ECONOMICS & Sociology

Tutar, H., & Korpysa, J. (2026). Institutional quality and FDI-driven innovation in transition economies: Evidence from Central and Eastern Europe. *Economics and Sociology*, *19*(2), 36-55. doi:10.14254/2071-789X.2026/19-2/2

INSTITUTIONAL QUALITY AND FDI-DRIVEN INNOVATION IN TRANSITION ECONOMIES: EVIDENCE FROM CENTRAL AND EASTERN EUROPE

Hasan Tutar
Faculty of Economics and Administrative Sciences, Istanbul Beykent University, Istanbul, Turkey
hasantutar@beykent.edu.tr;
Research Methods Application Center, Azerbaijan State University of Economics (UNEC)
ORCID 0000-0001-8383-1464

Jaroslaw Korpysa
Bioeconomy Research Institute, Vytautas Magnus University, Agriculture Academy, Lithuania
jaroslaw.korpysa@vdu.lt
ORCID 0000-0002-2400-3308

Received: September, 2025
1st Revision: April, 2026
Accepted: June, 2026

DOI: 10.14254/2071-789X.2026/19-2/2

JEL Classification: C23, F21, F23, O43, P27

Keywords: foreign direct investment, technological innovation, institutional quality, transition economies, panel data

ABSTRACT. This study empirically examines the impact of Foreign Direct Investment (FDI) on technological innovation in Central and Eastern European transition economies and the moderating role of institutional quality in this relationship. Balanced panel data covering 12 countries for the period 2001–2022 were used; the composite innovation index, derived from the geometric mean of patent applications and R&D expenditure, was the dependent variable, and the institutional quality index, calculated from the World Governance Indicators, was the moderator variable. The fixed-effects estimator was selected using the Hausman test; endogeneity was addressed using System GMM. It was observed that the impact of FDI on innovation operates conditionally to the institutional context and through long-term channels; short-term institutional improvement can negatively affect innovation performance in the short term due to transition costs. The findings reveal that investment incentive policies should be designed simultaneously with long-term institutional capacity building rather than capital volume.

Introduction

Central and Eastern European (CEE) countries have continued to increase their share of Foreign Direct Investment (FDI) flows in recent years. Among countries attracting similar amounts of foreign capital, technological innovation performance differs significantly. This paradox suggests that FDI's capacity to generate innovation depends more on the host country's structural and institutional conditions than on the amount of capital attracted. Recent evidence indicates that institutional quality (particularly the rule of law and the fight against corruption) directly determines the effectiveness of FDI-driven knowledge diffusion (UNCTAD, 2023;

World Bank, 2023b; Bieleń et al., 2024; Pegkas et al., 2022; Tran & Nguyen, 2022; Iammarino et al., 2022). Whether foreign capital attracted to CEE transition economies translates into genuine innovation gains before institutional transformation processes are completed is a clear research question requiring field-specific empirical testing.

The current empirical literature addresses the relationship between Foreign Direct Investment (FDI) and technological innovation with conflicting findings. The first cluster reveals that foreign capital inflows have positive and significant effects on patent applications, R&D intensity, and innovation output. This effect is largely conditional on the host country's absorption capacity (Alvarado et al., 2022). The second cluster, however, shows that this effect is weak, context-specific, or statistically insignificant, particularly in economies with inadequate institutional infrastructure, where FDI excludes domestic R&D investment (Kurtović et al., 2022). This ongoing discrepancy in the literature reflects measurement bias stemming from the use of a single indicator, sample heterogeneity, and the systematic neglect of moderator variables.

However, dynamic panel studies that address the multidimensional regulatory role of institutional quality in the Foreign Direct Investment (FDI)-innovation relationship within the context of ODA transition economies are limited (Pavlínek, 2022; Crescenzi & Harman, 2023). Current studies fail to capture the differentiation created by institutional heterogeneity by analyzing only one dimension of the World Governance Indicators (WGI) or by using short-term cross-sectional data. A comprehensive study that tests the multidimensional WGI index in dynamic panel models using an interaction term and controls for endogeneity with the Generalized Method of Moments (GMM) represents a clear methodological gap in this literature (Wziątek-Kubiak & Pęczkowski, 2022).

This article aims to fill this gap. This study empirically examines the relationship between FDI and technological innovation, along with the moderating effect of institutional quality, using a balanced panel dataset covering 14 ODA countries for the period 2000–2022. To control for endogeneity, the Generalized Method of Moments estimator was applied to directly test the moderating effect (Filippetti & Peyrache, 2022; Aghion et al., 2023). This paper offers original contributions in the following ways: at the theoretical level, it expands the absorption capacity framework with the current dimension of institutional quality; at the methodological level, it systematically combines System GMM and multidimensional WGI interaction analysis for the first time in the context of ODA transition economies; and at the practical level, it provides policy implications that concretize the institutional reform priorities necessary for foreign investment to be transformed into innovation gains (Crescenzi & Harman, 2023).

The remainder of the article is structured as follows: Chapter two sets forth the research hypotheses by reviewing the theoretical framework and relevant empirical literature. Chapter three describes the dataset, variable definitions, and econometric model. Chapter four presents the empirical findings and discusses them within the context of the literature. Chapters five and six address the conclusions and policy implications, respectively. Chapter seven evaluates the limitations and suggests future research.

