

Mapping the Paradox: A Quantitative Analysis of NATO's Military Spending, Conflict Exposure, and Social Sustainability (2014-2023)

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Abstract: *This study examines the relationship between military expenditure, conflict levels, and social sustainability among NATO countries from 2014 to 2023. Using data from SIPRI, GPI, and the World Bank, the analysis employs K-means clustering and correlational heatmapping to identify patterns in defense spending, peace indicators, and social resilience. The findings reveal that increased military expenditure does not consistently enhance peace or reduce conflict and is often negatively associated with social development. The study identifies three distinct country clusters based on expenditure profiles and security metrics. The results challenge traditional assumptions about defense spending and offer data-driven recommendations for balancing military commitments with human-centered development.*

Keywords: NATO, military expenditure, peace, social sustainability, conflict dynamics

1. Introduction

Since its founding in 1949, the North Atlantic Treaty Organization (NATO) has served as a collective defence for the transatlantic community¹. Originally conceived as a deterrent to Soviet aggression during the Cold War, the alliance has undergone successive phases of strategic transformation in response to evolving security threats, from post-Soviet regional instability to asymmetric warfare, cyber threats, and emergent multipolar competition².

Despite the unity of its charter, NATO remains internally heterogeneous. Its member states differ in terms of military capacity, threat perception and societal resilience.

While majority research has been done with context to NATO's external strategic posture, comparatively less analysis has focused on the differences among the member countries of NATO in terms of their military expenditure, peace, and security performance³.

Though such differences may be disadvantageous to alliances like NATO, they hold significant implications for burden sharing, strategic alignment and policy making, particularly in an era where consensus is increasingly difficult to achieve across a politically and economically diverse membership.

This study aims to assess the relationship between military expenditure, conflict dynamics, and social sustainability within NATO countries between 2014 and 2023 using data-

driven clustering and correlation techniques. Using data from Stockholm International Peace Research Institute⁴ (SIPRI) and the Institute for Economics and Peace (IEP)⁵ on global peace index (GPI) the research focuses on the following hypothesis:

- H1:** Countries can be meaningfully grouped into distinct clusters based on their military expenditure, conflict intensity, Global Peace Index score which reflect the security paradox and their social sustainability outcomes.
- H2:** There is a statistically significant association between conflict levels (categorical) and social sustainable indicators reflecting the trade-off between militarization and human centred development within NATO democracies. The countries with negative correlational heatmapping scores (-0.43) align with the security paradox.
- H3:** Military Expenditure directly correlates with Global Peace Index score and negatively correlates with social sustainability across NATO member states. (2014-2023)

To supplement the analysis the study uses K-Means clustering to classify the NATO member states. The research not only uncovers hidden patterns and trends among alliance members, grouping together those with similar behaviours or priorities, but also helps explain why different countries make different choices in their military and security policies. This research also contextualizes these trends with evolving conflict patterns and peacebuilding efforts.

The study is significant as it introduces a multidimensional analytical lens to evaluate alliance behaviour and security

¹ Office of the Historian, North Atlantic Treaty Organization (NATO), 1949 (Office of the Historian 2025) <https://history.state.gov/milestones/1945-1952/nato>

² A Samson, U Ikechukwu and O Amina, 'NATO Evolving Strategic Role after the Cold War: Examining U.S. Leadership in Global Security' (2025) 18(4) *Journal of Policy and Development Studies* 1–15 <https://doi.org/10.4314/jpds.v18i4.1>

³ J Ringsmose and S Rynning, 'NATO's Return to the Core: The Centrality of Collective Defence' (2017) 93(3) *International Affairs* 453–462.

⁴ SIPRI, *SIPRI Military Expenditure Database* (Stockholm International Peace Research Institute 2024) <https://www.sipri.org/databases/milex>.

⁵ Institute for Economics & Peace, *Global Peace Index 2023: Measuring Peace in a Complex World* (Institute for Economics & Peace 2023) <https://visionofhumanity.org/resources>

trade-offs, bridging theoretical discourse with policy-oriented recommendations. It challenges the conventional assumption that higher defense expenditure equates to higher peace outcomes and instead highlights the nuanced interplay between militarization and social development

1.1 Theoretical framework and theoretical gap

This research relies on the Paradox of security and Securitization theory to interrogate the relationship between military expenditure and social sustainability⁶ within NATO member states.

Rooted in the Copenhagen School, securitization theory⁷ suggests that issues are elevated to matters of security through political discourse, justifying extraordinary measures and resource allocation. The framework reveals that defence spending is not just an economic decision but an important act necessary for national survival and peace which is often impacted by social and economic factors⁸.

Concurrently the paradox of security theorizes that overspending on the military can cause long term instability in peace especially when it comes at the cost of social development and human security.

While existing literature often focuses on deterrence theory⁹ and strategic balance¹⁰, a significant theoretical gap lies in the correlational analysis of social sustainability outcomes¹¹ vis-à-vis defence posturing among NATO democracies.

This research bridges that gap by employing quantitative clustering and correlational tools to interrogate whether

securitized states are inadvertently sacrificing internal resilience in the pursuit of external security.

2. Review of literature

2.1 Military Expenditure and NATO's Deterrence and defence policy

Military expenditure has always been justified to avoid conflicts and maintain national peace and security¹². Taking NATO in context, its collective defence¹³ has necessitated consistent investments in armament and strategic infrastructure¹⁴. Researchers argue that such expenditure maintains peace through deterrence¹⁵.

Deterrence is a fundamental component of NATO's overall strategy¹⁶. This deterrence involves preventing conflicts and war, safeguarding allies and protecting Allies, maintaining freedom of decision and action¹⁷.

NATO's deterrence and defense posture is combination of nuclear, conventional, and missile defense capabilities. NATO retains the adaptability and freedom of action necessary to address the entire range of issues in a suitable and customized manner.

2.2 Geopolitical Shocks and militarization

The annexation of Crimea by Russia in 2014 marked a significant geopolitical risk¹⁸. Since then, Ukraine has remained under constant threat¹⁹. Being a part of the NATO member since from 2014 onwards, NATO has consistently improved its deterrence²⁰ and defence to ensure that Allies are ready to respond to any threat from any direction²¹. This led

⁶ T Balzacq, 'The Three Faces of Securitization: Political Agency, Audience and Context' (2005) 11(2) *European Journal of International Relations* 171–201 <https://doi.org/10.1177/1354066105052960>.

⁷ B Buzan, O Wæver and J De Wilde, *Security: A New Framework for Analysis* (Lynne Rienner Publishers 1998).

⁸ NTA Otukoya, 'The Securitization Theory' (2024) 11(1) *International Journal of Science and Research Archive* 1747–1755 <https://doi.org/10.30574/ijrsra.2024.11.1.0225>.

⁹ AL Burns, 'From Balance to Deterrence: A Theoretical Analysis' (1957) 9(4) *World Politics* 494–529 <https://doi.org/10.2307/2009422>; FC Zagare, 'Classical Deterrence Theory: A Critical Assessment' (1996) 21(4) *International Interactions* 365–387 <https://doi.org/10.1080/03050629608434873>.

¹⁰ C Kaysen, 'Keeping the Strategic Balance' (1968) 46(4) *Foreign Affairs* 665–675 <https://doi.org/10.2307/20039335>.

¹¹ SL Quackenbush, 'Deterrence Theory: Where Do We Stand?' (2011) 37(2) *Review of International Studies* 741–762 <https://doi.org/10.1017/S0260210510000896>.

¹² T Sandler and K Hartley, *The Economics of Defense* (Cambridge University Press 1995).

¹³ JR Deni, 'Collective Defence', in Edward Elgar Publishing eBooks (Edward Elgar 2023) 208–221 <https://doi.org/10.4337/9781839103391.00026>.

¹⁴ E Perot, NATO, the EU and the Return of Collective Defence, CSDS Policy Brief (2022) https://csds.vub.be/wp-content/uploads/2023/09/CSDS-Policy-brief_2212.pdf.

¹⁵ NATO, *Collective Defence and Article 5* (4 July 2023) https://www.nato.int/cps/en/natohq/topics_110496.html; NATO, *Deterrence and Defence* (10 October 2023) https://www.nato.int/cps/en/natohq/topics_133127.html.

¹⁶ E Neumayer, 'Weak and Strong Sustainability in the SEEA: Concepts and Measurement' (2003) 46(3) *Ecological Economics* 227–238.

¹⁷ NATO, *Collective Defence and Article 5* (4 July 2023) https://www.nato.int/cps/en/natohq/topics_110496.html; NATO, *Deterrence and Defence* (10 October 2023) https://www.nato.int/cps/en/natohq/topics_133127.html.

¹⁸ T Rostoks and I Mieriņa, 'NATO's Reassurance and the Willingness to Defend One's Country: Survey Evidence from Latvia' (2024) 34(3) *European Security* 386–406 <https://doi.org/10.1080/09662839.2024.2434087>.

¹⁹ N Walker, *Conflict in Ukraine: A Timeline (2014 – Eve of 2022 Invasion)* (House of Commons Library 22 August 2023) <https://commonslibrary.parliament.uk/research-briefings/cbp-9476/>;

O Merezhko, 'Crimea's Annexation by Russia – Contradictions of the New Russian Doctrine of International Law' (2015) 75 *Zeitschrift für ausländisches öffentliches Recht und Völkerrecht (ZaöRV)* <http://www.zaoerv.de>; R Sabitov, 'Crimean Crisis Through Russia–NATO Relations' Perspective' (2014) *ResearchGate* https://www.researchgate.net/publication/267855544_Crimean_crisis_through_Russia_-_NATO_relations_perspective.

²⁰ D Makio and A Fuccille, 'The 2014 Russian Invasion of Crimea: Identity and Geopolitics' (2023) 66(1) *Revista Brasileira de Política Internacional* <https://doi.org/10.1590/0034-7329202300113>.

²¹ PD Beaumont, J Wilhelmsen and KL Gjerde, 'Reimagining NATO after Crimea: Defender of the Rule-based Order and Truth?' (2024) 45(3) *Contemporary Security Policy* 396–425 <https://doi.org/10.1080/13523260.2024.2349393>.

²² NATO, *Deterrence and Defence* (10 October 2023) https://www.nato.int/cps/en/natohq/topics_133127.htm.

to increased militarization²² among the NATO member states from 2014-2023.

Recent data reveals a sharp escalation in global military expenditure²³, particularly in Europe. According to SIPRI estimates European countries collectively spent about \$588 billion on defence in 2023. This represents a substantial 16% increase compared to 2022 and a 62% increase from 2014²⁴.

This increase in military expenditure has been due to the Russia Ukraine war heightening geopolitical tensions and European concerns over regional security commitments.

2.3 The Paradox of Militarization and Peace

Researchers have highlighted the paradox where higher military expenditure negatively correlates with peace levels,²⁵ especially in conflict prone areas²⁶.

This paradox is also supported by the Global peace index²⁷ which reveals that most militarized countries are not necessarily the most peaceful, questioning the effectiveness of defence-based peace paradigms²⁸.

2.4 Cohesion of Alliances and Strategic Asymmetry

Interest in internal cohesion and strategic asymmetry has led to a great deal of research on the dynamics of military alliances, especially NATO²⁹.

Research like Stephen M. Walt's groundbreaking book *The Origins of Alliances*³⁰ (1987) examines how alliances are formed and maintained by destroying interests and threats.

The intricacies of alliance behaviour and the importance of a balanced economy and unity among member states are further examined in the book *Alliance Politics*³¹.

The difficulties of governance in regions with limited statehood are examined in Thomas Risse's edited collection, "Governance Without a State?"³² which also offers insights into the workings of non-state actors and international organizations such as NATO in complex situations. NATO *Renewed*³³ examines how the alliance has adjusted to post-Cold War circumstances and emphasizes its attempts to stay relevant in the face of shifting geopolitical conditions³⁴.

2.5 NATO 2 % defence Spending Target: Burden Sharing and Trade Offs

NATO adopted the 2% GDP defence spending guideline in 2006³⁵. It was adopted to ensure fair burden sharing among allies and to guarantee that member states maintain sufficient military capability for collective defence and security operations.

This target, though politically significant, is often not met by most countries, for example the United States. Scholars argue that this rule embodies the classic guns versus butter dilemma³⁶, as higher military expenditure often comes at the expense of social programs and sustainable development priorities⁷.

Consequently, the 2% guideline³⁷ serves not only as a metric of alliance commitment but also as a critical variable in

²² A Zima and IRSEM, *NATO and the War in Ukraine*, Research Paper No. 139 (IRSEM 2023) <https://www.irsem.fr/media/5-publications/nr-139-zima-nato-ukraine.pdf>

²³ European Council, *EU Defence in Numbers* (no date) <https://www.consilium.europa.eu/en/policies/defence-numbers/>

²⁴ N Tian, D Lopes da Silva, X Liang and L Scarazzato, *Trends in World Military Expenditure, 2023* (Stockholm International Peace Research Institute 2024) <https://doi.org/10.55163/BQGA2180>.

²⁵ NKA Arya, KC Pradhan and SM Mohapatra, 'Defence Expenditure and Economic Growth: A Cross-country Analysis of Peaceful and Conflict-prone Countries' (2024) *Research Square* <https://doi.org/10.21203/rs.3.rs-5647737/v1>; MN Aziz and MN Asadullah, *Military Spending, Armed Conflict and Economic Growth in Developing Countries in the Post-Cold War Era*, CREDIT Research Paper No. 16/03 (The University of Nottingham, Centre for Research in Economic Development and International Trade, 2016) <https://hdl.handle.net/10419/162744>; OD Sweidan, 'Geopolitical Risk and Military Expenditures: Evidence from the US Economy' (2023) 9(2) *Russian Journal of Economics* 201–218 <https://doi.org/10.32609/j.ruje.9.97733>.

²⁶ P Collier and A Hoeffler, 'Civil War', in T Sandler and K Hartley (eds), *Handbook of Defence Economics*, vol. 2 (Elsevier 2007) 711–739.

²⁷ Institute for Economics and Peace, *Global Peace Index 2023: Measuring Peace in a Complex World* (Institute for Economics & Peace 2023) <https://visionofhumanity.org/resources>

²⁸ MD Intriligator, 'The Peace Dividend: Myth or Reality?' (1996) *Contributions to Economic Analysis* 1–13 [https://doi.org/10.1108/s0573-8555\(1996\)0000235003](https://doi.org/10.1108/s0573-8555(1996)0000235003); M Fowler, 'Strategies for Peace', in HF Carey (ed), *Peacebuilding Paradigms: The Impact of Theoretical Diversity on Implementing Sustainable Peace* (Cambridge University Press 2020) 31–46; P Rosa and J Ludvík, 'Explaining European Military Integration: Theoretical

Perspectives in Relation to the Building of a Common Defence' (21 September 2023) *Digitální Repozitář UK* <http://hdl.handle.net/20.500.11956/187358>.

²⁹ MA Westerman and JC Muran, 'Investigating an Approach to the Alliance Based on Interpersonal Defense Theory' (2017) 27(5) *Psychotherapy Research* 620–641 <https://doi.org/10.1080/03050629608434873>; J Hodicky and others, 'Dynamic Modeling for Resilience Measurement: NATO Resilience Decision Support Model' (2020) 10(8) *Applied Sciences* 2639 <https://doi.org/10.3390/app10082639>; M Gniazdowski, 'Slovakia', in B Górka Winter and M Madej (eds), *NATO Member States and the New Strategic Concept: An Overview* (The Polish Institute of International Affairs 2010) 94–98; T Sandler and K Hartley, *The Economics of Defense* (Cambridge University Press 1995).

