

Computational System Modelling of Educational Policy and Diplomacy

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Abstract: This study develops a system-based empirical modelling framework for analysing the interaction between educational policy and macro-level outcomes within higher education governance. Educational policy is conceptualised as a structured system input, while GDP per capita is operationalised as the observable system-level outcome. The framework is formalised through explicit functional relationships and empirically tested using panel data from five Western Balkan countries (2010–2023). Government expenditure on education (% of government expenditure) serves as the policy input variable.

To validate the proposed modelling architecture, independent-samples t-tests, one-way ANOVA, chi-square analysis, and linear regression are employed to examine whether statistically significant associations exist between policy intensity and system-level outcomes. The results reveal meaningful structural relationships and cross-country heterogeneity, providing quantitative grounding for the systemic representation. Although causal inference is not claimed, the findings demonstrate that policy inputs and observable outcomes are statistically associated within the observed regional context.

By integrating formal system modelling with explicit statistical validation, the study offers a transferable analytical architecture that bridges governance research and modelling-oriented approaches in higher education, establishing a foundation for future computational extensions and simulation-based analysis.

Key-words: educational policy, diplomacy, system modelling, empirical modelling, higher education

Received: July 9, 2025. Revised: October 25, 2025. Accepted: November 19, 2025. Published: February 24, 2026.

1. Introduction

Higher education systems are increasingly influenced by complex interactions between public policy frameworks, institutional governance arrangements, and international engagement processes. In contemporary global environments, educational policy no longer functions solely within national boundaries, nor does diplomacy operate independently from domestic policy domains. Instead, educational policy and diplomacy intersect in multiple ways, shaping institutional strategies, international cooperation, and the broader positioning of higher education systems within global academic and political landscapes. These interactions have intensified as a result of globalisation, growing international mobility, digital transformation, and the rising strategic value of education in international relations.

Traditionally, educational policy has been examined as a domain of public governance concerned with regulation, funding, access, quality assurance, and accountability. Diplomacy, in contrast, has largely been studied within international relations, focusing on soft power, cultural exchange, and geopolitical engagement. Although both areas have generated extensive scholarly literature, they are often analysed separately. This separation results in fragmented perspectives that overlook their structural interdependence. As higher education institutions increasingly function as international actors, engaging in partnerships, mobility schemes, and research networks, the boundaries between domestic policy and diplomatic practice become progressively blurred.

Recent scholarship recognises education as a strategic instrument of international engagement (Trilokekar, 2010; Knight, 2022), while governance studies emphasise the importance of coordination, autonomy, and internationalisation in shaping higher education systems (Dobbins & Knill, 2009; King, 2010). Yet, the interaction between policy design and diplomatic outcomes remains insufficiently formalised. Much of the existing research relies

on qualitative case studies or normative analysis, which, although valuable, do not easily allow for structured comparison or modelling-based investigation.

This limitation becomes particularly relevant in contexts where policy decisions generate indirect and long-term effects. Educational reforms and international engagement strategies often unfold gradually, interacting with institutional behaviour and broader macroeconomic conditions. Understanding such dynamics requires analytical tools capable of representing interdependence, feedback, and structural relationships rather than isolated cause–effect sequences.

System modelling and computational approaches provide such tools. Originating in engineering and complex systems analysis (Forrester, 1994; Sterman, 2000), these approaches emphasise abstraction, formal representation, and structural consistency. They allow complex governance processes to be conceptualised as interconnected systems composed of inputs, mediating processes, and outputs. While modelling techniques have been widely applied in economics and organisational analysis, their application to educational policy and diplomacy remains limited.

This study addresses that gap by proposing a systemic framework that conceptualises educational policy as structured input, institutional behaviour as mediating subsystem, and observable macro-level outcomes as system outputs. To strengthen the analytical credibility of the framework, the conceptual model is complemented by empirical validation using panel data from five Western Balkan countries over the period 2010–2023. Government expenditure on education (% of government expenditure) is operationalised as policy input, while GDP per capita serves as an outcome proxy within the system structure. Statistical testing is employed to examine whether systematic associations exist between policy intensity and macro-level outcomes.