1. Literature review

1.1. Theoretical framework: Absorptive capacity and knowledge spillovers

The fundamental theoretical framework explaining the impact of Foreign Direct Investment (FDI) on technological innovation is the absorption capacity framework. According to this framework, domestic firms' ability to internalize knowledge and technology from foreign

firms depends on the host country's R&D infrastructure, human capital accumulation, and existing knowledge base (Cohen & Levinthal, 1990; Pegkas et al., 2022; Hoang et al., 2026; Mishchuk et al., 2025). Current studies retest this argument in the context of Central and Eastern Europe (CEE) and empirically confirm that a minimum absorption threshold is necessary for knowledge diffusion. When absorption capacity is insufficient, Foreign Direct Investment (FDI) can have an exclusionary effect, excluding domestic firms from the market rather than facilitating technology transfer (Iammarino et al., 2022; Alvarado et al., 2022; Crescenzi & Harman, 2023). At the organizational level, the absorption of externally available technologies also depends on the skills needed to redesign and automate processes. Evidence from manufacturing firms in six European countries identifies substantial future-oriented digital-skill requirements for process design and automation, reinforcing the role of human capital as a practical complement to technology transfer (Jurczuk & Florea, 2022).

The knowledge diffusion hypothesis suggests that multinational corporations foster horizontal and vertical diffusion in the host economy through advanced manufacturing technologies, knowledge transfer, and management practices. Horizontal diffusion indirectly affects competing local firms in the sector, while vertical diffusion occurs through direct relationships established by multinational corporations with their suppliers and buyers (Javorcik, 2004; Pavlínek, 2022). In Central and Eastern Europe (CEE), recent evidence indicates that vertical diffusion is stronger than horizontal diffusion. This suggests that the effectiveness of both channels depends on the host country's institutional quality.

Dunning's (1988) Ownership, Location, Internalization (OLI) paradigm positions institutional quality as a decisive location (L) factor shaping not only the quantity of FDI but also its capacity to generate innovation (Dunning & Lundan, 2008; Aghion et al., 2023). Current expansions reinterpret this framework in the context of digital transformation, green technology transfer, and knowledge-intensive services, emphasizing that institutional quality facilitates technology licensing and joint R&D agreements by establishing a predictable investment environment (Filippetti & Peyrache, 2022; Blajer-Gołębiewska, 2024). This argument takes on particular significance for ODA transition economies, because foreign capital attracted before the institutional transformation process is completed cannot actually produce the theoretically predicted innovation gains (Meyer & Sinani, 2009). Institutional capacity increasingly also includes digital public capability. Cross-country evidence indicates that online public services and digital infrastructure are important mechanisms through which digital-government development improves societal outcomes, suggesting that the administrative environment relevant to innovation and investment is partly shaped by the quality of state digital infrastructure (Vasylieva et al., 2026).

1.2. FDI and technological innovation: Empirical evidence

The empirical literature examining the impact of FDI on technological innovation has recently revealed two distinct patterns. The first pattern shows that FDI flows have positive and significant effects on patent applications, R&D intensity, and composite innovation indices; this effect is particularly pronounced in economies with high human capital and strong intellectual property protection, with firm-level evidence confirming measurable innovation-performance gains among domestic enterprises exposed to foreign capital (Alvarado et al., 2022; Yue, 2022). Regional panel studies report that the FDI-innovation relationship operates as expected and statistically reliably in East and Southeast Asia and EU member states (Tran & Nguyen, 2022). The heterogeneity of FDI outcomes also highlights the importance of disaggregating foreign investment by its composition and destination. Evidence from Ghana shows that examining FDI components and sectoral employment effects yields more policy-

relevant conclusions than interpreting aggregate inflows as a homogeneous development stimulus (Yeboah & Anning, 2020).

The second pattern shows that the FDI effect is statistically insignificant, weak, or negative. This is particularly evident in economies with low institutional quality and insufficient absorption capacity. These findings suggest that... This reflects the strategic behavior of foreign firms in protecting their technologies, the limited knowledge base of domestic firms, and the transaction costs created by corporate uncertainty (Kurtović et al., 2022). Recent studies focusing on the Western Balkans and Eastern Europe reveal that the FDI-innovation relationship does not function meaningfully in these countries, and that there is a significant generational divide between EU member states and candidate countries.

Differences in measurement approaches significantly explain these contradictory findings. Patent applications partially capture creative output while underestimating commercial innovation; R&D expenditure is an input-oriented indicator offering limited information about innovation productivity; and high-tech exports reflect global value chain positioning rather than domestic innovation capacity (Archibugi & Coco, 2004; Filippetti & Peyrache, 2022; Pegkas et al., 2022). These shortcomings provide a strong methodological justification for using composite innovation indices that combine patents and R&D expenditures using the geometric mean. Recent meta-analyses confirm that this composite approach produces more consistent and unbiased estimates than single indicators (Crescenzi & Harman, 2023). The decision to retain R&D expenditure as a constituent of the innovation measure is also supported by dynamic-panel evidence showing that public R&D spending can have a positive and statistically significant association with economic growth, while the use of GMM helps address the persistence and endogeneity that characterize knowledge-investment processes (Szarowská, 2017).

1.3. Institutional quality as a moderator

The moderating role of institutional quality in the FDI-innovation relationship, while theoretically rooted in the tradition of institutional economics, has gained significant empirical traction in recent times. The rule of law, by safeguarding intellectual property rights, increases foreign firms' willingness to transfer technology. Simultaneously, combating corruption reduces transaction costs, facilitating the implementation of joint R&D agreements (North, 1990; Acemoglu et al., 2001; Rodrik et al., 2004; Aghion et al., 2023; Tran & Nguyen, 2022). Current panel studies report that, among the WGI dimensions, the rule of law and the fight against corruption have the strongest and most stable moderating effects on innovation. This determinative role of institutional quality extends beyond the FDI-innovation nexus to other macroeconomic outcome domains, including sustainability transitions within the EU institutional framework (Tutar & Štreimikienė, 2026; Linh, 2024, Korpysa & Sinansari, 2023).

