking from early education through professional outcomes; and (4) AI-augmented pattern recognition to identify non-traditional creative pathways invisible to conventional assessment. Pilot validation in the Estonian system (N=1,847 students, 2023–2024) yields correlation coefficients of r=0.61 (entrepreneurial success) and r=0.57 (research productivity), both $p<0.001$, substantially exceeding the predictive validity of traditional GPA (r=0.31 and r=0.28 respectively). These results provide empirical justification for a proposed *Creative Competencies Framework 2030* (budget: €250 Mln over 5 years), with projected outcomes of a 60 percent improvement in creative talent identification accuracy and a 40 percent reduction in creative industry skills mismatch.

The cognitive-science literature on optimal learning environments (Sweller et al., 2019: 261–292; Kirschner et al., 2006: 75–86) supports a 70/30 integration principle: approximately 70 percent human-led instruction preserving social-emotional development and cultural transmission, combined with 30 percent AI-augmented personalization enabling adaptive pacing and immediate feedback. This ratio is not prescriptive but serves as a calibration anchor that should be systematically tested across subjects, age groups, and cultural contexts. Implementation challenges include teacher resistance (address through co-design); resource constraints (phased implementation prioritizing high-impact areas); equity concerns (ensure rural/disadvantaged access through mobile infrastructure, shared facilities).

4.3 Country-Specific Pathways (2025-2028)

Latvia (Building foundation) priority: Basic digital infrastructure in rural areas. Investment: €120 Mln. Success metrics: Universal broadband, teacher digital literacy >70 percent, AI pilots in 50 percent schools by 2028.

Lithuania (Scaling quality) priority: Teacher AI literacy at scale. Investment: €85 Mln. Success metrics: 80 percent teacher AI certification, AI tutoring in core subjects, 40 percent increase in personalized learning pathways.

Poland (Coordinating decentralization) priority: National AI-education standards for regional implementation. Investment: €340 Mln across 16 regions. Success metrics: Coherent national framework, regional adaptation capacity, 50 percent reduction in inter-regional disparities.

Hungary (Governance reform) priority: Depoliticizing education, establishing evidence-based AI integration. Timeline depends on political developments. Critical success factor: Restoration of academic autonomy and research independence.

Czech Republic (Deepening excellence) priority: Advanced AI-human collaboration in vocational training. Investment: €180 Mln (60 percent public, 40 percent private). Success metrics: Industry 4.0 integration in 80 percent vocational programs, 35 percent training

time reduction, 50 percent employment outcome improvement.

Slovakia (Leapfrogging) priority: Adopting successful Czech/Estonian models rapidly. Investment: €95 Mln (focus high-ROI areas). Success metrics: Proven model adaptation, 60 percent faster implementation than building from scratch, Tier 2 adopter status by 2028.

Estonia (Global leadership) priority: Pioneering next-generation AI-creativity integration. Investment: €65 Mln (R&D focus). Success metrics: Top 5 global ranking in AI-education, exportable models generating €50 Mln + consulting/licensing revenue, 25 percent increase in international talent attraction.

4.4 Talent Retention in the Trend of Digital Nomadism

Digital nomadism amplifies traditional brain drain through qualitatively new mechanisms: geographic arbitrage (Western salaries with home-country residence costs), virtual emigration (remote work for foreign employers transferring value creation abroad), and diaspora hollowing (unlike classical emigration, digital nomads generate minimal remittance flows and sparse home-country network effects). Estonia's 8700 digital nomads in 2024 (12 percent of the tech workforce) represent an estimated €180 Mln annual GDP contribution foregone—equivalent to 30 percent of the current education ministry budget. Poland's 156000 remote workers for foreign companies constitute an opportunity cost of approximately €2.4 B annually. Lithuanian "brain drain" to remote work - 23000 (2.8 percent) workers.

Strategic responses require reframing retention as *value capture* rather than geographic presence. Estonia's e-Residency program (188,000 participants from 178 countries by 2024) demonstrates that virtual institutional engagement can maintain economic ties despite physical mobility. Country-specific niche strategies—Estonia in e-governance and cybersecurity; Lithuania in fintech, biotechnology, and laser technology; Poland in gaming and smart agriculture; Czech Republic in industrial AI and automotive; Latvia in logistics AI; Slovakia in automotive AI and energy systems—offer the highest-return path to talent retention by generating domestic demand for precisely the competencies that diaspora workers have developed abroad.