³⁰ SM Walt, *The Origins of Alliances* (Cornell University Press 1987).

³¹ GH Snyder, *Alliance Politics* (Cornell University Press 1997).

³² T Risse, *Governance Without a State?* (Columbia University Press 2011).

³³ S Rynning, *NATO Renewed* (Springer 2005).

³⁴ WJ Thies, *Why NATO Endures* (Cambridge University Press 2009).

³⁵ NATO, *Information on Defence Expenditures* (3 April 2025) https://www.nato.int/cps/en/natohq/topics_49198.htm

³⁶ National Priorities Project, 'Guns versus Butter – Our Real Economic Challenge' (13 August 2007) <https://www.nationalpriorities.org/pressroom/articles/2007/08/13/guns-versus-butter-our-real-economic-challenge>

³⁷ M Eaglen and C Spiller, *Behind NATO's 2 Percent: Measuring the True Scope of Alliance Defense Investments and the NATO Defense Deficit*, AEI Foreign & Defense Policy Working Paper 2025 06 (American Enterprise Institute 2025) <https://www.aei.org/wp-content/uploads/2025/03/WP-Eaglen-Spiller-NATO.pdf>

assessing the intersection of security, economic trade-offs, and social sustainability.

For detailed data on spending trends and peace indices see Appendix figure 13-31.

2.6 Gaps and Study Contributions

Despite previous research on NATO, robust literature gaps remain especially regarding data driven clustering of alliance behaviour and integration of social sustainability into security analysis. This research was addressed with new quantitative methods and updated datasets.

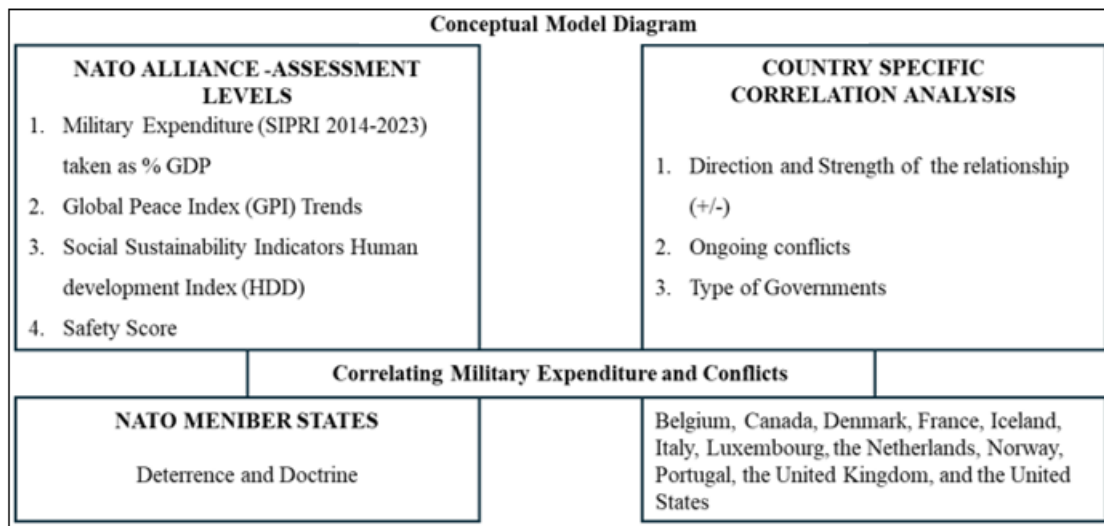


Figure 1: Conceptual Model Diagram

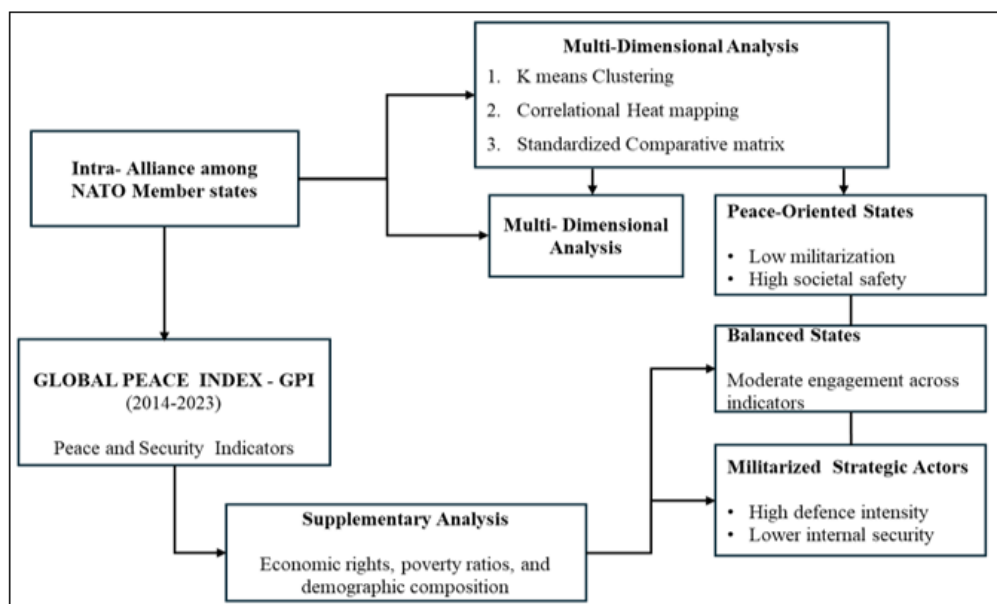


Figure 2: Multi- Dimensional Analysis.

3. Methodology

3.1 Research Design

The study employs a comparative quantitative research design³⁸ to observe trends in peace, security, and

militarization among NATO countries. Using longitudinal data from 2014-2023, the study categorizes NATO member states into empirically derived typologies according to their strategic peace and security profiles, the methods used are unsupervised machine learning, notably Correlational Heatmapping³⁹, K-Means clustering⁴⁰ and Chi Square Test⁴¹.

House of Commons Defence Committee, Shifting the Goalposts? Defence Expenditure and the 2% Pledge (no date) <https://publications.parliament.uk/pa/cm201516/cmselect/cmdfence/494/49406.html>

³⁸ WL Neuman, *Social Research Methods: Qualitative and Quantitative Approaches* (7th edn, Pearson Education 2014).

³⁹ A Dudaš, 'Graphical Representation of Data Prediction Potential: Correlation Graphs and Correlation Chains' (2024) *The Visual Computer* <https://doi.org/10.1007/s00371-023-03240-y>

⁴⁰ A Likas, N Vlassis and J Verbeek, 'The Global K-Means Clustering Algorithm' (2003) 36(2) *Pattern Recognition* 451-461 [https://doi.org/10.1016/s0031-3203\(02\)00060-2](https://doi.org/10.1016/s0031-3203(02)00060-2).

⁴¹ McHugh, M., 'The Chi-square Test of Independence' (2013) ResearchGate

3.2 Research Onion

The research methodology has been developed by referring to the Research Onion framework⁴². The following layers are included in the frameworks:

a) Research philosophy: Positivism.

Using ⁴³Saunders et al. (2019), Bryman, A. (2016), Cohen, L., Manion, L., & Morrison, K. (2018). and Collins and Hussey (2021), the study assumes that military expenditure social sustainability and peace levels can be classified using a quantitative approach. By applying machine learning algorithms and statistical tests the research has avoided any possible bias and analysed data to identify empirical patterns among NATO member states.

b) Approach: Deductive

Deductive approach proposed by Saunders et al. (2019), M., Lewis, P., & Thornhill, A. (2019)³⁵ was used to establish relationships between military spending and peace levels which guided the analysis. The research tested trends and verified them against observed patterns

and trends. This approach ensured methodological rigor and coherence.

c) Methodological choice: Quantitative and comparative analysis

This research employed a quantitative approach using statistical data to ensure unbiased results in comparing analysis across NATO member states allowed to identify distinct behaviour clusters and patterns in line with the peace level and the social sustainability of the country.⁴⁴

d) Time horizon: Longitudinal (2014-2023)

A longitudinal time horizon³⁵ enables tracking of national dynamics over the 2014–2023 period. This approach provides great analytical depth by revealing whether peace and military expenditure relations remain consistent or strengthen or weaken overtime⁴⁵.

e) Technique: Secondary Archival datasets from SIPRI and GPI and K-Means clustering analysis, Correlational Heatmapping, statistical tests ie. Chi square Test of independence was conducted to identify empirical groupings among NATO countries based on their defense and peace indicators⁴⁶.

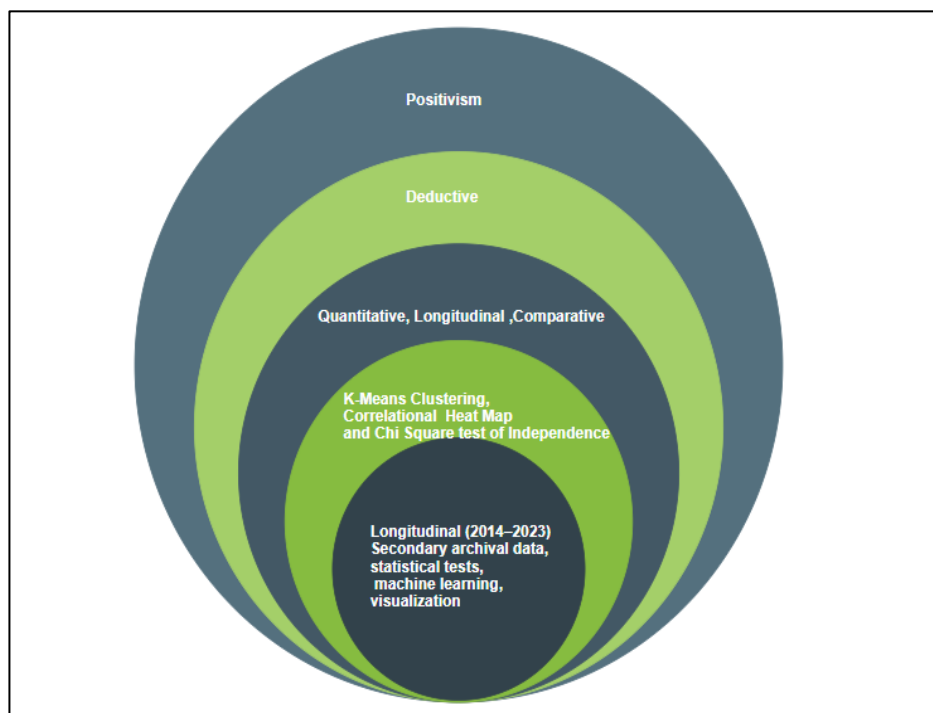


Figure 3: Research Onion ⁴⁷3.3 Data Sources

https://www.researchgate.net/publication/253336860_The_Chi-square_test_of_independence

⁴² M Saunders, P Lewis and A Thornhill, *Research Methods for Business Students* (8th edn, Pearson Education 2019).

⁴³H Arbale and DN Mutisya, 'Book Review: "Research Methods for Business Students" (Eighth Edition) by Mark N. K. Saunders, Philip Lewis, and Adrian Thornhill (Pearson Education, 2019)' (2024) 1(2) <https://doi.org/10.51867/aqsr.1.2.2>; P Collier and A Hoefler, 'Civil War', in T Sandler and K Hartley (eds), *Handbook of Defence Economics*, vol. 2 (Elsevier 2007) 711–739; J Winterton, 'Review: Business Research Methods ALAN BRYMAN and EMMA BELL. Oxford: Oxford University Press, 2007' (2008) 39(5) *Management Learning* 628–632 <https://doi.org/10.1177/13505076080390050804>.

⁴⁴ JW Creswell and JD Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (5th edn, SAGE Publications 2018); B Hancké, *Intelligent Research Design: A Guide*

for Beginning Researchers in the Social Sciences (Oxford University Press 2009).

⁴⁵ E Ruspini, *Introduction to Longitudinal Research* (Routledge 2002).

⁴⁶ AK Jain, 'Data Clustering: 50 Years Beyond K Means' (2010) 31(8) *Pattern Recognition Letters* 651–666 <https://doi.org/10.1016/j.patrec.2009.09.011>.

⁴⁷ AN Gamage, 'Research Design, Philosophy, and Quantitative Approaches in Scientific Research Methodology' (2025) 13(2) *Scholars Journal of Engineering and Technology* 91–103 <https://doi.org/10.36347/sjet.2025.v13i02.004>; A Melnikovas, 'Towards an Explicit Research Methodology: Adapting Research Onion Model for Futures Studies' (2018) 23(2) *Journal of Futures Studies* 29–44 [https://doi.org/10.6531/jfs.201812_23\(2\).0003](https://doi.org/10.6531/jfs.201812_23(2).0003); YS Park, L Konge and AR Artino, 'The Positivism Paradigm of Research' (2019) 95(5) *Academic Medicine* 690–694

The data sources for this study are as follows:

SN	Data Set	Source	Time Period
1.	Military Expenditure	Stockholm International Peace Research Institute (SIPRI) ⁴⁸	2014-2023
2.	Global Peace Index	Institute of Economics and Peace (IEP) ⁴⁹	2014-2023
3.	Social Sustainability Index	World Bank (Social Sustainability Global Database) ⁵⁰	2014-2023

3.3 Data Processing

3.3.1 Country Selection

A complete list of 31 NATO member states, as of 2023, was used as the sample frame. States for which GPI data were missing for one or more years were excluded to maintain consistency and robustness in the data.

3.3.2 Clustering Technique

<https://colab.research.google.com/drive/1wvuh-orLcb3dGTuRtUoltMEhREmJct2py?authuser=1#scrollTo=b54e84df>

To validate the robustness of clustering among NATO countries, both the K-means clustering and hierarchical clustering were applied to the Global peace index dataset spanning from 2014-2023. The Silhouette score was used as an objective metric to assess the cohesion and separation of clusters generated by each method. A Silhouette score is a method of identifying the number of clusters in each country ensuring cluster significance.

The K-means clustering obtained the following results:

The optimal K value is: 3.