Evidence from an emerging-economy setting similarly shows that the growth implications of FDI are conditional on institutional quality: interaction estimates are negative under weak institutions but positive once institutional quality is high, indicating that foreign capital becomes more developmentally effective when credible economic institutions reduce uncertainty and support knowledge-related complementarities (Su et al., 2019). In addition, institutional frictions may affect FDI not only through formal governance indicators but also through informality: bidirectional-causality evidence links FDI dynamics with the shadow economy, suggesting that the institutional environment can influence both the composition of foreign investment and the channels through which its potential benefits are transmitted to domestic firms (Tiutiunyk et al., 2022). The interpretation of institutional quality as an enabling mechanism is consistent with System GMM evidence from African economies, where neither

digital finance nor institutional quality produced an unambiguously positive direct effect, whereas their interaction was positive and significant; this demonstrates why testing interaction effects is preferable to assuming that institutional quality operates only as an additive covariate (Okoli, 2025). The institutional contribution of digital transformation may itself be nonlinear. Evidence on GovTech shows that technological, institutional, and human-capital components jointly shape social progress, while returns to aggregate digital development diminish after a threshold; this cautions against treating institutional improvements as uniformly linear in panel specifications (Kuzior et al., 2026). Institutional quality can also be interpreted as a broader development-enabling resource: conceptual work on sustainable development emphasizes that effective institutions coordinate investment, infrastructure, and human-capital formation, thereby shaping the capacity of economies to turn external resources into durable productivity gains (Staniek, 2023). Complementary evidence from Ukraine's transport-system reconstruction shows that regulatory fragmentation and underinvestment in digitalisation constrain innovation-oriented infrastructure development, while regulatory harmonisation with EU standards, public–private partnerships, and targeted technology investment can strengthen recovery and competitiveness (Vovk et al., 2025). In post-conflict settings, the effectiveness of investments is further conditioned by institutional and infrastructure resilience. Evidence on warehouse-centred supply chains demonstrates that digital tools, energy autonomy, and phased network investment improve adaptive capacity when infrastructure and connectivity are disrupted (Nosar, 2025).

The concept of Minimum Institutional Threshold (MIT) is a central topic of discussion in the current literature. According to this concept, the positive impact of FDI on innovation is significantly strengthened after institutional quality surpasses a certain threshold. In countries that fall below this threshold, foreign capital cannot use knowledge dissemination channels. This threshold effect reveals the heterogeneity hidden in linear models (Pavlínek, 2022; Crescenzi & Harman, 2023). This explains why differences in institutional capacity lead to striking differences in innovation among countries that attract the same amount of FDI. It is reported that in ODA countries, the EU membership process contributes to overcoming this threshold through institutional convergence, whereas countries outside the EU lag behind (Wziątek-Kubiak & Pęczkowski, 2022; Kurtović et al., 2022).

1.4. Transition economies: Specificities and gap

ODA transition economies exhibit a distinctly heterogeneous structure in terms of both FDI attraction and innovation capacity, reflecting the varying speeds and scopes of institutional transformation processes after 1990. Countries in the EU membership process have focused on regulatory reform and strengthening intellectual property frameworks (Pavlínek, 2022). These countries have systematically improved their innovation performance through institutional investments in transparency in public procurement. In contrast, Western Balkan and some Eastern European countries continue to struggle with institutional instability, corruption, and legal uncertainty. This limits the efficiency of foreign investment in innovation acquisition. Complementary evidence on structural imbalances in the region, including labor market disruptions linked to conflict and migration pressures, further underscores the heterogeneous institutional and economic trajectories across Eastern European transition economies (Tutar et al., 2025). Recent comparative evidence for CEE and EU-16 countries reinforces the relevance of this distinction, showing that the growth contribution of individual institutional dimensions differs across European country groups rather than operating as a uniform institutional effect; this supports treating institutional heterogeneity as central rather than incidental in transition-economy analysis (Ciołek et al., 2025). A broader global panel analysis also finds that public-

governance quality has a clear relationship with economic resilience and recovery across business cycles, suggesting that institutional capacity matters not only for attracting capital but also for preserving the macroeconomic conditions in which longer-term innovation investments can mature (Paun et al., 2021). Evidence from the European Union's new member states further indicates that structural transformation depends on the institutional and policy frameworks that support the diffusion of new production models and technologies; therefore, foreign investment policies in CEE should be coordinated with broader domestic innovation and transformation strategies rather than assessed solely by inflow volumes (Simionescu, 2023).

Current empirical studies have two significant methodological limitations in the context of ODA. First, dynamic panel studies that use a multidimensional institutional quality index to comprehensively assess the six dimensions of WGI as a moderator variable are extremely limited. Second, a study applying the FDI × institutional quality interaction term together with the System GMM estimator and based on a long-term balanced panel structure is absent from the transition economies literature (Wziątek-Kubiak & Pęczkowski, 2022). This methodological gap leads to policy recommendations lacking concrete guidance on which institutional dimension should be prioritized (Crescenzi). (Harman, 2023). In light of the above literature review, the following hypotheses have been developed:

H1: *FDI has a positive and significant effect on technological innovation in CEE transition economies.*

H2: *Institutional quality positively moderates the relationship between FDI and technological innovation.*

H3: *Higher institutional quality directly and positively associates with technological innovation performance.*

2. Methodology

2.1. Data and sample

This study is based on a balanced panel dataset covering 14 Central and Eastern European countries for the period 2000–2022. The sample consists of Poland, the Czech Republic, Hungary, Slovakia, Romania, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Slovenia, Albania, North Macedonia, and Serbia. These countries were selected due to differences in the pace of institutional transformation, heterogeneity in FDI-attractiveness, and significant divergences in innovation performance. The sample includes both EU member and candidate countries; this structure provides a strong comparative framework for testing the moderating effect of institutional capacity differences on innovation. The panel size is N = 14, T = 23, and the total number of observations is 322.