Success metrics (2025-2030): reduce net brain drain by 40 percent; increase diaspora investment by 200 percent; achieve top-25 global ranking in at least one specialized domain per country; increase quality of life indices by 15 percent; establish digital diaspora contribution equivalent to 2 percent GDP.

5. Conclusions and Priorities

5.1 Principal findings

This study advances understanding of AI-education integration in moderate innovator economies through those primary contributions introducing and empirically documenting:

First, the AI Competency Paradox as a structural feature of CEE labor markets. AI integration accelerates technical skill acquisition 60-80 percent while simultaneously increasing deficit in unmeasured meta-competencies hardest to teach (creativity, ethical reasoning, adaptability, emotional intelligence). This creates labor market bifurcation: workers developing complementary meta-competencies alongside AI-augmented technical skills command 34 percent wage premiums; those relying exclusively on algorithmic skill development face displacement risk (Eurostat Labour Force Survey, 2022-2024). Theoretically, this extends task-based framework (Autor, 2015; Brynjolfsson & McAfee, 2014: 145-178) by demonstrating that AI's primary effect is not task substitution but competency redefinition—a distinction with profound implications for curriculum design and qualification frameworks. Competency half-lives decreased from 10-15 years to 3-5 years, creating unprecedented challenges for educational systems designed around relatively stable curricula.

Second, the study provides the first systematic empirical documentation of *regional innovation strategy divergence*. Analysis reveals two distinct and path-dependent CEE innovation trajectories—*Digital leapfrogging* (Baltic, Estonia: R&D return 7.2:1) and *Industrial deepening* (Visegrad, Czechia: R&D return 3.8:1)—with quantified efficiency differentials that falsify the "moderate innovator" homogeneity assumption prevalent in the literature (Radosevic & Yoruk, 2013). Czech, Poland, Hungary, Slovakia leverage manufacturing legacies through European value chain integration, applying AI as process optimizer rather than core product. Higher absolute R&D expenditure (Czech: 2.13 percent GDP vs. Estonia: 1.82 percent) supports capital-intensive approach. These trajectories exhibit path-dependence and high switching costs, suggesting early strategic choices create 10-15 year lock-in effects. Policy implication: countries cannot easily pivot between strategies without substantial transition costs.

Third, proposed *Multi-Dimensional Creativity Assessment Framework* (MDCAF): current international indices inadequately capture creativity determinants essential for innovation. MDCAF incorporates: process-based metrics (ideation velocity, conceptual flexibility); culturally-calibrated evaluation rubrics; longitudinal tracking from early education through professional outcomes; AI-augmented pattern recognition identifying non-traditional creative pathways. Pilot validation in Estonian system (N=1847 students, 2023-2024) demonstrates correlation between MDCAF scores and subsequent entrepreneurial success. It delivers predictive validity (r=0.61) that substantially exceeds GPA-based models (r=0.31), establishing an empirical proof-of-concept for culturally calibrated creativity assessment as a policy-actionable measurement instrument.

5.2 Regional Disparities and the Stakes of Inaction

Globalization transformed traditional national and even professional criteria of education: huge attention is given to informatics, management, law in all selected countries under review; but integrative interdisciplinary approach highlights the attention to some customary ethnic traditions by using multicriteria decision analysis. The technological innovations open doors to innovative productivity in the education studies and better integration of national traditions into humanities and culture. Modern education techniques are applied for converting intellectual property into professional intelligence quotient in most of the countries but with different success depending on funding and smart ICT infrastructure. The dictate of consumer society resulting as two-sided consequence of globalization is stimulating the growth of personal and societal needs, development of personalities and at the same time, causes a person's unilateral interest and degradation dangers that must be carefully monitored and mitigated through balanced educational approaches. The modernization of competency education and skills training under globalization impact requires integrating and developing more the critical, entrepreneurial, creative thinking and social capital skills by using more widely the innovative abilities of contemporary smart technologies.

The 33.5-point Estonia–Hungary differential in AI integration scores is not a measurement artifact but a signal of diverging developmental trajectories whose gap is projected to widen to 45+ points by 2030 without policy intervention, as AI-integrated education systems generate compounding advantages through network effects, talent agglomeration, and brain retention differentials (Estonia tech sector brain drain: 8.2 percent vs. Hungary: 23.7 percent). Hungary's case is analytically instructive: five education minister changes between 2018 and 2024 demonstrate that political instability constitutes the binding constraint on AI integration, not financial or technical capacity. Recovery requires governance stabilization as a precondition for any technical intervention to be effective.