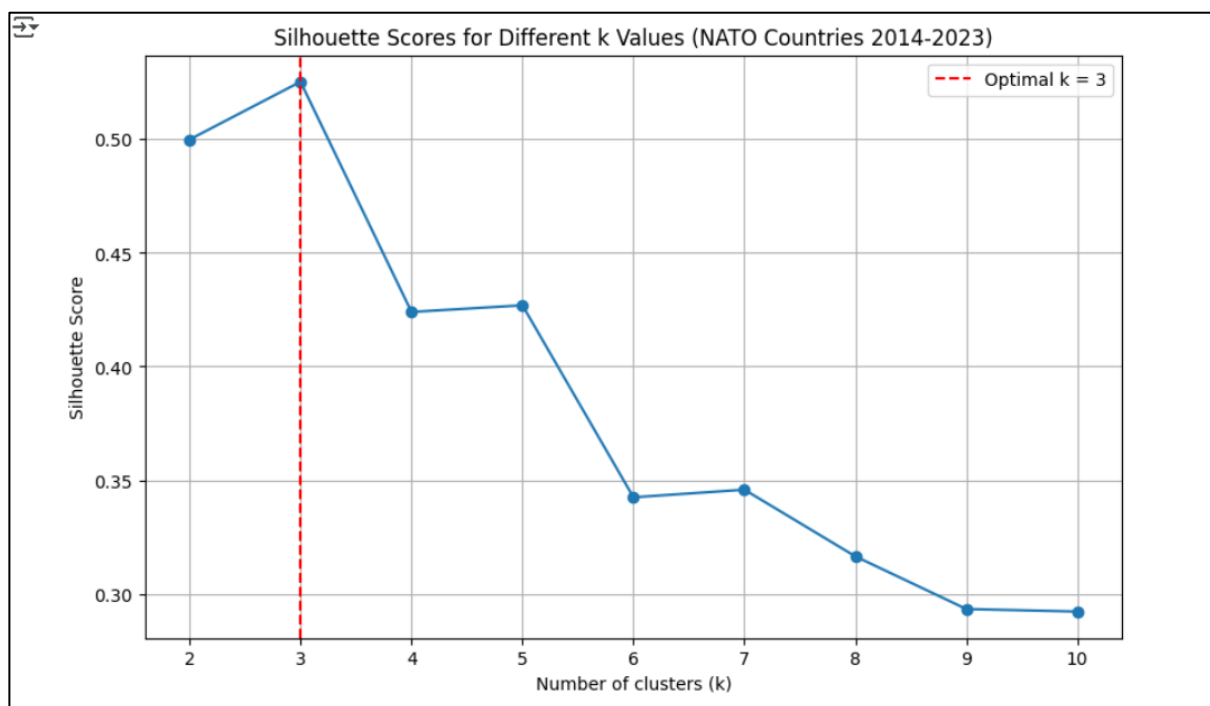


Figure 4: Silhouette score

The optimal Silhouette score is: 0.476571412265190

The hierarchical clustering obtained the following result:
Silhouette score for hierarchical clustering: 0.5206728918963038

K-Means clustering resulted in a higher Silhouette score (0.5253) compared to Hierarchical clustering (0.5207).

This suggests that based on the Silhouette metric, the clusters found by K-Means are slightly better defined and separated for this dataset.

3.3.3 K-Means Algorithm

The K-Means algorithm was selected due to its efficiency and interpretability in multidimensional unsupervised classification tasks. The algorithm aims to minimise intra-cluster variance by assigning each observation to the nearest centroid within k specified clusters.

3.3.4 Optimal Cluster Count

The Elbow Method was used to determine the ideal number of clusters. Plotting the total within-cluster sum of squares (inertia) versus different choices of k is what this method

<https://doi.org/10.1097/acm.0000000000003093>; F Schrag, 'In Defense of Positivist Research Paradigms' (1992) 21(5) *Educational Researcher* 5–8 <https://doi.org/10.3102/0013189X021005005>.

⁴⁸ SIPRI, *SIPRI Military Expenditure Database* (Stockholm International Peace Research Institute 2024) <https://www.sipri.org/databases/milex>

⁴⁹ Institute for Economics & Peace, *Global Peace Index 2023: Measuring Peace in a Complex World* (Institute for Economics & Peace 2023) <https://visionofhumanity.org/resources>

⁵⁰ World Bank, *Social Sustainability Global Database* (World Bank 2023) <https://datacatalog.worldbank.org/search/dataset/0061880/Social-Sustainability-Global-Database>

does. The Elbow Method visually identified an inflection point at $K = 3$, suggesting three natural categories in the data.

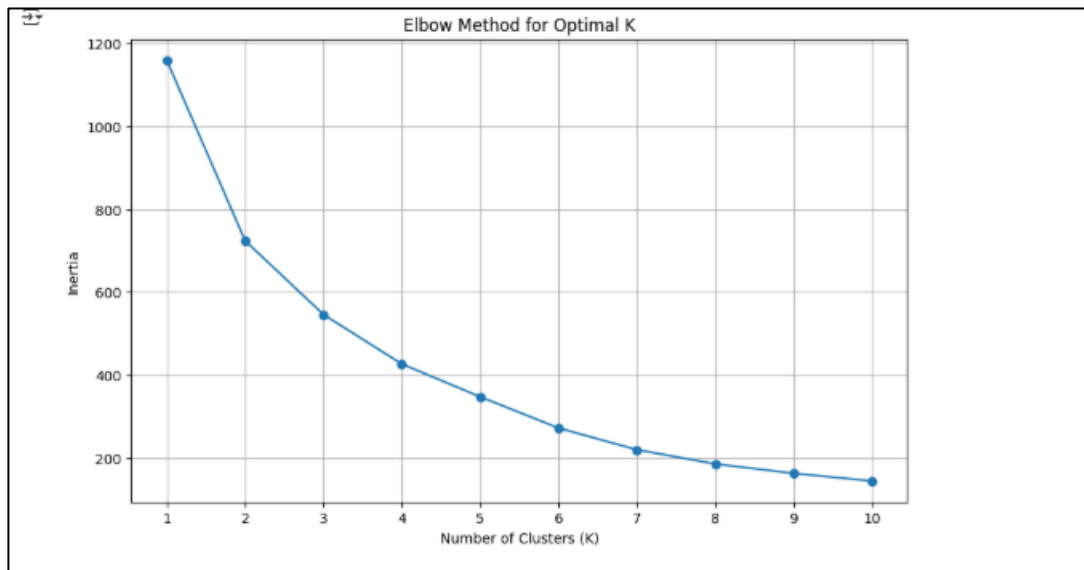


Figure 5: Elow Method

3.3.5 Tools and Technologies

All analyses were conducted in Python 3.11 using pandas, matplotlib, seaborn, and scikit-learn. The complete implementation, along with visualisations and source code, is accessible via the corresponding Google colab Notebook:

<https://colab.research.google.com/drive/1AeyyXs51CWQjxu4arWoyCDJAg4WQizVj#scrollTo=2f9c5212>

This study contributes to discussions on military spending, peace, and social sustainability, while upholding transparency and integrity.

1) Ethics statement

The research paper was conducted using multidimensional data sources obtained from reputable and publicly available sources including Stockholm International Peace Research Institute (SIPRI), Institute of Economics and Peace and the World Bank. There was negligible involvement of human participants so issues regarding privacy did not occur. All data was analysed carefully ensuring accurate attribution to

conventional academic standards. Every effort was made to avoid bias, interpretation, and plagiarism.

This research was conducted independently with 20% funding from Next genius precollege summer scholarships / Docent research scholarship awarded to the author.

2) Analysis

This section details the analysis of NATO member states across three intersecting dimensions of military expenditure, peace index, and social sustainability over the period 2014–2023. The methodological integration of correlational analysis with K-means clustering enables a comprehensive view of underlying patterns and power alignments across time. The K-means analysis and correlation heatmapping are used to observe trends in the datasets.

3.4 K-Means Clustering of NATO countries.

The K-means divides NATO countries in 3 distinct clusters. The cluster Centres (in original scale) are presented below:

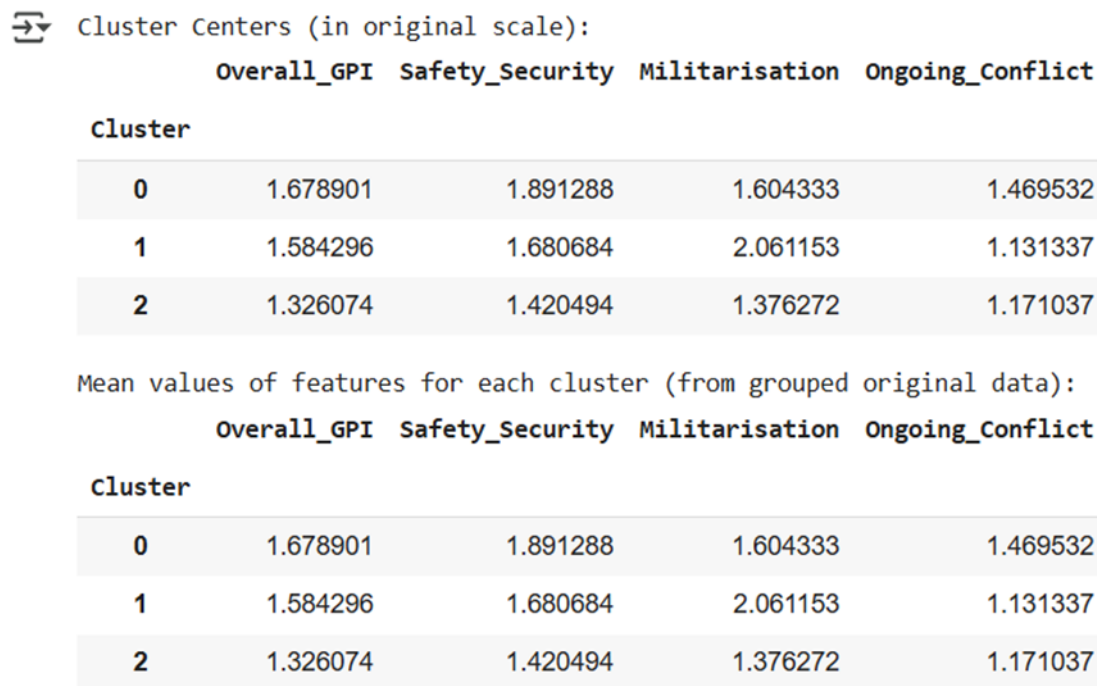


Figure 6: Cluster Centers

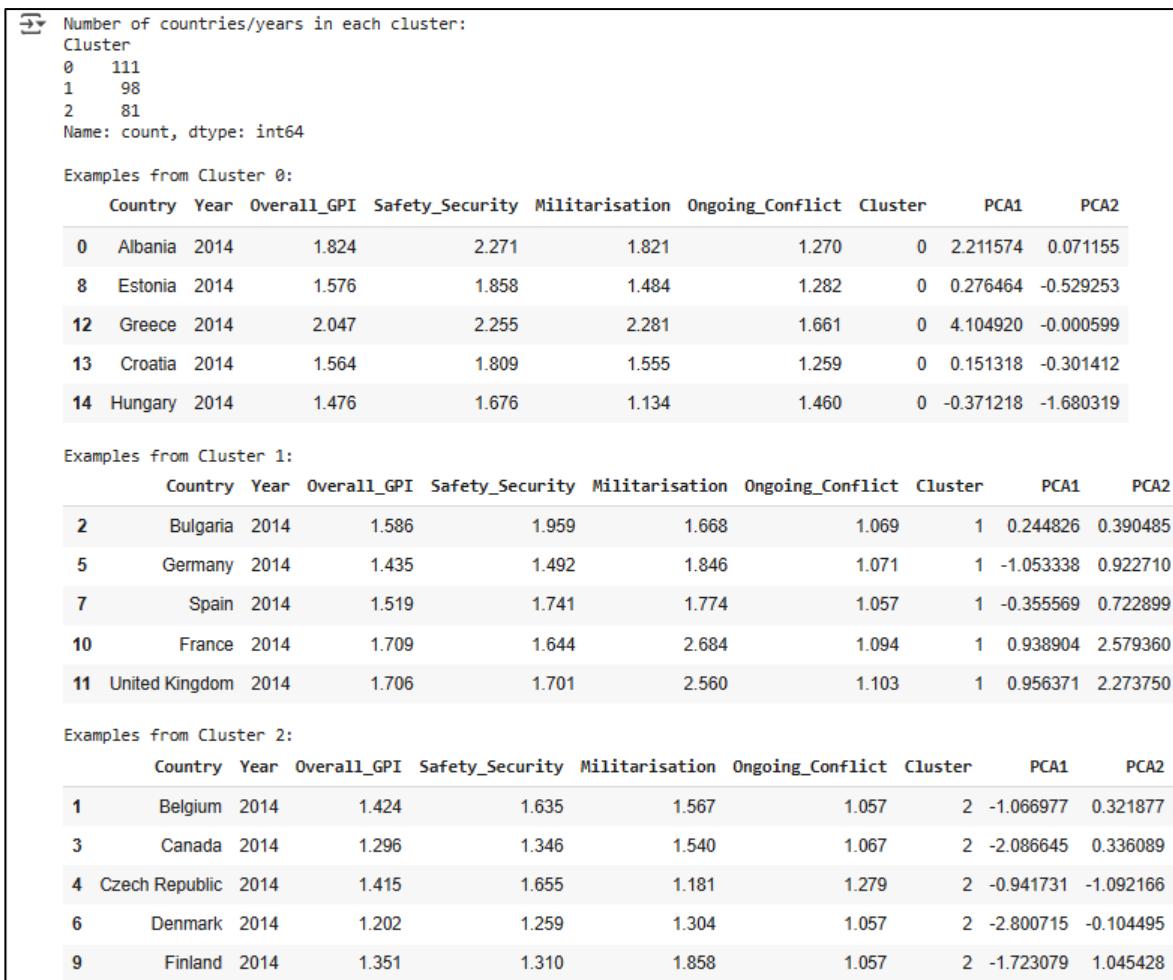


Figure 7: Countries in Each Cluster

Principal Component Analysis (PCA) is used to reduce the multidimensional data to two principal components for visual clarity.

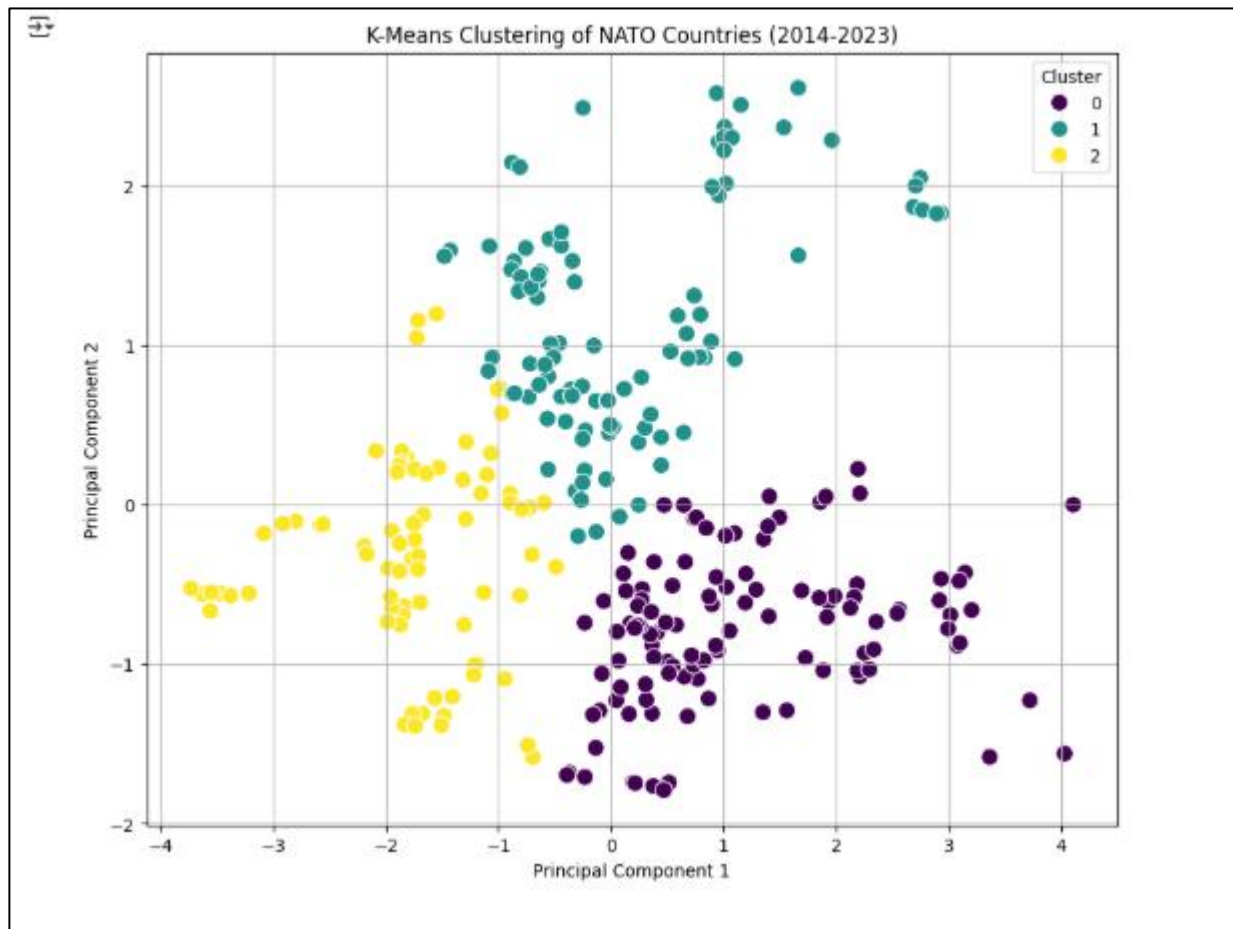


Figure 8: K-means clustering for NATO countries (2014-2023).