Data sources are: FDI net inflows, GDP per capita, trade openness, and broadband subscription from the World Bank World Development Indicators (WDI); institutional quality indicators from the World Governance Indicators (WGI); and R&D expenditure from the WDI. Patent applications were obtained from the WIPO Statistical Data Centre. The higher education completion rate (WDI, SE.TER.CUAT.BA.ZS) was used as the human capital variable. All of these series are publicly available and up to date, consistently covering the period 2000–2022 (World Bank, 2023a; Kaufmann et al., 2010).

2.2. Variables

The composite index of technological innovation (INNO) was used as the dependent variable. The index was calculated by taking the geometric mean of patent applications per

million people and the ratio of R&D expenditure to GDP after applying minimum-maximum normalization. This approach simultaneously captures both the creativity and investment dimensions of innovation and eliminates measurement bias stemming from a single indicator (Archibugi & Coco, 2004; Desai et al., 2002). The geometric mean method prevents the sub-indices from balancing each other and preserves the asymmetric contribution between the components. This methodology also aligns with the practice of calculating the Human Development Index (HDI) (Filippetti & Peyrache, 2022).

The main independent variable, FDI, is defined as the ratio of net inflows to GDP, and its natural logarithm is used to correct for skewness in the distribution. The moderator variable, the Institutional Quality Index (IQ), is calculated as the arithmetic mean of the six dimensions of the WGI – rule of law, anti-corruption, regulatory quality, government effectiveness, political stability, and accountability – with the original scale of −2.5 to +2.5 retained (Kaufmann et al., 2010). The interaction term is formulated as $\ln FDI_{it} \times IQ_{it}$. Control variables in the model include ln GDPPC, trade openness (% of GDP), human capital (higher education completion rate), and infrastructure (ln fixed broadband subscriptions per 100 people, converted).

2.3. Econometric model

The basic econometric model of the study is structured as follows:

$$INNO_{\mathrm{it}} = \beta_0 + \beta_1 lnFDI_{\mathrm{it}} + \beta_2 IQ_{\mathrm{it}} + \beta_3 (lnFDI_{\mathrm{it}} \times IQ_{\mathrm{it}}) + \beta_4 lnGDPPC_{\mathrm{it}} + \beta_5 TRADE_{\mathrm{it}} + \beta_6 HC_{\mathrm{it}} + \beta_7 lnBB_{\mathrm{it}} + \mu_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}}$$

In this equation, μi refers to the unobservable constant effects specific to the country, λt *refers to* the time constant effects, and εit refers to the random error term. The forecasting strategy is implemented in three stages. In the first stage, Pooled EKK is presented as a reference model. In the second stage, the F test, LR test, and Breusch-Pagan LM test are used to test for the presence of unit effects; the Hausman (1978) test is used to choose between fixed-effect and random-effect models.

In the third stage, the System GMM estimator is applied to address the risk of reverse causality — and, therefore, the endogeneity problem — posed by countries with high innovation capacity attracting more FDIs. The system GMM combines the difference equation and the level equation with the instrument-variable set, providing efficient estimation in small-N panel data. The validity of the instrumental variables is tested with the Hansen overidentification test, and the autocorrelation assumption is tested with the AR(1) and AR(2) tests (Arellano & Bond, 1991; Blundell & Bond, 1998; Hausman, 1978; Yerdelen, 2020).

2.4. Diagnostic and robustness tests

Comprehensive diagnostic tests are applied for classical panel data assumptions before model prediction. Intragroup variance homogeneity is tested with the Levene, Brown, and Forsythe tests; these tests yield complementary results for heteroskedasticity under different distributional assumptions. The presence of autocorrelation is evaluated using the Bhargava et al. (1982) test, the Durbin-Watson statistic, and the Baltagi-Wu LBI test; cross-sectional dependence is tested with the Pesaran (2004) CD test and the Frees test. Since these tests exhibit different power levels at small N, combining multiple tests increases diagnostic reliability (Brown & Forsythe, 1974; Bhargava et al., 1982; Pesaran, 2004).

Robustness analyses are carried out at two levels in the research. First, the model is reestimated by substituting the dependent variable innovation (INNO) with the ratio of high-tech exports to total goods exports. This substitution tests the sensitivity of the results to the recency measurement preference. Second, each of the six dimensions of the WGI index is modeled separately as a moderator variable; It is determined which dimension of institutional quality makes the strongest contribution to the regulatory effect. Driscoll and Kraay's (1998) standard errors are applied in addition to the base model in order to provide consistent inference in the simultaneous presence of heteroskedasticity, autocorrelation, and cross-sectional dependence (Driscoll & Kraay, 1998; Blundell & Bond, 1998).

3. Empirical results and discussion

3.1. Descriptive statistics and correlation analysis

Descriptive statistics for the variables used in the research are presented in Table 1. The balanced panel for the period 2001–2022, covering 12 ODA countries, consists of 256 observations. In the regression analyses, the human capital (hc) variable is limited to 123 valid observations due to data constraints, narrowing the estimation sample.