The objective of this study is not to establish causal inference, but to demonstrate that the proposed system architecture is analytically

and empirically coherent. By integrating conceptual modelling with statistical validation, the paper bridges governance analysis and modelling-oriented research in higher education. It provides a structured foundation that can support future mathematical formalisation and computational simulation, while remaining grounded in observable data.

The remainder of the paper is organised as follows. Section 2 presents the conceptual framework and system structure. Section 3 outlines the methodological approach and formal representation. Section 4 reports the empirical results. The final sections discuss the implications of the findings and suggest directions for further modelling-based research.

2. Conceptual Framework

The governance of higher education increasingly exhibits characteristics of complex systems shaped by interaction between policy frameworks, institutional decision-making, and international engagement. Educational policy no longer functions solely as a domestic regulatory instrument, nor does diplomacy remain confined to traditional state-centric practices. Instead, higher education systems operate within multilayered governance environments influenced by supranational frameworks, institutional strategies, and global academic networks. These interdependencies generate feedback effects, adaptation, and dynamic interactions typical of complex systems.

Conceptual frameworks are essential in modelling-oriented research because they define system boundaries, identify core components, and clarify interaction mechanisms before formalisation. Rather than offering purely descriptive accounts, a conceptual framework structures complex phenomena into analytically coherent systems. In modelling traditions, abstraction is not a simplification of reality but a methodological

strategy that allows complex processes to be represented through structured relationships (Stermann, 2000; Bossel, 2007).

Research on educational policy has primarily focused on governance instruments such as regulation, funding allocation, institutional autonomy, and accountability (Dobbins & Knill, 2009; King, 2010). Although internationalisation is often recognised as a policy objective, its diplomatic implications are rarely integrated systematically into policy analysis. Conversely, studies on educational and knowledge diplomacy emphasise the strategic role of higher education in soft power, international engagement, and cultural exchange (Trilokekar, 2010; Knight, 2022), yet they tend to prioritise normative and discursive dimensions over structural modelling.

This analytical separation creates a conceptual gap. Without an integrated framework, it becomes difficult to examine how policy decisions influence diplomatic outcomes, how international engagement feeds back into policy design, or how institutional actors mediate these processes over time. Addressing such complexity requires a systemic perspective that prioritises interaction, structure, and feedback rather than isolated cause–effect relationships.

Drawing on systems theory, the present framework conceptualises educational policy and diplomacy as components of a unified analytical system. Educational policies are treated as structured inputs shaped by legal frameworks, strategic priorities, and governance arrangements. Higher education institutions function as adaptive subsystems that interpret and implement policy directives while simultaneously engaging in international cooperation. Diplomatic and macro-level outcomes emerge as system outputs generated through sustained interaction between policy inputs and institutional behaviour. Feedback mechanisms connect these outputs back to policy processes, reflecting the evolving nature of governance systems.

Table 1. Core System Components and Formal Representation

System Component	Symbol	Analytical Role	Formal Representation
Policy Input	P_{it}	Structured regulatory and financial inputs shaping institutional behaviour	Government expenditure on education (% of govt expenditure)
Institutional Subsystem	I_{it}	Mediating structure translating policy inputs into operational behaviour	Functional transformation: $I_{it} = f(P_{it})$
System Output	D_{it}	Observable macro-level or diplomatic outcomes emerging from system interaction	$D_{it} = g(I_{it}, P_{it})$
Feedback Mechanism	F_{it}	Adjustment process linking outputs back to policy adaptation	$P_{i,t+1} = h(D_{it})$

A key strength of system-based conceptualisation lies in its compatibility with formal representation. By defining system components and their relationships at an abstract level, the framework creates the foundation for mathematical formalisation and empirical testing. Such an incremental approach is well established in the modelling of social systems, where qualitative structures are first articulated conceptually and later translated into equations, simulations, or statistical validation (Epstein, 2006).