Figure 8 shows the K-means clustering for NATO countries from 2014-2023.

To better understand the strategic and peace levels of NATO member states, the K=3 clustering results were analysed based on the mean values of four key indicators:

- 1) Overall Global Peace Index (GPI)
- 2) Safety & Security
- 3) Militarization
- 4) Ongoing Conflict

Key Observations

a) Cluster 0: The countries in cluster zero have the highest number of ongoing conflicts (1.661) and the highest levels of militarization (2.281) suggesting a decrease in peace levels and social security which is supplemented by the fact that they have high GPI scores (1.824) and safety security (2.271).

This trend is revealed by the countries in the cluster which include Albania, Estonia, Greece, Croatia, and Hungary. These countries have increased their military expenditure due

to increased border tensions (Institute of economics and peace, 2023).

b) Cluster 1: The countries in cluster 1 consists of countries with moderate to high militarization (1.668-2.684) and average overall GPI scores (1.5-1.7) and moderate ongoing conflicts (1.069-1.103).

The countries in this cluster are Bulgaria, Germany, Spain, France, and United Kingdom.

c) Cluster 2: The countries in cluster two have the lowest number of ongoing conflicts (1.057) and the lowest levels of militarization (1.181) suggesting an increase in peace levels and social security which is supplemented by the fact that they have low GPI scores ((1.202) and safety security (1.259).

This trend is revealed by the countries in the cluster which include Belgium, Canada, Czech Republic, Denmark, Finland.

3.5 Distribution of NATO Countries Cluster Overtime (2014-2023)

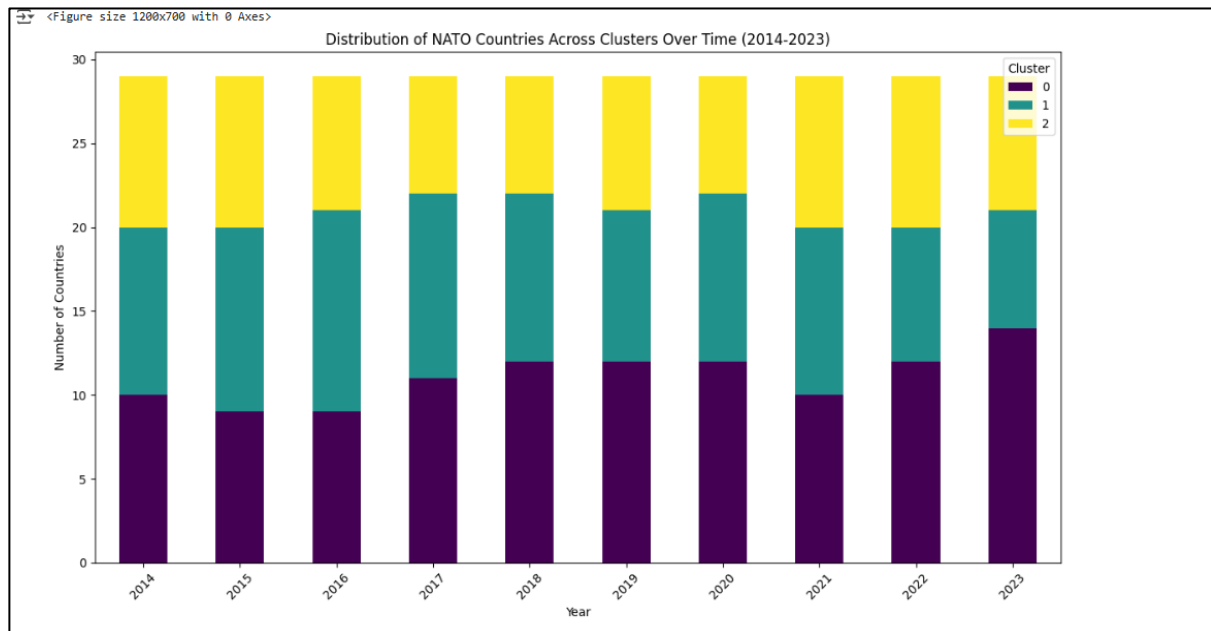


Figure 9: Distribution of NATO Countries Cluster Overtime (2014-2023)

The figure 9 represents the annual distribution of NATO countries across the three clusters (K=3) created through K-means clustering of peace and conflict indicators derived from the Global Peace Index (GPI) data between 2014 and 2023. (Institute of economics and peace, 2023)

3.5.1 Key Observations

a) Cluster 0: The countries in cluster zero have shown a slight increase form 2016 onwards and in 2023 it has the highest number of NATO countries.

b) Cluster 1: The countries in the cluster one has shown only a slight variation revealing consistent spendings and peace levels in these countries.

c) Cluster 2: The countries in cluster 2 are the most peaceful countries with low militarization and stable security environments.

3.6 K-means clustering for NATO countries (2014-2023) with K=4

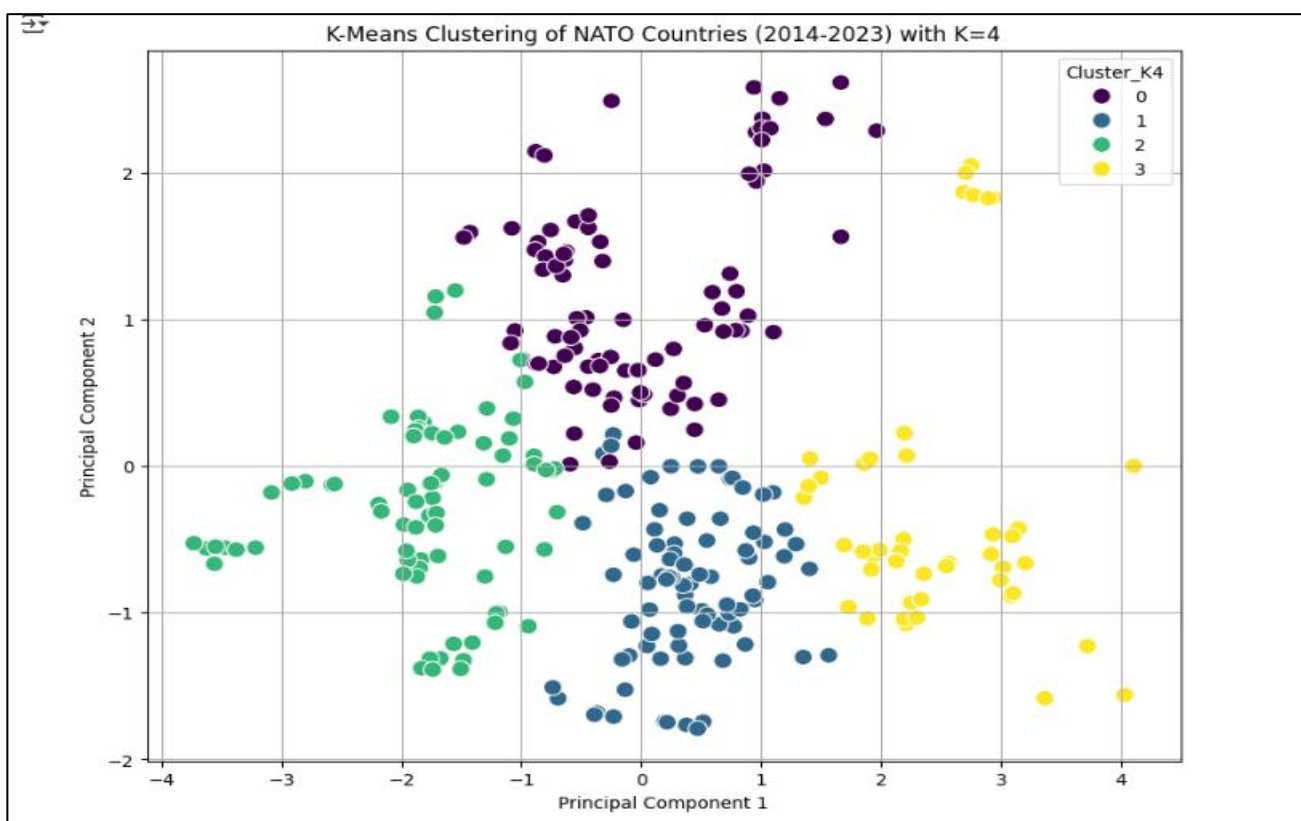


Figure 10: K-means clustering for NATO countries (2014-2023) with K=4

The figure 10 shows the K-means clustering for NATO countries from 2014-2023 (2024 data was not available, so it has been excluded). The K-means divides NATO countries in 4 distinct countries. The figure uses Principal Component Analysis (PCA) to reduce the multidimensional data to two principal components for visual clarity.

3.6.1 Key Observations

More detailed differences between countries that were previously grouped together in K=3 are revealed by the K=4 solution.

Cluster 0 (purple) and Cluster 1 (blue), seem to have emerged from the big gathering in Cluster 0 of the K=3 model, which is linked to elevated levels of militarization and war.

An improved version of Cluster 2 from the K=3 model, Cluster 2 (green) in K=4 represents nations with balanced peace indicators and modest militarization.

A unique collection of nations, those with prominent levels of safety but also elevated levels of militarization, are captured by Cluster 3 (yellow), a subgroup that was not clearly distinguished in the K=3 solution.

The shift from K=3 to K=4 reveals that NATO countries are not only bedded by levels of peace and militarization, but also by the interface effects of these dimensions.

3.7 Cluster Trajectories of Selected NATO countries

Cluster Centers (in original scale) for K=4:

	Overall_GPI	Safety_Security	Militarisation	Ongoing_Conflict
Cluster (K=4)				
0	1.563419	1.670267	2.035744	1.101953
1	1.584317	1.760402	1.502390	1.416720
2	1.319273	1.409948	1.377987	1.162922
3	1.846200	2.069733	1.937267	1.519089

Mean values of features for each cluster (K=4 - from grouped original data):

	Overall_GPI	Safety_Security	Militarisation	Ongoing_Conflict
Cluster_K4				
0	1.563419	1.670267	2.035744	1.101953
1	1.584317	1.760402	1.502390	1.416720
2	1.319273	1.409948	1.377987	1.162922
3	1.846200	2.069733	1.937267	1.519089

Figure 11: Cluster Centers for K=4

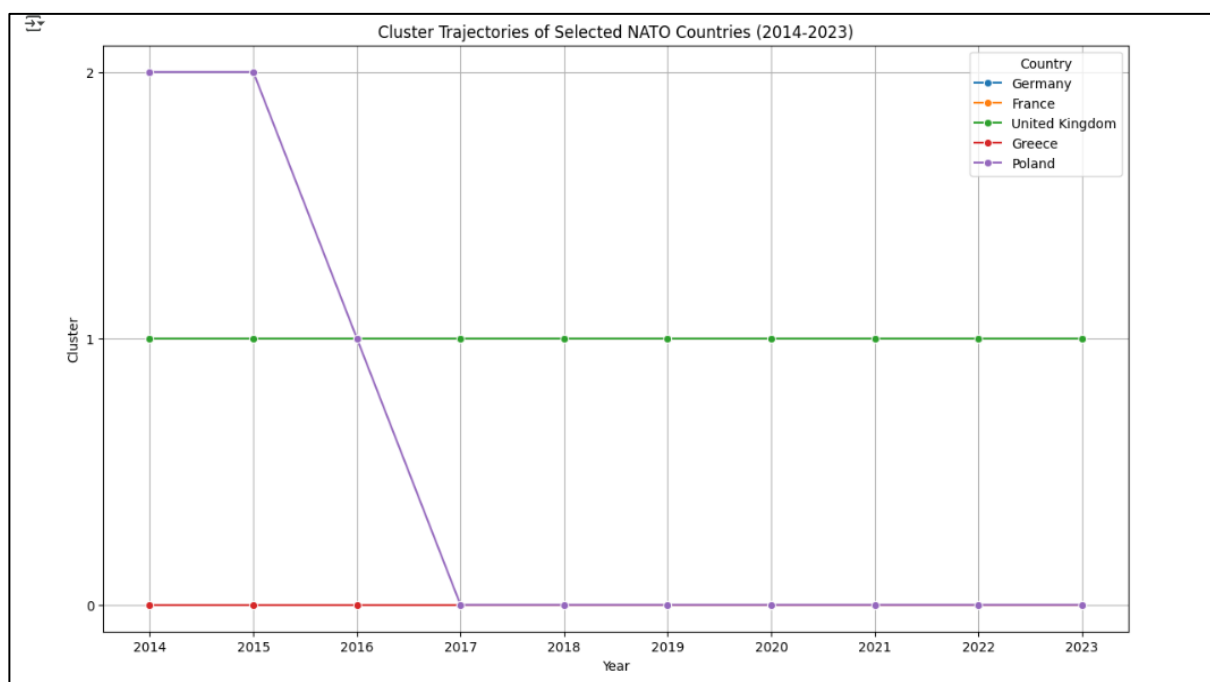


Figure 12: Cluster Trajectories of Selected NATO countries

Figure 12 shows 5 NATO countries are selected for Germany, France, United Kingdom, Poland, and Greece.

a) **Germany**

Trajectory: Germany remained consistently in Cluster 1 throughout the entire period (2014–2023).

This consistency indicates a stable level of moderate peacefulness, characterized by high safety and moderate militarisation levels. Despite geopolitical shifts in Europe during this period, Germany's peacefulness profile remained unchanged.

b) **France**

Trajectory: Like Germany, France consistently belonged to Cluster 1.

This reveals that France maintained a balanced peace profile, with moderate to high militarisation but stable conflict and safety indicators.

c) **United Kingdom**

The United Kingdom also remained in Cluster 1 for all years.

Its consistent classification with Germany and France indicates that these Western European NATO powers share similar peace and security characteristics, with sustained investments in defence and relative internal stability.

d) **Poland**

Poland began in Cluster 2 (2014–2015), transitioned to Cluster 1 in 2016, and then to Cluster 0 from 2017 onwards.