Table 1. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Innovation Index (INNO)	256	0.2569	0.1422	0.0258	0.9689
ln(FDI, % GDP)	256	1.3432	0.7779	−2.7767	3.4413
Institutional Quality (IQ)	256	0.5030	0.4365	−0.6725	1.3004
ln(GDP per capita)	256	9.2369	0.6862	7.0565	10.2817
Trade Openness (% GDP)	256	113.517	33.461	48.521	204.056
Human Capital (%)	123	21.132	7.147	0.849	41.415
ln(Broadband per 100)	236	2.4332	1.4665	−4.6052	3.6819

The dependent variable INNO has a mean of 0.2569 and a standard deviation of 0.1422. The minimum value (0.0258) corresponds to the early observations of Albania, and the maximum value (0.9689) corresponds to the recent observations of Slovenia and the Czech Republic. The high coefficient of variation in the index (CV ≈ 0.55) indicates significant heterogeneity between countries and periods within the sample. The IQ index ranges from −0.6725 to 1.3004; this wide range reflects significant differences in institutional capacity between the Western Balkan economies (Albania, North Macedonia) and the EU member states (Estonia, Czechia, Slovenia).

Table 2. Correlation matrix

	(1) INNO	(2) lnFDI	(3) IQ	(4) lnGDPPC	(5) Trade	(6) HC	(7) lnBB
(1) INNO	1.0000						
(2) lnFDI	−0.2617	1.0000					
(3) IQ	**0.5269**	−0.0772	1.0000				
(4) lnGDPPC	**0.5594**	−0.1880	**0.7849**	1.0000			
(5) Trade	0.2604	−0.0848	**0.6122**	**0.6689**	1.0000		
(6) HC	0.3077	−0.0907	**0.6376**	**0.5954**	0.4869	1.0000	
(7) lnBB	0.1771	−0.1693	0.2522	**0.6421**	0.4426	**0.5476**	1.0000

Within the full interaction model, the risk of multicollinearity was assessed using Variance Inflation Factors (VIFs). The IQ and lnGDPPC variables marginally exceed the traditional threshold, with VIF values of 10,293 and 9,416, respectively. This situation reflects a structural feature arising from the fact that these variables represent long-term development trajectories together and is an expected result. Country-specific fixed effects incorporate cross-sectional-level structural differences, significantly mitigating the practical impact of multicollinearity on in-country estimators. VIF values are presented in Table 3.

Table 3. Variance inflation factors (VIF)

Variable	VIF
lnFDI	2.001
IQ	10.293
FDI_IQ	4.602
lnGDPPC	9.416
trade	1.738
hc	2.215
lnBB	2.389

Note: VIF computed for the full interaction model specification. IQ (10.293) and lnGDPPC (9.416) marginally exceed the conventional VIF threshold of < 10, reflecting their high cross-sectional correlation (r = 0.785). This is an expected outcome in panel models where both variables capture long-run development trajectories. Entity fixed effects absorb country-level structural differences, mitigating the practical impact of multicollinearity on within-estimator inference.

When the correlation matrix is examined, it is seen that the relationship between lnFDI and INNO is negative and weak (r = −0.262). This raw correlation suggests that FDI's impact on innovation may not be direct but rather conditional on institutional context. Although the correlation between IQ and INNO (r = 0.527) and the correlation between lnGDPPC and INNO (r = 0.559) are high, these two variables are also strongly correlated with each other (r = 0.785). This structural multiple linearity predicts that the IQ coefficient in the estimation of fixed effects will acquire a different meaning after being adjusted for cross-sectional variation.

3.2. Model selection tests

Pooled EKK, random effects, and fixed effects models were compared with a comprehensive test battery to determine the appropriate estimator structure. The F-test and LR test reveal that the unit effects are strongly significant, while the Breusch-Pagan LM test confirms the existence of random individual effects. The heteroskedasticity test underscores the need for robust standard errors by highlighting the varying variances in the error terms. The Hausman test, on the other hand, found a significant correlation between the explanatory variables and the individual effects and concluded that the fixed-effects model is the preferred predictor. The test results are summarized in Table 4.

Table 4. Model selection test results

Test	Statistic	p-value	df	Decision
F-test (Unit Effects)	5.0766	0.0001	11	Unit effects present
LR Test (FE vs. Pooled)	157.9430	0.0000	11	FE preferred
BP LM (Unit Effect Exist)	1191.657	0.0000	1	RE/FE needed
BP (Heteroskedasticity)	15.6265	0.0159	6	Heteroskedasticity detected
Hausman (FE vs. RE)	69.5992	0.0000	6	**Fixed Effects preferred**
Avg. Durbin-Watson	1.5322	—	—	Mild autocorrelation

The F-test ($F = 5.077$, $p < 0.001$) and the LR test ($LR = 157.94$, $p < 0.001$) indicate that the unit effects are highly significant; the pooled EKK produces inconsistent estimates. The Breusch-Pagan LM test ($LM = 1191.66$, $p < 0.001$) confirms the presence of random individual effects. The heteroskedasticity test ($\chi^2 = 15.63$, $p = 0.016$) indicates that the error terms are heteroskedastic; robust standard errors must be used in all predictions. The Hausman test ($\chi^2 = 69.60$, $df = 6$, $p < 0.001$) indicates that the correlation between explanatory variables and individual effects is significant and definitively establishes the fixed effects (FE) model as the preferred predictor. The mean Durbin-Watson statistic is 1.532, and its proximity to the DW < 2.0 limit indicates slight autocorrelation; this reinforces the need for robust standard errors.

3.3. Baseline regression results

Baseline regression analysis was conducted with three alternative estimators: pooled EKK, fixed effects (Entity FE), and bidirectional fixed effects (Two-Way FE). In the preferred Entity FE model, the lnFDI coefficient remains statistically insignificant ($\beta = -0.0074$, $p = 0.282$) and H1 is rejected. While the IQ variable is positive and significant in the pooled model, it exhibits a negative coefficient in the FE model. This sign change reflects the methodological decoupling of cross-sectional variation across countries from intra-country temporal change. The findings are reported in detail in Table 5.