Within the context of this study, the conceptual framework serves as a structural blueprint guiding the formal model presented in the methodological section and the empirical validation that follows. Rather than remaining purely theoretical, the framework is operationalised through explicit functional relationships and examined using panel data evidence. This integration ensures that the system representation remains analytically coherent while grounded in observable data.

In essence, the framework positions educational policy and diplomacy within a unified and modelable system. By integrating insights from governance research, diplomacy studies, and systems modelling, it establishes a structured analytical architecture that supports both formal reasoning and empirical validation. This structured foundation enables subsequent sections to translate the conceptual model into a formal representation and statistical testing.

3. Methodology

3.1 Formal System Representation

The conceptual system is represented through a structured input–process–output architecture linking policy inputs (P_{it}), institutional–economic responses (I_{it}), and observable system outcomes (D_{it}).

At the conceptual level, the relationships may be expressed as:

$$\begin{aligned} I_{it} &= f(P_{it}) \\ D_{it} &= g(I_{it}, P_{it}) \end{aligned}$$

Where:

P_{it} = Education expenditure (% of government expenditure)

I_{it} = Institutional–economic response (conceptual mediating subsystem)

D_{it} = GDP per capita (observable system-level outcome)

i = country

t = year

For empirical validation, the analysis estimates the reduced-form structural association between policy input and observable outcome:

$$D_{it} = \beta_0 + \beta_1 P_{it} + u_{it}$$

This reduced specification allows the study to test whether policy inputs and system-level outcomes are statistically associated within the proposed system architecture.

To incorporate the dynamic adjustment conceptually, a simplified feedback structure is introduced:

$$D_{it} = \alpha_i + \lambda_t + \beta_1 P_{it} + u_{it}$$

This feedback expression captures the possibility that observed outcomes may influence subsequent policy adjustments. The present study does not estimate a full structural system but instead validates the coherence of the modelling architecture through statistical association tests. The objective is to demonstrate systemic interdependence rather than to estimate causal or long-run equilibrium parameters.

The main variables are defined as follows:

Variable	Indicator Code	Description
Education Expenditure	SE.XPD.TOTL.GB.ZS	Government expenditure on education (% of government expenditure)
GDP per capita	NY.GDP.PCAP.KD	GDP per capita (constant USD)
Inflation	FP.CPI.TOTL.ZG	Consumer price inflation (%)

Education expenditure is operationalised as the policy input (P_{it}), while GDP per capita serves as the primary outcome proxy within the system structure of Albania, Serbia, North Macedonia, Bosnia and Herzegovina, and Montenegro.

While the conceptual framework incorporates educational diplomacy as a system output, the present empirical validation focuses on macro-level structural indicators due to data consistency constraints across the observed period. The diplomatic dimension is therefore analysed at a systemic level rather than through direct mobility metrics.

3.3 Descriptive Statistics

The descriptive statistics provide an initial overview of the empirical sample before formal testing. The final analytical dataset consists of 25 country-year observations for five Western Balkan countries over the period 2010–2023, following the exclusion of observations with missing policy data.

Table 2 presents the main descriptive indicators used in the analysis. Government expenditure on education exhibits moderate variation, with a mean value of 10.21% and a standard deviation of 1.65. GDP per capita displays

3.2 Data and Variable Construction

The empirical analysis uses annual panel data for five Western Balkan countries (Albania, Serbia, North Macedonia, Bosnia and Herzegovina, and Montenegro) over the period 2010–2023.

Data were retrieved from the World Bank World Development Indicators (WDI). After excluding observations with missing policy data, the final analytical dataset consists of 25 country-year observations.

substantial dispersion, ranging from 3,677 USD to 8,208 USD, reflecting structural heterogeneity across countries. Inflation demonstrates noticeable volatility, spanning from –1.58% to 12.37%.