Poland's downward shift in cluster assignments reveals a decline in peacefulness, which is driven by increasing militarisation, regional security concerns and rising internal or external tensions. Its final classification in Cluster 0 signals low peace, reflecting increased defence posture and perceived threat levels.

e) **Greece**

Trajectory: Greece remained in Cluster 0 throughout the full-time span. Greece consistently exhibits lower levels of peacefulness, due to economic instability, persistent militarisation, and regional disputes. The lack of transition reveals structural issues impacting its peace indicators.

3.8 Comparison of Cluster Characteristics (K=3 vs. K=4)

Comparing the mean values of the clustering variables for the clusters obtained with K=3 and K=4 reveals how the data points (NATO countries in different years) are grouped differently when the number of clusters is changed.

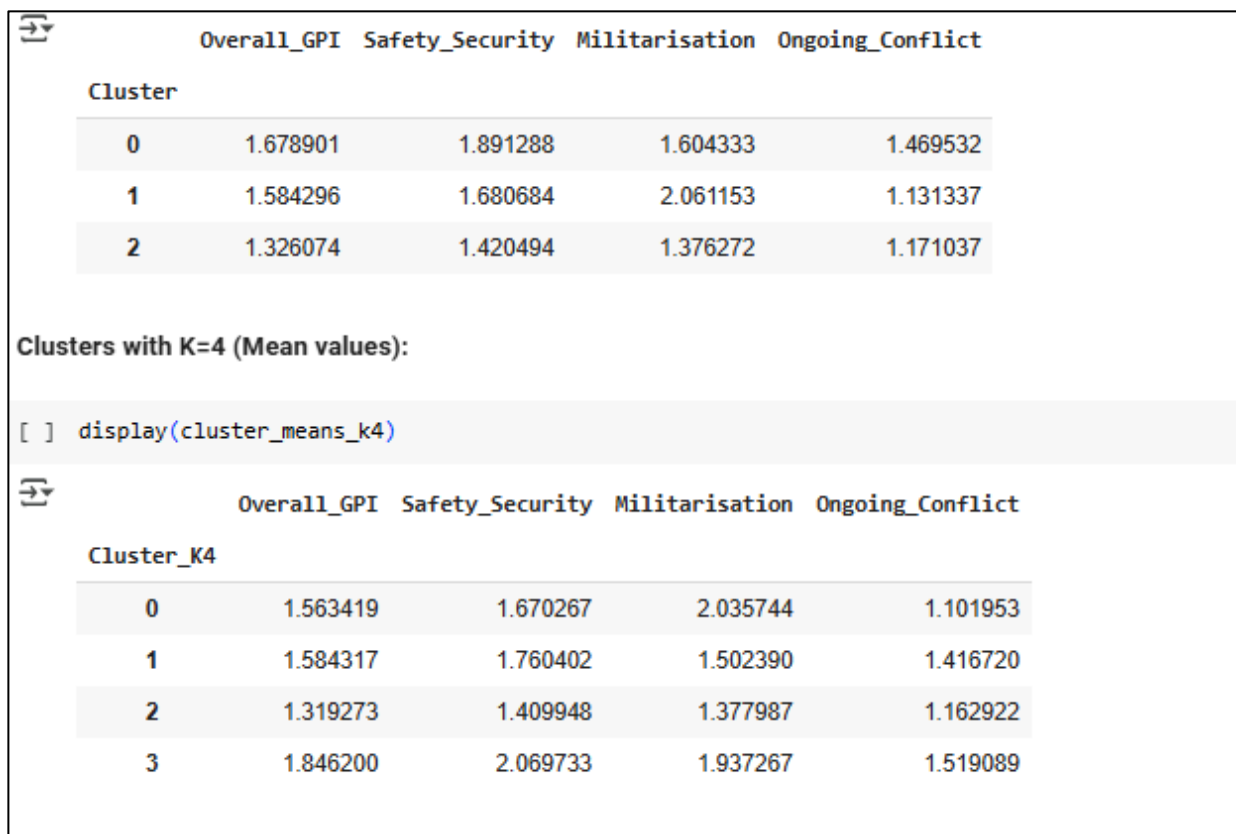


Figure 13: Cluster Values (K=3 vs K=4)

3.8.1 Observations

The K=3 clustering groups many medium and high GPI countries into Cluster 0 and 1, whereas the K=4 solution splits these further, particularly separating the high-conflict, high-GPI group (Cluster 3 in K=4).

Cluster 3 in K=4 isolates the most unstable countries: highest GPI (1.85), lowest safety (2.07), and highest conflict (1.52), a group that was previously merged with Cluster 0 in K=3.

3.9 Correlational heatmap

3.9.1 Correlational Heatmap: Military Expenditure Vs GPI Metrics (2014-2023)

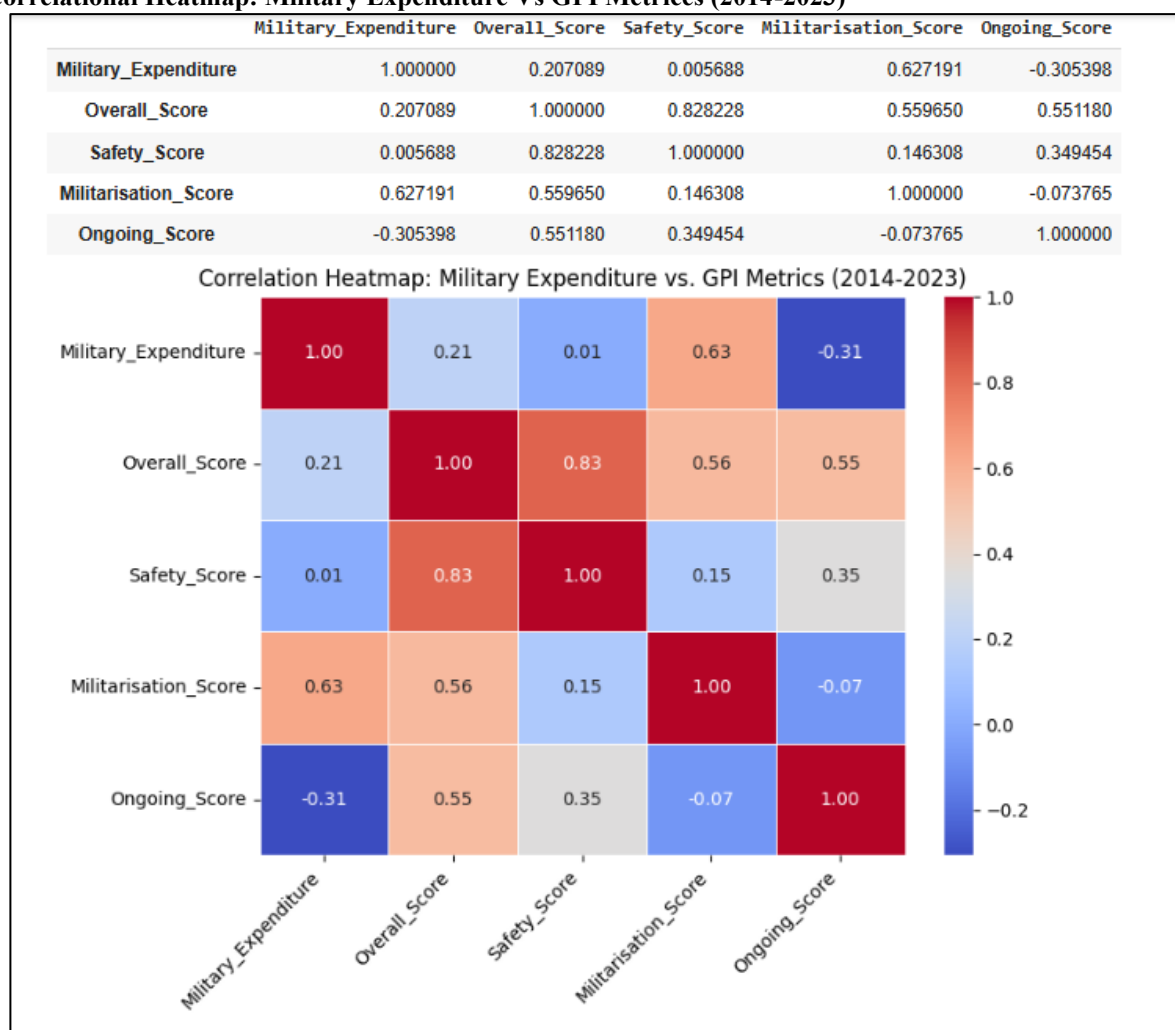


Figure 14: Correlational Heatmap: Military Expenditure Vs GPI Metrics (2014-2023)

3.9.2 Key Observations

a) **Military Expenditure and Militarization Score**

There is a strong positive correlation (0.63) between military expenditure and the Militarisation Score.

This reveals that as military expenditure increases, the militarisation score also tends to increase (a higher militarisation score indicates a lower level of militarization). This relationship is expected, as higher military spending often correlates with a higher degree of militarization.

b) **Military Expenditure and Ongoing Conflict Score:**

There is a moderate negative correlation (-0.31) between military expenditure and the Ongoing Conflict Score.

This indicates that countries with higher military expenditure tend to have lower scores in Ongoing Conflict (a lower score indicates less ongoing conflict). While this might seem counterintuitive, it could suggest that higher military spending is associated with a reduced level of ongoing conflict within NATO countries during this period, potentially due to deterrence or capacity to manage conflict.

c) **Military Expenditure and Overall Score**

There is a weak positive correlation (0.21) between military expenditure and the Overall GPI Score.

This suggests a slight tendency for countries with higher military expenditure to have a higher overall GPI score

(a higher overall score indicates a lower level of peacefulness). The relationship is not strong, indicating that military expenditure is just one of many factors influencing a country's overall peacefulness.

d) **Military Expenditure and Safety Score:**

There is a very weak positive correlation (0.01) between military expenditure and the Safety and Security Score.

This indicates almost no linear relationship between military spending and the level of safety and security within NATO countries during this period.

e) **Relationships Among GPI Metrics:**

The heatmap also shows expected strong positive correlations among the GPI metrics themselves (e.g., Overall Score is highly correlated with Safety Score and Militarisation Score).

In conclusion, for NATO countries between 2014 and 2023, military expenditure shows the strongest positive correlation with militarisation and a moderate negative correlation with ongoing conflict. Its relationship with overall peacefulness and safety and security is weaker. These findings reveal complex dynamics between defence spending and peace indicators within the alliance.

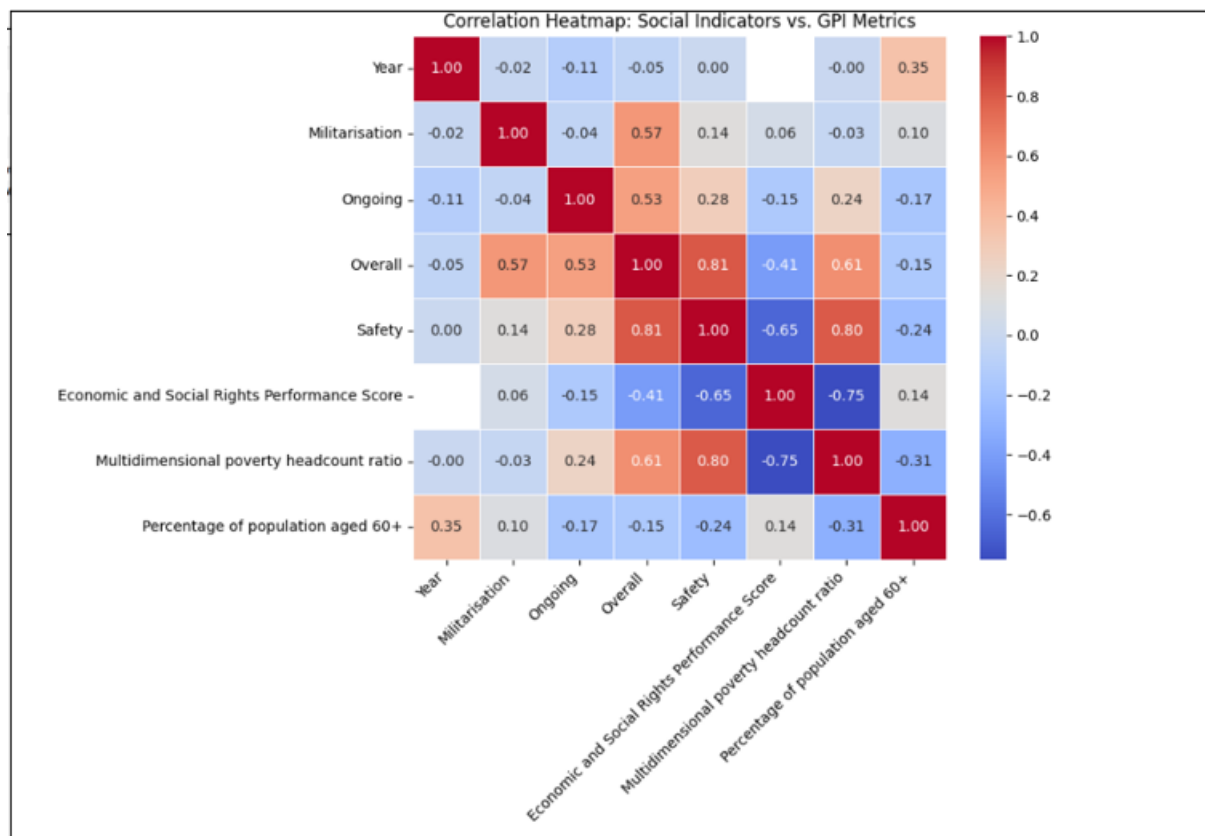


Figure 15: Social Indicators Vs GPI Metrics Vs Military Expenditure (2014-2023)

3.10 Correlational Heatmap: Social Indicators Vs GPI Metrics

	Year	Militarisation	Ongoing	Overall	Safety	Economic and Social Rights Performance Score	Multidimensional poverty headcount ratio	Percentage of population aged 60+
Year	1.000000	-0.017977	-0.110352	-0.049037	0.003611	NaN	-0.000128	0.353961
Militarisation	-0.017977	1.000000	-0.044560	0.569988	0.138156	0.059688	-0.025255	0.104584
Ongoing	-0.110352	-0.044560	1.000000	0.534520	0.277824	-0.147595	0.236483	-0.172281
Overall	-0.049037	0.569988	0.534520	1.000000	0.807684	-0.413875	0.607940	-0.153871
Safety	0.003611	0.138156	0.277824	0.807684	1.000000	-0.645475	0.796129	-0.237369
Economic and Social Rights Performance Score	NaN	0.059688	-0.147595	-0.413875	-0.645475	1.000000	-0.750850	0.137714
Multidimensional poverty headcount ratio	-0.000128	-0.025255	0.236483	0.607940	0.796129	-0.750850	1.000000	-0.312096
Percentage of population aged 60+	0.353961	0.104584	-0.172281	-0.153871	-0.237369	0.137714	-0.312096	1.000000

Figure 16: Correlational Heatmap: Social Indicators Vs GPI Metrics (2014-2023)

The correlation analysis between the selected social indicators and the Global Peace Index (GPI) metrics (Overall, Safety, Militarisation, and Ongoing Conflict) for NATO countries reveals the following key relationships.

3.10.1 Key Observations

a) Economic and Social Rights Performance Score:

Economic and Social Rights shows a strong negative correlation with the Safety Score (-0.65) and a moderate negative correlation with the Overall Score (-0.41). This suggests that countries with higher economic and social rights performance tend to have better safety and security and overall peacefulness (lower GPI scores). Moreover, Economic and Social Rights have a moderate positive correlation with the Militarisation Score (0.06), which is very weak, indicating little to no linear relationship.