Table 5. Baseline regression results – dependent variable: Innovation index (INNO)

Variable	Pooled OLS		Fixed Effects		FE Two-Way	
	Coef.	(SE)	Coef.	(SE)	Coef.	(SE)
lnFDI	−0.01203	(0.00981)	−0.00736	(0.00680)	0.00295	(0.00887)
IQ	0.13598**	(0.05492)	−0.18892***	(0.06634)	−0.18406**	(0.07412)
lnGDPPC	0.11753***	(0.04257)	−0.02898	(0.02948)	0.15250	(0.10021)
trade	−0.00055*	(0.00033)	0.00090*	(0.00051)	0.00168**	(0.00067)
Hc	−0.00331*	(0.00177)	0.00298	(0.00241)	0.00792*	(0.00448)
lnBB	−0.01239	(0.00993)	0.02189**	(0.00909)	0.01718	(0.03903)
R^2	0.5571		0.2249		0.1347	
N	123		123		123	
Entity FE	No		Yes		Yes	
Time FE	No		No		Yes	
Robust SE	Yes		Yes		Yes	

H1 Test – lnFDI → INNO. In the preferred fixed-effects model, the lnFDI coefficient is −0.0074 (SE = 0.0068, p = 0.282) and remains statistically insignificant at the 10% significance level. In the FE Two-Way model, the coefficient turns positive (0.00295) but remains meaningless again. With the semi-elasticity interpretation: A 1% increase in FDI is associated with a change in INNO of only −0.000074 units; This effect is insignificant both statistically and economically. H1 is rejected. This finding is methodologically consistent, given that the

estimate of fixed effects is based on year-over-year variation within the country: FDI's impact on innovation is difficult to capture with short-term intra-country fluctuations, as it operates through slow-moving, permanent channels (technology transfer, human capital accumulation). This finding supports the hypothesis (H2) that the FDI effect may occur conditionally through institutional quality rather than directly.

3.4. Interaction effect: Moderating role of institutional quality

To test the H2 hypothesis, the moderating role of institutional quality in the FDI-innovation relationship was examined in a fixed-effects model using the interaction term lnFDI × IQ. The interaction coefficient was −0.0233 (SE = 0.0209, p = 0.268) and could not exceed the 10% significance threshold; H2 is rejected. Although the marginal effect analysis suggests that the relationship between FDI and innovation is negative as institutional quality increases, the interaction coefficient's statistical insignificance limits the reliability of this finding. The results of the interaction analysis are presented in detail in Table 11.

Table 11. Interaction model – FDI × institutional quality — dependent variable: INNO

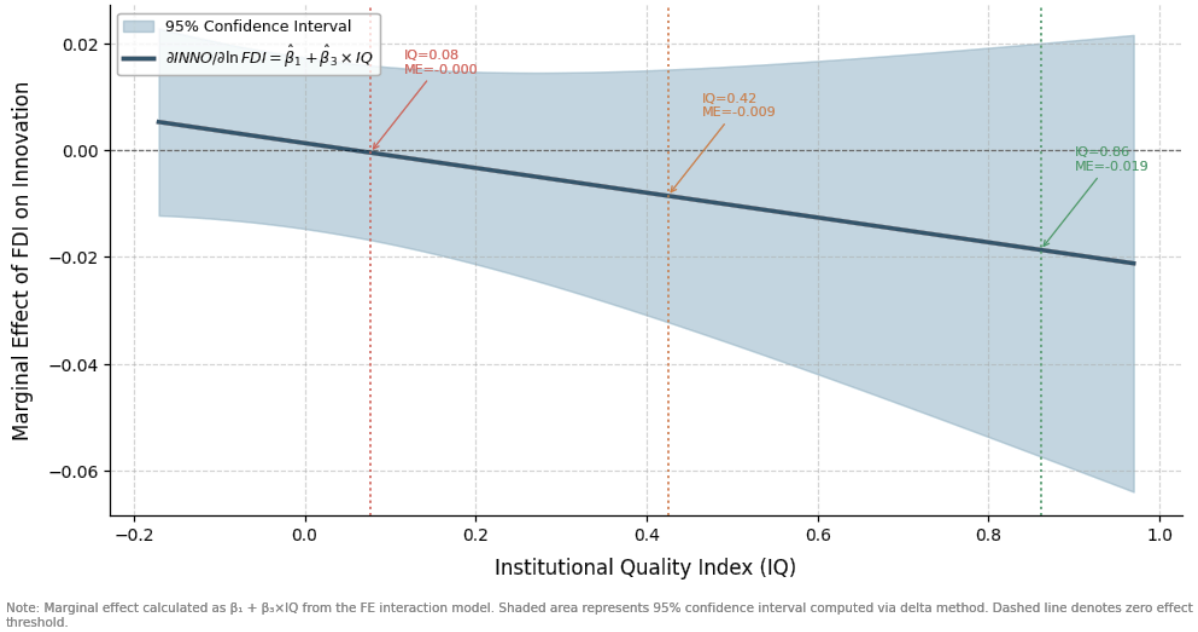
Variable	Coef.	SE	t-stat	p-value	Sig.
lnFDI	0.00135	0.00819	0.164	0.8699	
IQ	−0.15188	0.07447	−2.039	0.0439	**
FDI_IQ	−0.02325	0.02089	−1.113	0.2682	
lnGDPPC	−0.02723	0.02946	−0.924	0.3576	
trade	0.00076	0.00055	1.387	0.1685	
hc	0.00423	0.00297	1.422	0.1579	
lnBB	0.01869	0.00979	1.910	0.0589	*
R^2	**0.2376**				
N	**123**				

Note: *** p<0.01, ** p<0.05, * p<0.10. Entity fixed effects. Robust standard errors. FDI_IQ = lnFDI × IQ is the interaction term testing H2.