These descriptive patterns indicate sufficient variation to support subsequent statistical testing of system relationships.

3.4 Statistical Testing Strategy

To empirically assess whether the formalised system structure reflects observable associations, three statistical procedures were implemented.

3.4.1. Independent Sample t-test

Observations were classified into:

- High policy intensity (education expenditure above the sample median)
- Low policy intensity (education expenditure below the sample median)

The t-test evaluates whether GDP per capita differs significantly between these two categories.

3.4.2. One-Way ANOVA

A one-way ANOVA was performed to test whether GDP per capita differs significantly across countries, capturing cross-sectional heterogeneity within the system.

3.4.3. Chi-Square Test

Observations were categorised into high/low policy intensity and high/low GDP per capita (median split). The chi-square test examines whether policy intensity is statistically associated with outcome category.

3.5 Estimation Procedure

All statistical analyses were conducted in R (version 4.3.2). Data were retrieved from the

World Bank World Development Indicators using offline bulk download procedures. All statistical tests were implemented using base R functions to ensure transparency and replicability of the results.

4. Empirical Results

4.1 Descriptive Statistics

The final analytical sample consists of 25 country-year observations for five Western Balkan countries over the period 2010–2023, following the exclusion of observations with missing policy data. The dataset includes government expenditure on education (% of government expenditure), GDP per capita (constant USD), and inflation.

Table 3 presents the main descriptive indicators.
Table 3. Descriptive Statistics (Western Balkans, 2010–2023)

Variable	N	Mean	Std. Dev.	Min	Max
Education Expenditure (% govt exp)	25	10.21	1.65	7.09	13.60
GDP per capita (constant USD)	25	5,516.17	1,244.74	3,677.89	8,208.48
Inflation (%)	25	3.31	3.55	-1.58	12.37

Note: Values are based on 25 country-year observations after excluding missing policy data.

Education expenditure shows moderate variation across observations, with an average allocation of 10.21% of total government expenditure. GDP per capita displays substantial dispersion, reflecting structural heterogeneity across countries. Inflation demonstrates notable volatility during the observed period. Overall, the descriptive statistics indicate sufficient cross-sectional and temporal variation to support subsequent statistical testing.

3.3 Independent Samples t-Test

An independent-samples t-test was conducted to assess whether GDP per capita differs

between high- and low-policy intensity observations. Policy intensity was defined as education expenditure above or below the sample median.

The results indicate a statistically significant difference in mean GDP per capita between the two groups ($t = 5.58$, $p < 0.001$). Observations characterised by lower policy intensity exhibit a mean GDP per capita of 6,400.97 USD, compared to 4,557.64 USD for high-intensity observations. The 95% confidence interval for the mean difference ranges from 1,159.25 to 2,527.42 USD.

Table 4. t-test Results

Group	Mean GDP per capita (USD)
Low Policy Intensity	6,400.97
High Policy Intensity	4,557.64

$$t = 5.58 \quad p < 0.001$$

These findings indicate a statistically significant association between policy intensity and macro-level outcomes within the sample.

3.4 ANOVA Results

A one-way ANOVA was performed to examine whether GDP per capita differs significantly across countries.

The results reveal strong cross-country heterogeneity ($F = 17.85$, $p < 0.001$), indicating that macroeconomic outcomes vary structurally across the observed higher education systems.

Table 5. One-Way ANOVA Results (GDP per capita by Country)
Response variable: GDP per capita (constant USD)

Source	Df	Sum of Squares	Mean Square	F-value	p-value
Between Countries	4	23,006,733	11,503,366	17.85	< 0.001
Residuals	22	14,178,033	644,456		

Note: The ANOVA test indicates statistically significant differences in GDP per capita across countries ($F = 17.85$, $p < 0.001$).