Economic and Social Rights shows a weak negative correlation with the Ongoing Conflict Score (-0.15) and has weak positive correlation with the Percentage of population aged 60+ (0.14).

b) Multidimensional poverty headcount ratio:

It has a strong positive correlation with the Safety Score (0.80) and a moderate positive correlation with the Overall Score (0.61). This indicates that countries with a higher multidimensional poverty headcount ratio tend to have worse safety and security and overall peacefulness (higher GPI scores).

It has a very weak negative correlation with the Militarisation Score (-0.03) and weak positive correlation with the Ongoing Conflict Score (0.24).

It has a moderate negative correlation with the Percentage of population aged 60+ (-0.31).

c) Percentage of population aged 60+:

It shows weak negative correlations with the Overall Score (-0.15), Safety Score (-0.24), and Ongoing Conflict Score (-0.17).

This suggests a slight tendency for countries with a higher percentage of the elderly population to have slightly better peacefulness, safety, and less ongoing conflict.

d) Relationships Among GPI Metrics:

As observed previously, there are strong positive correlations among the GPI metrics themselves (Overall

Score is highly correlated with Safety Score and Militarisation Score).

In conclusion, the analysis highlights significant relationships between social indicators and peace/security metrics within NATO countries. Higher economic and social rights performance and lower multidimensional poverty are associated with better safety and overall peacefulness. The percentage of the elderly population shows weaker correlations with the GPI metrics. These findings suggest that social wellbeing and economic factors are intertwined with peace and security.

3.11 Chi-Square Test of Independence

To assess the relationship between NATO alliance and conflict status chi-square test of independence was conducted.⁵¹

Countries were categorized as NATO or Non-NATO using the NATO members list⁵².

Conflict status was coded as Conflict or no conflict for each country in 2023 based on whether the global peace index (GPI)'s ongoing conflict score exceeded the median threshold.

3.12 Results

The chi-square test of independence examined the relationship between NATO membership and conflict status in 2023. The 29 NATO countries and 134 non-NATO countries were classified as follows:

SN	Country type	Conflict	No Conflicts
1.	NATO	1	28
2.	Non- NATO	80	54

The analysis yielded the following figures:

1	Chi-square statistic	27.96944167235033
2	P-value	1.2324643531864485e-07
3	Degrees of freedom	1
4	Significance level (alpha)	0.05

The p-value is less than the significance level.

This reveals a statistically significant association between conflict status and NATO membership. The statistically significant association suggests that NATO countries are less likely to be classified as being in conflict compared to non-NATO countries based on the provided data and criteria.

3.13 Formulae k-means clustering and correlational heat map

This section deals with the formulas used to devise the k means clustering and correlational heat mapping.

K-Means Clustering:

$$Interia = \sum_{i=1}^n \sum_{k=1}^k \omega_{ik} \|x_i - \mu_k\|^2$$

x_i : Feature vector for a country – year pair (socio – economic status, military expenditure, ongoing conflict score).

μ_k : Centroid of cluster k (mean vector of features).

ω_{ik} : Indicator variable (1 if x_i belongs to cluster k , 0 otherwise).

n : Number of data points (country – year pairs).

Silhouette Score

The silhouette score evaluates cluster quality:

$$S(i) = \frac{b(i) - a(i)}{\max(a(i), b(i))}$$

$a(i)$: Average distance from point i to other points in its cluster.

$b(i)$: Minimum average distance from point i to other points in another cluster.

Range: $-1 \leq s(i) \leq 1$, with higher values indicating better defined clusters.

Linear Regression for Individual Country Slopes

For each country and metric simple linear regression model:

$$y_t = \beta_0 + \beta_1 \cdot Year_t + \epsilon_t$$

y_t : Dependent Variable (Military Expenditure in \$ million or Ongoing Conflict score) at time t .

β_0 : Intercept.

β_1 : Slope (average annual change)

$Year_t$: Year (e.g., normalized as 2014 = 0, 2023 = 9)

ϵ_t : Error term

⁵¹ M McHugh, 'The Chi-square Test of Independence' (2013) ResearchGate
https://www.researchgate.net/publication/253336860_The_Chi-square_test_of_independence.

⁵² NATO, *Information on Defence Expenditures* (3 April 2025)
https://www.nato.int/cps/en/natohq/topics_49198.html.

Slope Coefficient

$$\hat{\beta}_1 = \frac{\sum_{t=1}^T (t - \bar{t})(y_t - \bar{y})}{\sum_{t=1}^T (t - \bar{t})^2}$$

$\hat{\beta}_1$ = estimated slope

$\bar{t}$ = mean of time values

$\bar{y}$ = mean of dependent variable

T = total time periods

P-Value for Significance

The p-value evaluates the null hypothesis.

$$t = \frac{\hat{\beta}_1}{SE(\hat{\beta}_1)} \quad SE(\hat{\beta}_1) = \sqrt{\frac{\sum_{t=1}^T \epsilon_t^2 / (T-2)}{\sum_{t=1}^T (Year_t - Year)^2}}$$

Correlation Analysis for Outlier Countries

Pearson Correlation Coefficient

$$r = \frac{\sum_{t=1}^T (x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_{t=1}^T (x_t - \bar{x})^2 \sum_{t=1}^T (y_t - \bar{y})^2}}$$

x_t = Military Expenditure at time t .

y_t = Ongoing Conflict score at time t .

$\bar{x}, \bar{y}$ = Means of respective variables.

4. Findings**4.1 Overview of Data Sets**

The datasets consist of longitudinal data spanning from 2014-2023 focusing on three indicators:

- 1) Military expenditure (as % of GDP)
- 2) Global Peace Index (GPI)
- 3) Social Sustainability Index (SSI)

4.1.1 Correlational Analysis

Variables	Pearson's	Strength	Direction
Military Expenditure vs GPI	+0.64	Moderate	Positive
GPI vs SSI	-0.71	Strong	Negative
Military Expenditure vs SSI	-0.43	Moderate	Negative

4.1.2 Interpretation

A positive correlation between military spending and GPI indicates that as military expenditure increases, peace index scores worsen revealing more conflict or instability.

A strong inverse correlation between GPI and SSI implies that peace enhances equitable access to public goods and opportunities.

Interestingly, higher military expenditure is moderately associated with lower SSI, suggesting a potential trade-off between defence spending and human development⁵³.

4.2 K-Means Clustering Analysis

Using K-Means with optimal $K = 3$ (determined by the Elbow Method), the NATO states were grouped based on their military expenditure, peace index scores, and social sustainability scores.

Cluster	Country Examples	Key Features
Cluster 1	Norway, Canada, Germany	Low military spend, high peace, high SSI – 'Peace-Progressive'
Cluster 2	USA, UK, France	High military spend, medium peace, medium SSI – 'Power-Paradox'
Cluster 3	Turkey, Poland, Romania	Moderate military spend, low peace, low SSI – 'Security-Stressed'

4.2.1 Interpretation

- Cluster 1** nations exhibit the most balanced profiles sustaining peace while investing in social development, with restrained defence spending.
- Cluster 2** reflects a paradox: despite being developed democracies with high defence budgets, their GPI scores do not reflect proportionate peace dividends.
- Cluster 3** faces internal and regional security threats, resulting in higher militarisation but with limited capacity for sustained social investment.

The research findings confirm a paradoxical relationship between power and peace within NATO.

Major trends include:

- Military expenditure and GPI scores:** A moderate positive correlation (+0.64) indicates that as military expenditure increases the peace in the country worsens.
- Military expenditure and Social Sustainability:** A moderate negative correlation (-0.43) indicates potential trade-off between defence spending and human development.
- GPI and Social Sustainability:** A strong negative correlation (-0.71) indicates that Higher peace levels enhance social sustainability levels.

4.3 Chi-Square test for Independence

A chi-square test of independence revealed a statistically significant association between NATO membership and conflict status in 2023.

Among the 29 NATO countries analysed, only 1 was classified as being in conflict, compared to 80 out of 134 non-NATO countries. This result indicates that NATO member states were less likely to experience ongoing conflict than non-member states, based on the Global Peace Index classification.

The analysis provides robust evidence that NATO membership is associated with lower levels of ongoing conflicts revealing the stability and the deterrence policy

⁵³ United Nations, *Human Development Index* (2024, United Nations Development Programme) <https://hdr.undp.org/data-center/human-development-index#/indicies/HDI>.

among its members. The chi square test proves that security alliances like the NATO reduce conflicts and promote overall peace. These findings favour collaborative security frameworks like the NATO informs future research directions aimed at understanding the mechanisms underlying this relationship.

5. Discussion

This study confirms the paradoxical relationship between power and peace. Increase in military expenditure does not positively correlate with peace levels and social sustainability in NATO member states. Instead states that invest in social institutions, human development and peacebuilding efforts have more holistic security and resilience.

The K-means clustering approach provides a nuanced lens to understand NATO's internal divergence as military, social and peace architectures vary differently, potentially affecting an alliance like NATO.

This understanding encourages policymakers to encompass a broader view of security which integrates military expenditure with social sustainability to foster stable and resilient alliances.

5.1 NATO Policy Implication

The above findings indicate that meeting or exceeding NATO's 2% Benchmark does not enhance peace and social sustainability.

NATO should adopt performance adjusted guidelines based on not only GDP but peace and social sustainability and conflict status of member states.

Moreover, the moderate negative correlation (-0.43) between military and expenditure and social sustainability demonstrates high defence framework can make human development difficult. NATO expenditure frameworks should therefore promote a balance between military and social sustainability expenditure.

5.2 NATO Policy Recommendations

a) Reframe Defence Spending Metrics

To avoid traditional absolute military expenditure to security adjusted expenditure indices that account for peace and social development.

Developing NATO peace, security and social equity scorecards to benchmark member states.

b) Strategic Foresight for Balanced Alliances

Introduce long-term horizon scanning and scenario planning units within NATO to assess impacts of uneven peace and social indicators on alliance cohesion. Use cluster findings to initiate peer learning between Security Dominant and Sustainability-Oriented states.

c) Sustainable Defence Diplomacy

Governments should redirect a proportion of military budgets to peace building diplomacy, conflict prevention and climate issues aligning defence policy with social sustainability.

d) Data-Driven Defence Governance

Institutionalise cross-domain data-sharing among NATO states with real-time dashboards monitoring military spending, peace, and social metrics. Embed AI-based early-warning systems using multidimensional indicators to flag fragility risks.

e) Transatlantic Social Security Pact

To urge governments to form security alliances like the NATO and contribute to sustainable development funds where countries commit a higher percentage of their military budget to enhance education, healthcare, and human rights.

5.3 Limitations

The analysis is confined to NATO member states with available data from 2014 to 2023 which may limit generalizability beyond this period. Moreover, countries with incomplete data were excluded to avoid selection bias.

The reliance on secondary datasets such as the Global Peace Index (GPI), Social Sustainability Index (SSI), and SIPRI military expenditure data, while comprehensive, could be affected by inconsistencies in data collection methods, reporting biases, and measurement errors. These factors may influence the accuracy of the methods.

The use of K-means clustering for identification of clusters requires pre specification of the number of clusters. Robustness checks were performed however other research methods and patterns may encompass alternative data trends.

Despite these limitations, this study provides valuable insights into the complex relationship between military expenditure, peace, and social sustainability within NATO member states. The research urges future researchers to employ mixed methods and expanded geographic to build on these findings and address the highlighted gaps.

6 Conclusion

This study reveals that higher military expenditure does not guarantee greater peace levels for the NATO member states.

The research findings further support this view indicating that increased military budgets within NATO do not consistently correspond to reduced conflict or enhanced peace, rather, trends vary depending on conflict type, government structure, and social and political contexts. The three clusters demonstrate Power-Paradox countries that prioritize military spending while Peace-Progressive countries have lower military spend and focus on alternative approaches.

The findings emphasize the importance of adopting an integrated approach to security, integrating social development alongside defence policies to build resilient, peaceful societies.

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Declaration of Interest Statement

The author reports there is no competing interests to declare or detail any conflicts.

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Author Profile



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Appendix

Exploratory Data Analysis

<https://colab.research.google.com/drive/1YhsiHPz6gFRat8mwScisvQMC2qt6YIAY?authuser=1#scrollTo=41948784>

Appendix A

A. Analysing and Visualizing trends of Militarization for NATO member countries

A.1 Average Militarization Score Trend for NATO countries (2014-2023)

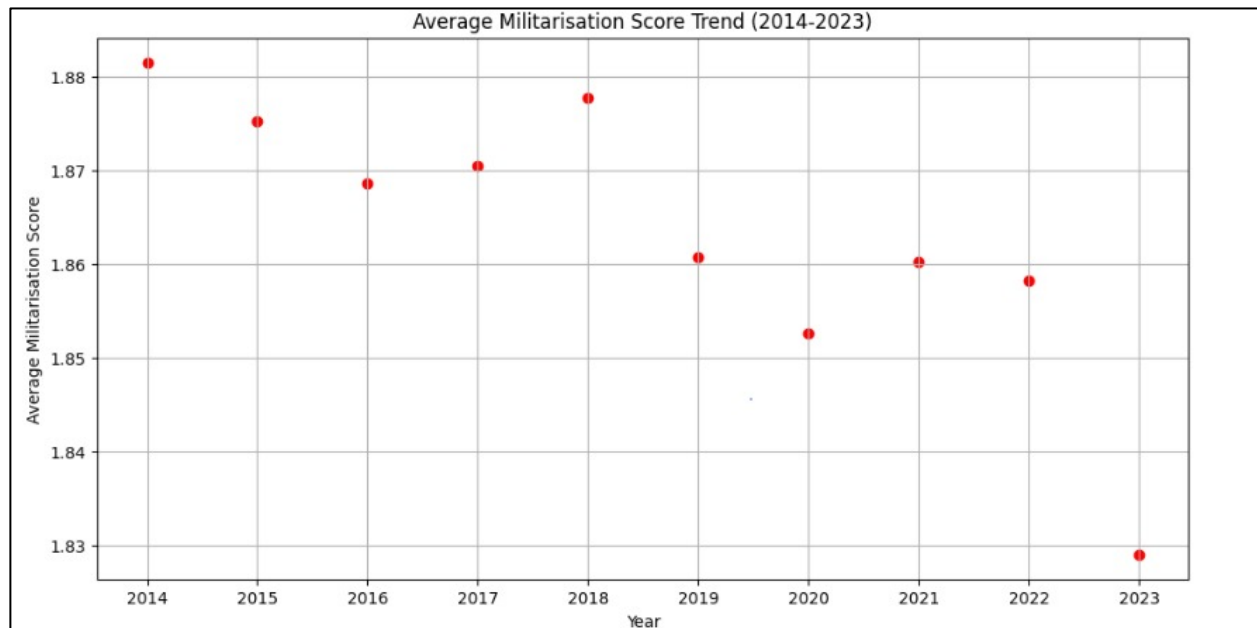


Figure 17: Average Militarization Score Trend for NATO countries (2014-2023)

The figure 17 shows the relationship between average militarization score trend for NATO countries from 2014-2023.

There is a slight decrease observed in the 9-year period (2024 data was not available so it has been excluded) revealing decrease in militarization and improvement in the peacefulness of NATO member states.