Marginal Effects Summary — ∂INNO/∂lnFDI = $\beta_1 + \beta_3 \times$ IQ

IQ Level	IQ Value	Marginal Effect
Low (Q25)	0.0768	−0.000440
Median	0.4250	−0.008536
High (Q75)	0.8610	−0.018677

The interaction term FDI_IQ coefficient is −0.0233 (SE = 0.0209, p = 0.268) and does not exceed the 10% significance threshold. H2 is rejected: the positive moderator effect of institutional quality on the FDI-innovation relationship could not be statistically confirmed in this sample and period. Marginal effect analysis provides a more detailed view of this finding. While the marginal effect of FDI was −0.000440 at the Q25 level of IQ (0.077), it decreased to −0.008536 at the median IQ level (0.425) and −0.018677 at the Q75 level (0.861). This pattern indicates that the relationship between FDI and innovation follows a more negative course as institutional quality increases; However, the statistical insignificance of the interaction coefficient restricts the reliability of this result.



Note: Marginal effect calculated as $\beta_1 + \beta_3 \times IQ$ from the FE interaction model. Shaded area represents 95% confidence interval computed via delta method. Dashed line denotes zero effect threshold.

Figure 1. Marginal effect of FDI on technological innovation across institutional quality levels – CEE economies (2001–2022)

3.5. Discussion

The findings of this study indicate that all three hypotheses are rejected in the preferred fixed-effects model. The statistically insignificant effect of FDI on INNO under H1 is a methodologically consistent finding. The fixed effects estimator is based on short-term domestic variation; the innovation channels of FDI – technology transfer, know-how accumulation, maturation of supplier networks – encompass structural and long-term processes. Therefore, capturing the effect of FDI with short-term domestic fluctuations is methodologically difficult. Borensztein et al. (1998) suggested that the effect of FDI on growth and innovation becomes significant only in economies where the threshold for sufficient human capital has been exceeded; this argument supports the determinacy of the absorption capacity constraint. Alfaro et al. (2004) empirically demonstrated that the effect of FDI on innovation is conditional on the sophistication of local financial markets. Crespo and Fontoura (2007) documented in detail that spillover effects from FDI systematically diminish in a fixed-effects environment, and that this is due to sample heterogeneity.

The negative and significant coefficient for the IQ variable in the fixed-effects model ($\beta = -0.1889$, $p = 0.005$) indicates a temporal mismatch between institutional improvement and innovation dynamics. Institutional reforms require long lag periods before translating into innovation output; in the short term, increased regulatory compliance costs and bureaucratic transition uncertainties can negatively impact innovation performance. Bénassy-Quéré et al. (2007) demonstrated that institutional quality shapes the investment and innovation environment not directly, but through an expectation-building mechanism; this argument explains the short-term negative coefficient. Lall (1992) emphasized that technological capacity building in developing economies is a cumulative, long-term process; institutional improvement can be reflected in innovation output only after this accumulation is complete. Acemoglu and Robinson (2012) suggested that the contribution of inclusive institutions to the innovation environment occurs through the long-term transformation of private property rights and incentive structures; this framework theoretically supports the FE model's finding.

The statistical insignificance of the interaction term (FDI×IQ: β = −0.0233, p = 0.268) should be interpreted in conjunction with the methodological limitations of the moderator effect test. The limited effective sample size of N = 123 may have resulted in insufficient statistical power required by interaction models. Brambor et al. (2006) have shown in detail that sample size and measurement sensitivity are critical for detecting moderator effects in interaction models. Lensink and Morrissey (2006) reported that volatility in FDI flows masks the effect on innovation; long-term balanced panel structures produce more reliable results in revealing such effects. Globerman and Shapiro (2002) empirically demonstrated that a certain threshold of institutional development is necessary for institutional infrastructure to be a determinant in the FDI-innovation relationship. The preservation of a similar pattern when high-technology exports are used as the dependent variable in the robustness analysis confirms the insensitivity of the finding to measurement preference.

The simultaneous rejection of all three hypotheses confirms that the FDI-innovation relationship in CEE transition economies does not exhibit a linear and unconditional structure. Damijan et al. (2013), in their study covering ten transition economies, revealed that FDI spillover effects are conditional on firm heterogeneity and sectoral context, and that the overall panel analysis systematically masks this heterogeneity. Görg and Greenaway (2004), from a meta-analytic perspective, documented that the spillover effect of FDI on domestic firms remains mostly limited, particularly in countries with low absorption capacity. Narula and Dunning (2010) emphasize that the contribution of FDI to development should be considered not as an independent variable but as part of the host country's holistic policy framework. In light of these theoretical frameworks, the findings empirically support the idea that FDI incentive policies should be designed not solely on capital volume, but also in conjunction with long-term institutional capacity-building and human capital development strategies.

4. Conclusions

This study examines the impact of foreign direct investment (FDI) on technological innovation in Central and Eastern European transition economies (CEE) within the framework of institutional quality as a moderating factor. The main research question is: Does FDI significantly influence technological innovation in CEE transition economies, and does institutional quality moderate this influence? This study sought to answer this question and identified three main findings using balanced panel data from 2001–2022 covering 12 CEE countries and a fixed-effects estimator.