The broader lesson for CEE policy is that the window for strategic positioning is narrowing. Countries that establish coherent AI-education coordination bodies, deploy MDCAF-type assessment instruments, and create institutional mechanisms for diaspora value capture before 2028 will compound those advantages through the 2030s. Those that do not risk a form of permanent technological periphery that no subsequent catch-up investment can fully reverse—a structural outcome that the path-dependence literature (Arthur, 1989) identifies as characteristic of technology-intensive development phases

5.3 Limitations and Research Priorities

Reliance on international indices (GII, GTCI) introduces measurement artifacts prioritizing quantifiable indicators that systematically underweight qualitative factors (institutional culture, tacit knowledge transfer, creative ecosystems) for which no standardized cross-national data exist. Temporal coverage (2022-2024 with 2030 projections) faces obsolescence risk given accelerating AI change. Counterfactual absence—we document correlation between AI integration and innovation outcomes but cannot definitively establish causation. Sample limitations—eight countries enable depth but limit generalizability.

The 2022–2024 temporal coverage faces obsolescence risk given the pace of AI development; the 2030 projections should be treated as scenario anchors rather than point forecasts. This study documents strong correlations between AI integration and innovation outcomes but cannot fully establish causal direction.

The research priorities follow directly from these limitations: (1) longitudinal cohort studies (minimum 5-year) tracking competency development in AI-augmented vs. conventional educational settings, controlling for socioeconomic confounders; (2) cross-cultural validation of the MDCAF across CEE national contexts to assess measurement stability; (3) systematic experimentation on optimal human-AI instruction ratios across subjects, age levels, and learning objectives; and (4) economic modeling of digital diaspora contribution mechanisms and the conditions under which remote work generates positive spillovers (knowledge transfer, network effects) vs. net extraction for home economies.

As the research revealed, the core innovation determinants applied in the international evaluations of sustainable macroeconomic development do not detail some sophisticated aspects determining the impact of professional competencies on innovativeness of business and education. As a result, they do not suggest the most rational solutions for the competitive education quality or business policy in the selected country as well as do not assess the lifestyle differences and specific needs resulting from deep social differentiation. The review of multiparametric interactions revealed the criterial inadequacy of competence parameters used by international experts for some sustainable evaluations of innovation processes.

Next 5-7 years will determine whether CEE maintains knowledge economy competitiveness or falls into "middle-income trap" as AI-amplified productivity gaps widen. Success requires simultaneous attention to technical infrastructure; human capacity; institutional frameworks; creative ecosystem cultivation. Creativity measurement represents most fundamental challenge. Until education systems reliably identify, nurture, and assess creative capacity—the human competency least susceptible to AI substitution—policy risks optimizing outdated metrics.

Countries successfully navigating this transition secure decades of competitive advantage; those that falter risk permanent technological periphery.

It is important to update systematically the smart techniques of self-learning and also personal training plans and aspirations, providing increasing access to the rapidly

developing e-technologies for individual innovative skills developing, initiative, rational competitiveness and entrepreneurship, also sense of community and teamwork by realizing new ideas not ignoring national traditions, customs and lifestyles. Student involvement in scientific research and related innovative business activities through specially prepared study programs, professional practices and other forms of cooperation with business smart specialization events, as well as the international exchange of knowledge databases and ICT packages, organization (jointly with foreign academic institutions) of graduate courses for teachers and students, and recognition of common diplomas for specialists—all this makes positive impact on development of professional competence.

Better opportunities to continue professional studies and to use smart infrastructure and latest digital technology for research and professional skills development, as well as grants and other incentives for young postgraduates is creating necessary conditions for more wide development of perspective research and innovative business ideas. The impact of globalization as important source of economic competitiveness influences innovative efficiency by uneven modes and forms.

Policy must systematically update self-learning techniques and provide increasing access to e-technologies for developing individual innovative skills, while not ignoring national traditions, customs, and lifestyles. The structural deficiencies in measuring and fostering intrinsic motivation and creative risk-taking remain the most critical constraint to achieving top-tier innovative performance. Moderate innovators face a choice that is simultaneously educational, institutional, and geopolitical: lead in defining human-AI complementarity in education, or become passive recipients of models developed elsewhere. The analytical framework developed here—organized around the AI Competency Paradox, two empirically documented catch-up trajectories, and the creativity measurement crisis—provides a basis for policy that is both theoretically grounded and empirically actionable. The evidence reviewed here suggests that the technical and financial prerequisites for the former are available; what remains is the institutional will to deploy them coherently and consistently.

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Data Availability Statement

The data used to support the findings of this research are available from the corresponding authors upon request.

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