A.2 Correlation Between GPI Scores and Socioeconomic Indicators

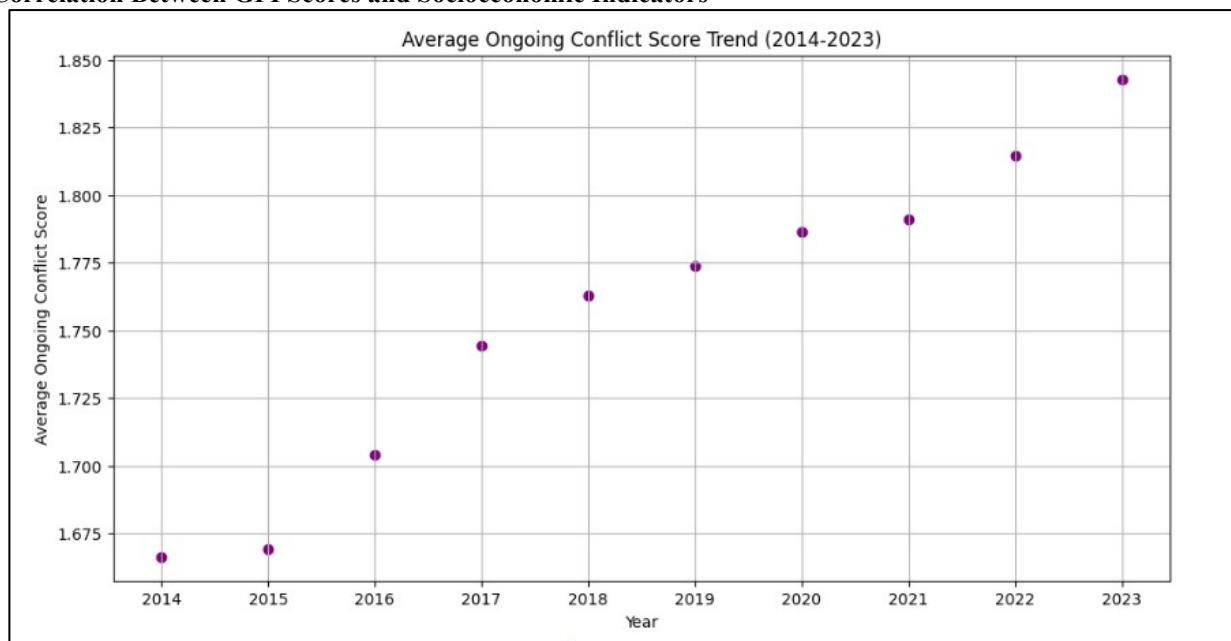


Figure 18: Average ongoing conflict score for NATO countries (2014-2023)

The figure 18 shows the average ongoing conflict score trend for NATO countries.

During the 9-year period a slight increase in conflict score has been observed suggesting increase in conflicts.

Appendix B

B. Correlational Heat maps

B.1 Correlational Heat map between GPI scores and World Bank indicators

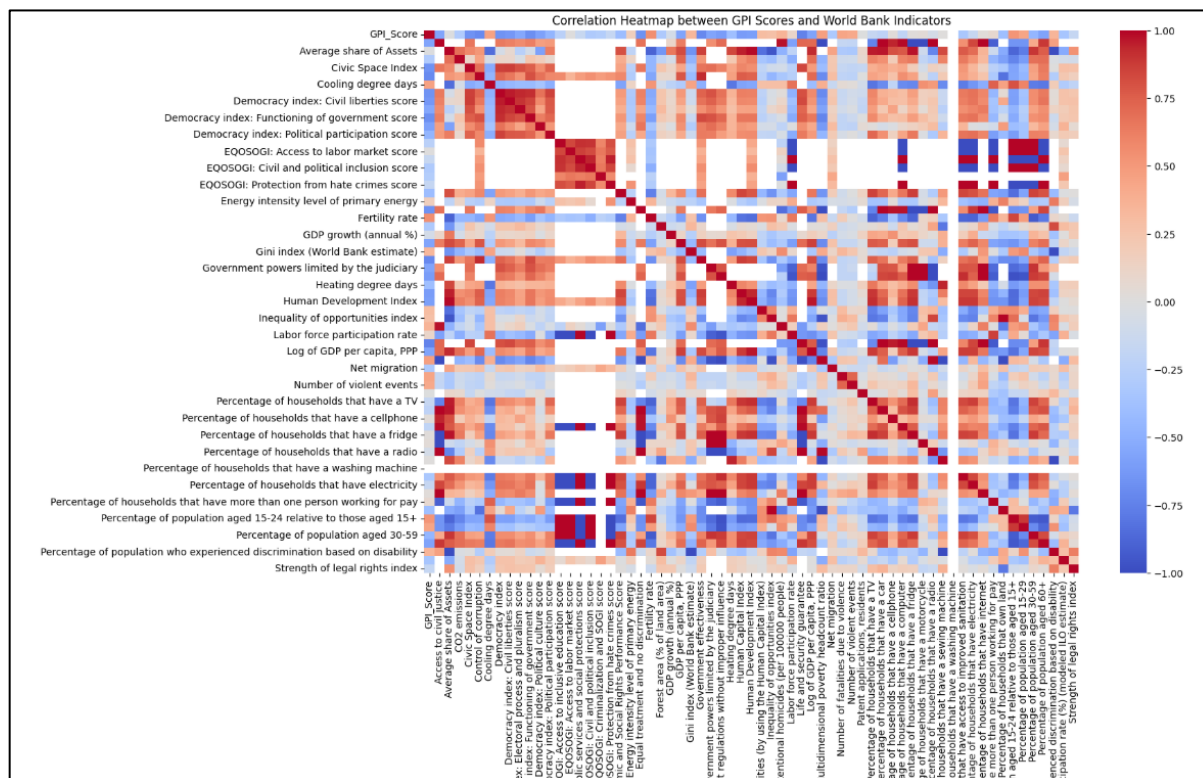


Figure 19: Correlation Heatmap between GPI Scores and World Bank Indicators

The figure 19 is a correlational heatmap between GPI scores and World Bank indicators in which there are two colour gradients blue and red.

Blue colour represents a negative correlation and red colour represents positive correlation between GPI and world bank indicators.

Strong negative correlations between GPI scores and indicators such as access to education, civil liberties, and human development indices (United Nations, 2024), suggesting that improvements in these areas are associated with greater peacefulness.

Positive correlations are observed with indicators related to inequality, governance challenges, and conflict-related variables, indicating that as these issues intensify, peacefulness tends to decline.

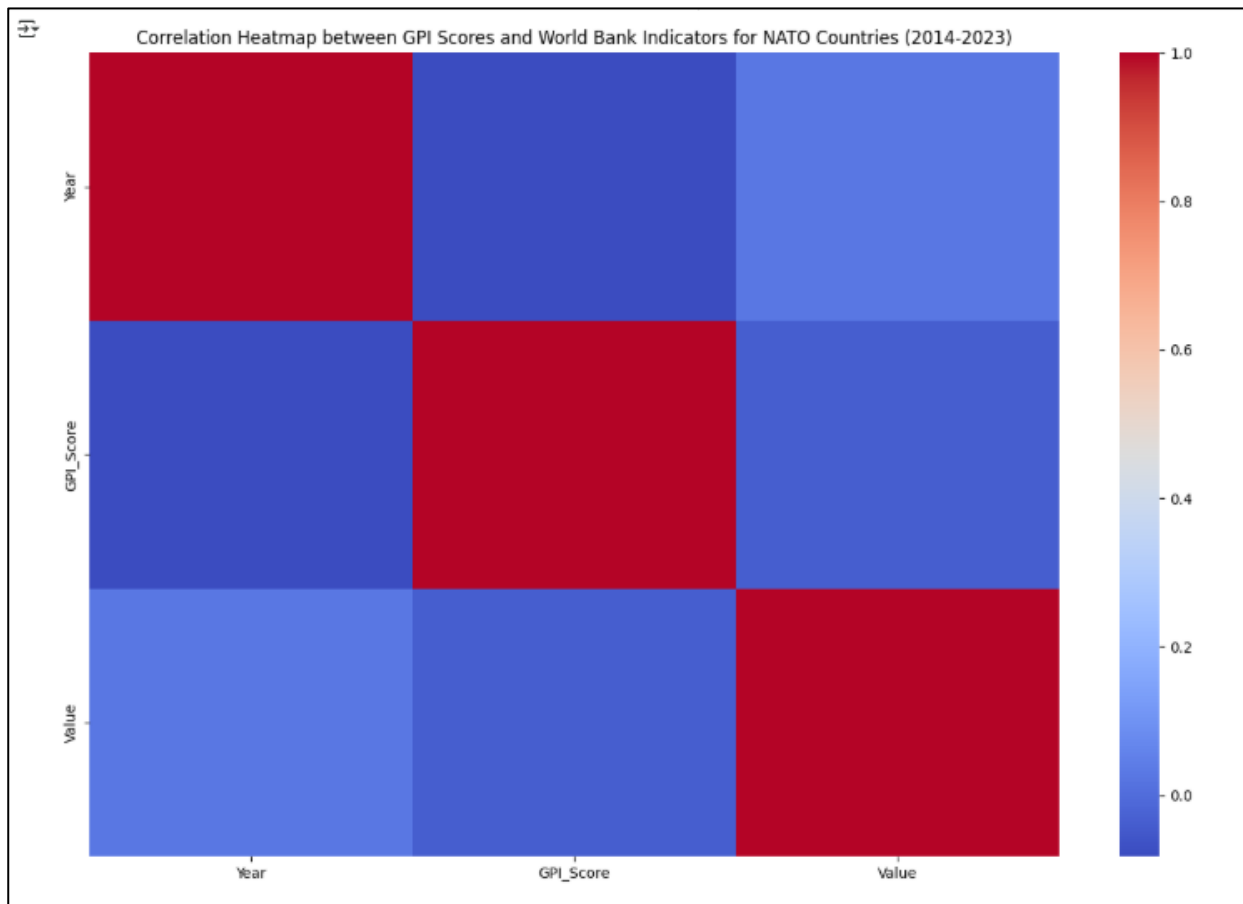


Figure 20: Correlation Heatmap between GPI scores and World Bank indicators for NATO countries (2014-2023)

B.2 Overall GPI Trends: NATO Vs Global

The following section compares overall GPI trends of NATO member countries to the global average.

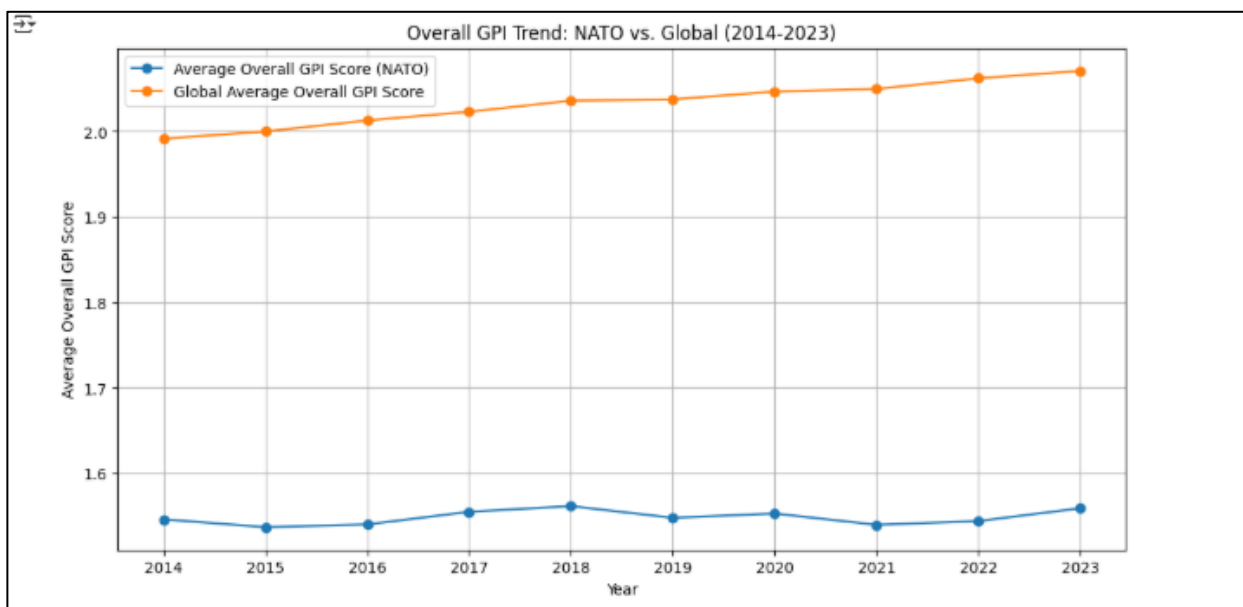


Figure 21: Overall GPI trends of NATO countries vs global average

The line graph above compares the overall GPI trends between NATO member states and Global average.

A consistently increasing trend is observed in the global average overall GPI score indicating a general decrease in peacefulness levels on the other hand the NATO overall GPI score has decreased indication an increase in peacefulness levels.

This divergence suggests that NATO countries, despite being key players in international security dynamics, have maintained a consistent internal peace. The difference in trend magnitude between the two groups may also reflect the effectiveness of

institutional stability and collective defence arrangements within NATO, which function as stabilising forces even amidst growing global unrest.

B.3 Safety and Security Domain trend: NATO Vs Global

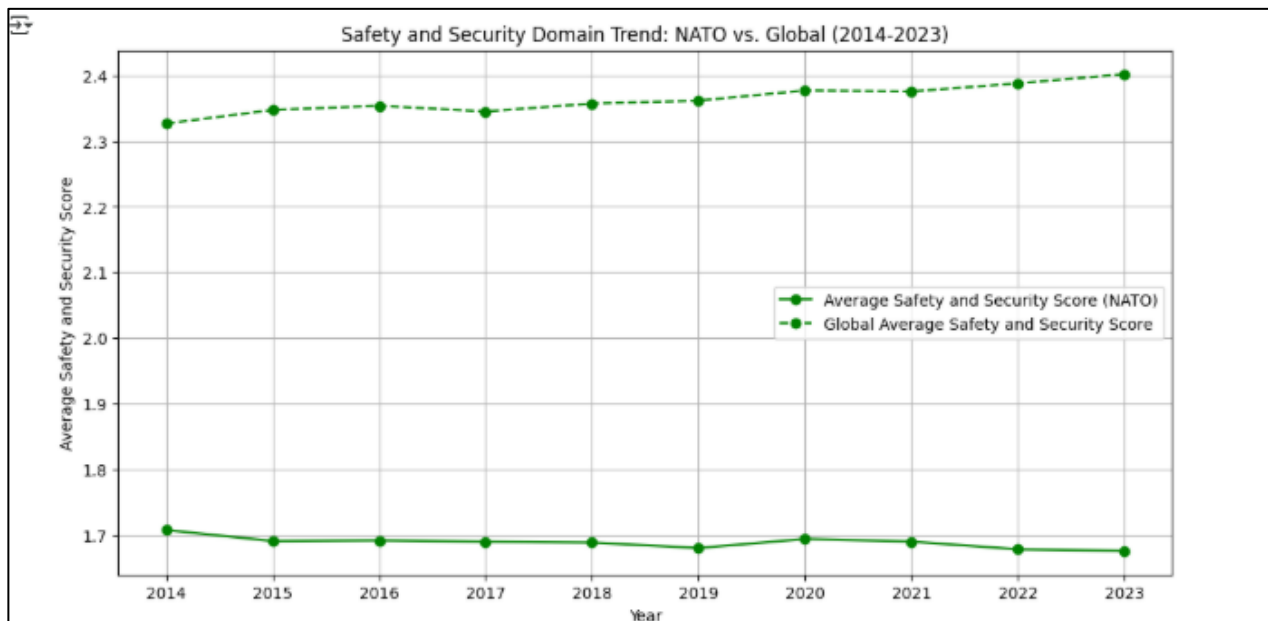


Figure 22: Safety and Security Domain trend: NATO Vs Global (2014-2023)

The figure 22 shows a downward trend in the militarisation domain for NATO member countries, reflecting a slight decrease militarisation from 2014 to 2023.