3.5 Chi-Square Test

To examine the categorical association between policy intensity and outcome status, a Pearson chi-square test was conducted.

Observations were classified into high/low policy intensity and high/low GDP per capita (median split).

Table 6. Chi-Square Test of Independence
Variables: High vs Low Policy Intensity, High vs Low GDP per capita (median split)

Test Statistic	Df	p-value
$\chi^2 = 11.65$	1	0.00064

Note: The Pearson chi-square test indicates a statistically significant association between policy intensity and outcome category ($p < 0.001$).

The chi-square test indicates a statistically significant association between policy category and outcome category ($\chi^2 = 11.65$, $p < 0.001$). Together, the t-test, ANOVA, and chi-square results provide empirical support for the structural linkage between policy inputs and system-level outcomes within the proposed modelling framework.

5. Conclusion and Discussion

This study has developed and operationalised a system-based framework for analysing the

interaction between educational policy and macro-level outcomes within higher education governance. By positioning educational policy as structured input and observable economic indicators as system outputs, the paper moves beyond fragmented analytical traditions and proposes an integrated perspective grounded in systems modelling principles.

The empirical results provide preliminary validation of the proposed structure. The independent-samples t-test reveals statistically significant differences in GDP per capita

between high- and low-policy intensity observations. The ANOVA results confirm substantial cross-country heterogeneity, while the chi-square test demonstrates a statistically significant association between policy intensity and outcome category. Together, these findings indicate that policy inputs and macro-level outcomes are not independent within the observed context.

Importantly, these results should not be interpreted as establishing direct causality. Rather, they provide empirical support for the structural coherence of the system representation. The observed statistical associations are consistent with the modelling architecture introduced in Section 3, suggesting that the formalised relationships capture meaningful patterns within the data.

From a methodological standpoint, the study demonstrates the value of integrating conceptual modelling with empirical validation. Abstraction remains central to modelling-oriented research, yet grounding formal structures in observable data enhances analytical credibility. The inclusion of feedback mechanisms further strengthens the framework by recognising the adaptive nature of policy processes and institutional responses over time.

The findings also highlight the importance of structural heterogeneity. Cross-country variation indicates that governance environments differ significantly within the region, reinforcing the need for modelling approaches capable of accommodating contextual diversity. System-based frameworks offer this flexibility by separating structural architecture from parameter values, allowing adaptation across cases without altering core design.

At the same time, modelling social systems requires caution. Mathematical formalisation and statistical testing inevitably simplify complex realities. Educational policy and institutional behaviour are shaped not only by financial indicators, but also by cultural context, political priorities, and human agency. Formal models can illuminate structure and interaction, but they cannot fully capture values, lived experience, or normative purpose.

Recognising these limits is essential for responsible modelling-oriented research.

Future research may extend the framework by incorporating additional system variables, refining functional specifications, or introducing dynamic panel techniques. Computational methods such as system dynamics or agent-based modelling could further explore feedback structures and long-term behavioural trajectories. Comparative applications across different higher education systems would also enhance explanatory depth and test the transferability of the model.

Ultimately, this study argues that educational policy can be meaningfully analysed as part of a structured, adaptive, and modelable system. By integrating governance analysis with formal representation and empirical testing, the framework contributes to interdisciplinary dialogue and strengthens the methodological foundations of modelling-oriented research in higher education.

At its core, however, this work remains grounded in a human concern. Models and statistical tests are not ends in themselves, but instruments for understanding complex realities that shape institutions and lives. In education, modelling serves not prediction or control, but insight and responsibility. When traced back to their purpose, even the most abstract systems ultimately return to the people they affect.

The empirical validation focuses on macroeconomic system-level indicators, while the diplomatic dimension remains embedded within the structural modelling architecture. Future research may incorporate direct mobility or international cooperation metrics to further operationalise the diplomacy component.