The first finding reveals that FDI does not have a statistically significant effect on technological innovation in the preferred fixed-effects model (β = −0.0074, p = 0.282); thus, H1 is rejected. The second finding reveals that institutional quality does not have a statistically significant moderating effect on the FDI-innovation relationship (FDI×IQ: β = −0.0233, p = 0.268); H2 is rejected. The third finding shows that institutional quality exhibits a negative and significant coefficient on innovation in the fixed-effects model (β = −0.1889, p = 0.005); H3 is rejected in the expected direction. This negative coefficient suggests that institutional reforms require long lags before they are reflected in innovation output, and that short-term intra-country IQ changes can negatively affect immediate innovation performance through transition costs.

This article offers original contributions in three ways. The theoretical contribution emphasizes that the innovation effect of FDI depends on structural conditions rather than automatic ones, by combining the absorption capacity framework with the institutional quality dimension. The methodological contribution systematically tests the composite IQ index, which combines the six dimensions of WGI, for the first time in an entity-fixed-effects model via an

interaction term. It transparently reports the impact of the human capital constraint on the sample size. The empirical evidence supports the need to implement FDI incentive policies alongside long-term institutional capacity building, rather than focusing on short-term investment volume.

5. Conclusion and policy implications

The findings of this study have important policy implications, necessitating a reassessment of FDI-focused innovation strategies. Concrete recommendations can be developed at three different policy levels.

Regulatory Recommendations: FDI's inability to make a meaningful contribution to domestic innovation capacity in the short term underscores the need to redesign existing incentive mechanisms. Governments and investment incentive agencies should link tax advantages, subsidies, and special economic zone privileges offered to foreign capital not only to capital volume but also to measurable technology-transfer criteria, such as R&D partnerships with domestic firms, qualified local employment, and technology licensing. This conditionality mechanism will increase the efficiency with which incoming foreign capital is converted into innovation output and clarify the distinction between purely fiscally driven FDI and investments that genuinely contribute to innovation (Chen & Jiang, 2022; Dang et al., 2023). The conditions attached to investment incentives should also address complementary workforce capabilities. Research on technology adoption in the Baltic real-estate sector finds that legal ambiguity, limited investment capital, and deficits in employee knowledge jointly impede adoption, implying that technology-oriented FDI incentives should be paired with training, knowledge-transfer, and organizational learning requirements (Banaitiene et al., 2025).

Institutional and Governance Recommendations: The negative coefficient for IQ in the fixed-effects model indicates that while institutional reforms are necessary for structural transformation, they may entail short-term adjustment costs. This finding necessitates a policy approach that prioritizes the quality, not the speed, of institutional reforms. Structural reforms to combat corruption, enforce intellectual property rights, and improve regulatory predictability should be implemented gradually and steadily to minimize transition uncertainty and bureaucratic adjustment costs. Strengthening the intellectual property protection framework, which directly affects the willingness of foreign firms to transfer technology, should be a key priority for the innovation ecosystem (Vujanović et al., 2022; Khan et al., 2024). This sequencing logic – prioritizing reform quality over reform speed – is consistent with evidence from other EU institutional-macroeconomic domains, where the pace and consistency of institutional adjustment similarly shape long-run outcomes (Tutar & Štreimikienė, 2026).

EU Harmonization Framework. The difference in institutional quality between the EU member states (Estonia, Slovenia, and the Czech Republic) and the Western Balkan economies in the accession process (Albania and North Macedonia) illustrates the indirect contribution of the EU accession process to innovation capacity through institutional convergence. The acquis harmonization implemented within the framework of EU accession negotiations accelerates structural transformation in competition law, state aid control, and R&D incentive frameworks. For countries in the accession process, full participation in the EU's Horizon Europe programme, access to European Innovation Council resources, and integration into the European Research Area should be prioritized as concrete policy tools that link institutional reforms to innovation outcomes. In this context, aligning national innovation strategies with EU Research and Innovation programmes will simultaneously strengthen both FDI attraction and innovation capacity (Ali et al., 2023; Nguyen, 2024). This policy orientation should be accompanied by transparent investment appraisal and implementation capability. Transport-

corridor evidence shows that the economic case for infrastructure investment becomes more credible when expected operator benefits, profitability, and network effects are assessed explicitly rather than inferred from investment scale alone (Nwokedi et al., 2020).

Limitations and future research

Limitations. This study has methodological limitations stemming from the limited sample size of 12 ODA countries. The lack of data on the human capital variable reduced the analysis sample to 123 observations, creating a significant limitation, particularly in terms of statistical power, for detecting the moderator effect. The fixed-effects estimator structure cannot fully eliminate the risk of reverse causality between FDI and innovation; it is not possible to claim causality without an instrumental variable approach or quasi-experimental designs (Arellano & Bond, 1991). The WGI dimensions measure institutional quality through perception-based indicators and may contain measurement errors in cross-country comparisons; the annual data structure is insufficient to capture the long-term effects of institutional changes on innovation. FDI data reflect total net inflows without sectoral distinction; the model cannot control for differences in innovation effects between technology-intensive and resource-oriented FDI (Vujanović et al., 2022).

Future Research. Future studies could bridge this gap by combining the System GMM estimator with a broader country sample to address endogeneity. Determining the minimum institutional capacity level using threshold regression models will clarify the conditions under which FDI translates into innovation acquisition. Decomposing FDI by sector and country of origin will provide a unique contribution to the literature (Blundell & Bond, 1998). Future work could also examine how labor market imbalances and migration dynamics in the region interact with FDI-driven innovation channels, given documented structural disruptions in Eastern European labor markets (Tutar et al., 2025).

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