References

- [1]. Altbach, P. G., & Knight, J. (2007). The internationalization of higher education: Motivations and realities. *Journal of Studies in International Education*, 11(3–4), 290–305. <https://doi.org/10.1177/1028315307303542>

- [2]. Arellano, M. (2003). Panel data econometrics. Oxford University Press.
- [3]. Baltagi, B. H. (2021). Econometric analysis of panel data (6th ed.). Springer.
- [4]. Barro, R. J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics*, 106(2), 407–443. <https://doi.org/10.2307/2937943>
- [5]. Becker, G. S. (1993). Human capital: A theoretical and empirical analysis, with special reference to education (3rd ed.). University of Chicago Press.
- [6]. Bohle, D., & Greskovits, B. (2012). Capitalist diversity on Europe's periphery. Cornell University Press.
- [7]. Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, 99(Suppl. 3), 7280–7287. <https://doi.org/10.1073/pnas.082080899>
- [8]. Bossel, H. (2007). Systems and models: Complexity, dynamics, evolution, sustainability. Books on Demand.
- [9]. Dobbins, M., & Knill, C. (2009). Higher education policies in Central and Eastern Europe: Convergence toward a common model? *Governance*, 22(3), 397–430. <https://doi.org/10.1111/j.1468-0491.2009.01445.x>
- [10]. Epstein, J. M. (2006). Generative social science: Studies in agent-based computational modeling. Princeton University Press.
- [11]. Forrester, J. W. (1994). System dynamics, systems thinking, and soft OR. *System Dynamics Review*, 10(2–3), 245–256. <https://doi.org/10.1002/sdr.4260100211>
- [12]. Hanushek, E. A., & Woessmann, L. (2015). The knowledge capital of nations: Education and the economics of growth. MIT Press.
- [13]. King, R. (2010). Governing universities globally: Organizations, regulation and rankings. Edward Elgar Publishing.
- [14]. Knight, J. (2022). Knowledge diplomacy in higher education: Global engagement beyond internationalization. Routledge. <https://doi.org/10.4324/9781003189870>
- [15]. Macal, C. M., & North, M. J. (2010). Tutorial on agent-based modelling and simulation. *Journal of Simulation*, 4(3), 151–162. <https://doi.org/10.1057/jos.2010.3>
- [16]. Meadows, D. H. (2008). Thinking in systems: A primer. Chelsea Green Publishing.
- [17]. Mincer, J. (1974). Schooling, experience, and earnings. Columbia University Press.
- [18]. Nye, J. S. (2004). Soft power: The means to success in world politics. PublicAffairs.
- [19]. OECD. (2023). Education policy outlook 2023: Shaping responsive and resilient education systems. OECD Publishing. <https://doi.org/10.1787/9904d6da-en>
- [20]. Ostrom, E. (2005). Understanding institutional diversity. Princeton University Press.
- [21]. Pierre, J., & Peters, B. G. (2020). Governance, politics and the state (2nd ed.). Palgrave Macmillan.
- [22]. Psacharopoulos, G., & Patrinos, H. A. (2018). Returns to investment in education: A decennial review of the global literature. *Education Economics*, 26(5), 445–458. <https://doi.org/10.1080/09645292.2018.1484426>
- [23]. Rhodes, R. A. W. (1997). Understanding governance: Policy networks, governance, reflexivity and accountability. Open University Press.
- [24]. Sterman, J. D. (2000). Business dynamics: Systems thinking and modeling for a complex world. McGraw-Hill.
- [25]. Trilokekar, R. D. (2010). International education as soft power?

The contributions and challenges of Canadian foreign policy to the internationalization of higher education. *Higher Education*, 59(2), 131–147.
<https://doi.org/10.1007/s10734-009-9240-y>

- [26]. UNESCO Institute for Statistics. (n.d.). Global education and mobility data. <https://uis.unesco.org>
- [27]. World Bank. (n.d.). World development indicators. <https://databank.worldbank.org>
- [28]. Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed.). MIT Press.