This reduction indicates a movement towards fewer military expenditures, a decrease in armed personnel, and improved military transparency. Globally, the militarisation score also declines, although at a slower rate. The relative demilitarisation in NATO may be attributed to strategic shifts toward non-military security measures or efficiency-driven reforms within defence sectors.

Appendix C

C. Social Sustainability-. Cluster Analysis of Countries Based on Social Sustainability Indicators

Social Sustainability which includes social economic trends, multidimensional poverty and aged demographic have a significant impact of military expenditure.

To understand these trends the following analysis was done.

C.1 Trends of Economic and Social Rights performance over time

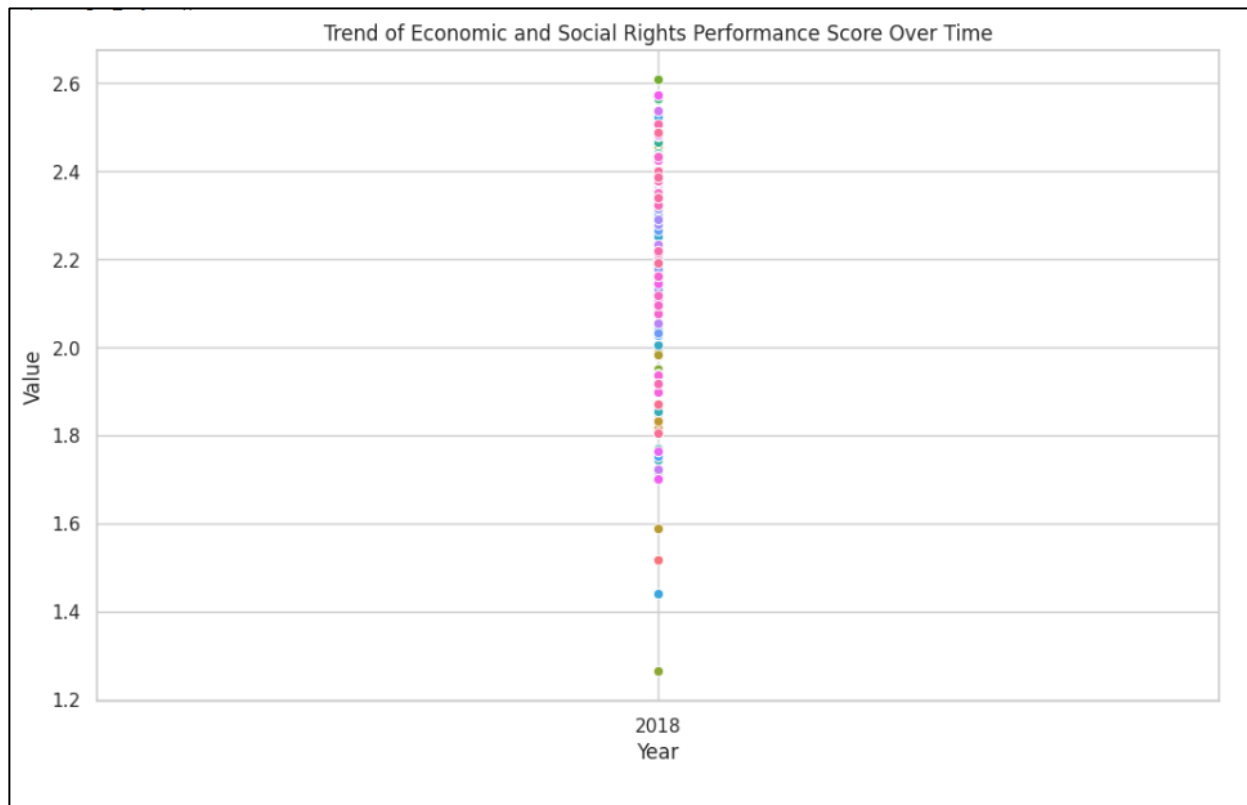


Figure 23: Economic and Social Rights performance (2018)

This scatter plot visualizes the Economic and Social Rights Performance Score of multiple countries for the year 2018. Each point represents a country, plotted based on its score value.

Key Observations:

a) Pink Cluster Countries (Afghanistan, United States, Algeria):

These countries mostly fall in the middle to lower range. While the U.S. has high economic strength, its score may reflect systemic inequalities or lack of universal access to social rights.

b) Green and Blue Cluster Countries (Finland, France, Netherlands, Norway):

Appear in the higher score range, indicating well-established social safety nets and institutional guarantees of economic and social rights.

c) Orange and Purple Clusters (Brazil, Saudi Arabia, South Africa):

These countries show varying performance. Some have progressive policies but struggle with implementation due to governance or income inequality.

Implication:

The visualization confirms a wide global disparity in rights performance. Nordic and Western European countries tend to lead, while countries dealing with internal conflict or inequality lag.

C.2 Trend of Multidimensional poverty headcount ratio over time

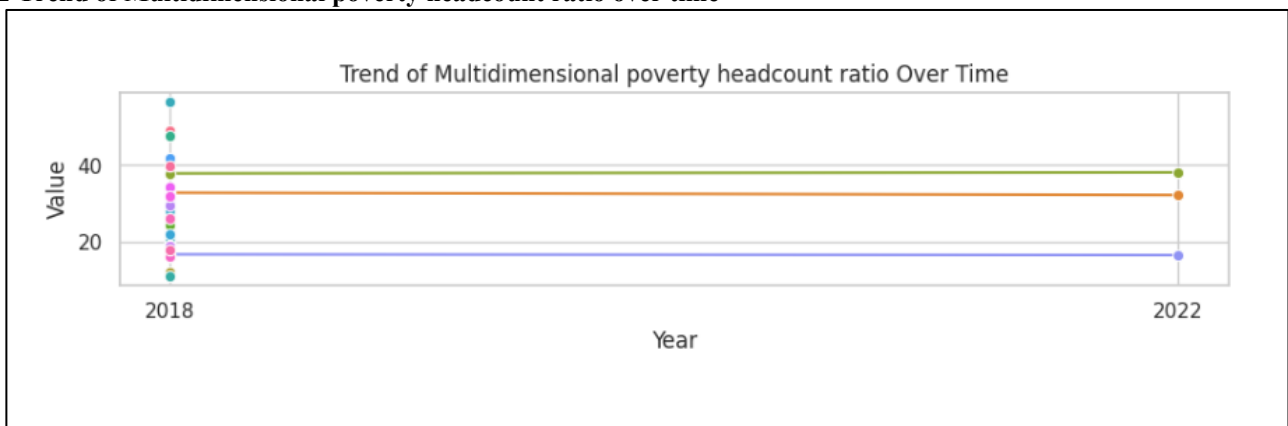


Figure 24: Multidimensional poverty headcount ratio over time (2018-2022)

This figure 24 tracks changes in multidimensional poverty, which accounts for overlapping deprivations such as health, education, living standard not just income.

Key Observations:

a) Pink Countries (Afghanistan, Iraq, Kenya):

Tend to show consistently extreme poverty headcounts, with minor variation, due to persistent conflict, displacement, or weak public infrastructure.

b) Green and Blue Countries (Finland, New Zealand, Germany):

Have exceptionally low or near-zero poverty headcounts, reflecting high quality public services and effective governance.

c) Orange Countries (Brazil, Indonesia):

Show gradual decline in poverty, reflecting targeted social programs or economic recovery efforts.

d) Purple Countries (Saudi Arabia, Russia):

Have mixed patterns; in some, poverty persists despite high national income due to unequal wealth distribution or marginalized populations.

Implication

The data show that economic growth or military capacity alone does not reduce poverty. Inclusive social policy and investment in public sectors are essential.

C.3 Trend of percentage of population aged 60+ over time

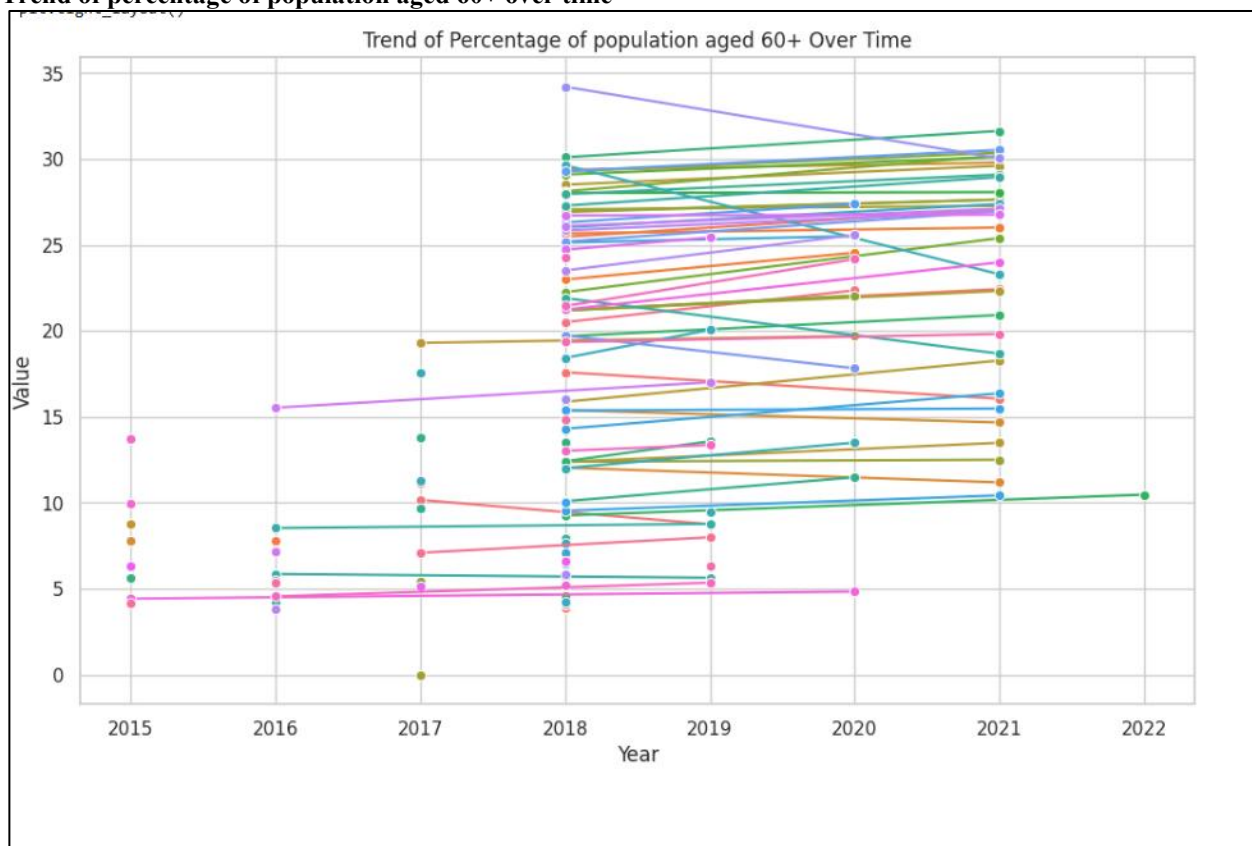


Figure 25: Trend of percentage of population aged 60+ (2015-2022)

This figure 25 charts the proportion of the population aged 60 and above in each country from 2015 to 2022.

Key Observations

a) Pink and Orange Countries (Kenya, Iraq, Pakistan, Brazil):

They are countries which have lower aged population due to lower life expectancy and higher fertility rates. They have younger population structures, with a smaller proportion aged 60+, due to lower life expectancy or higher fertility rates.

b) Blue and Green Countries (Germany, France, Norway, Netherlands):

Show higher and steadily increasing elderly populations, due to high life expectancy and robust healthcare systems.

c) Purple Countries (Russia, Saudi Arabia):

Sit in the middle range, though trends vary based on demographic shifts and policy environments.

Implication

Countries with aging populations face future demands on pensions, elderly healthcare, and labour markets, requiring strategic social planning something often at odds with high military focused budgets.

This figure 25 shows more nuanced trends in population aging, offering visibility into countries with either rapid aging or youth heavy population.

Key Observations

- Rapid Aging:** Observed in Japan, Germany, France: These countries where aging is a known policy issue. These countries may have to reform pension systems or healthcare access.
- Youth Dominant Countries:** Like Pakistan, Nigeria, Kenya show consistently low elderly population shares, which may ease pension burdens but increase demand for jobs and education.
- Transitional Cases:** Russia, Mexico, Turkey show gradual aging, where demographic transition is underway but not yet at Western European levels.

C.4 Trend of Multidimensional Poverty Overtime

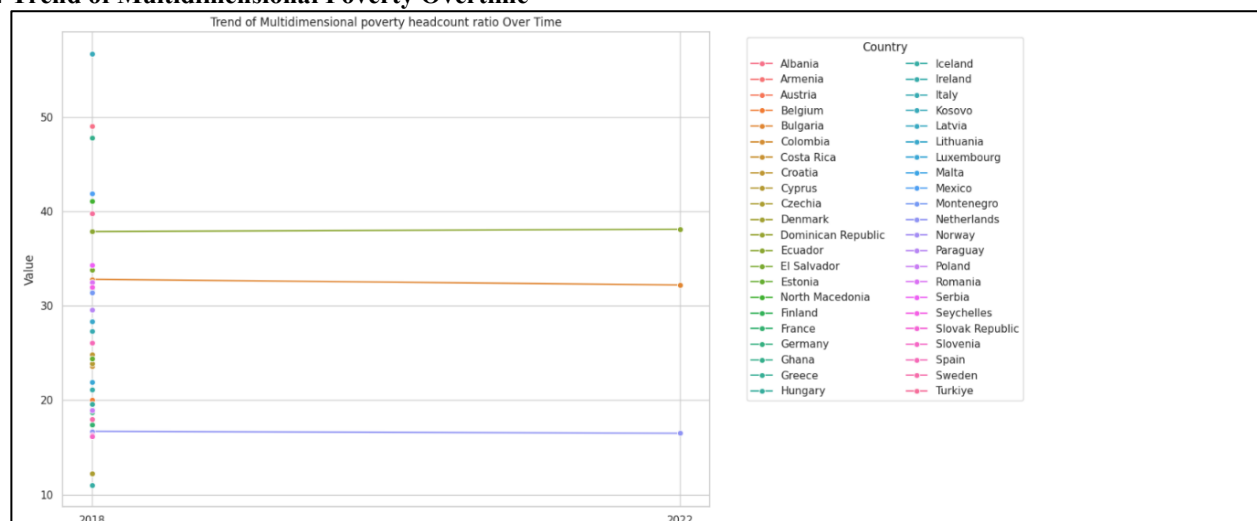


Figure 26: Multidimensional Poverty Overtime (2018-2022)

This is a clearer version of the multidimensional poverty trend graph, allowing for better isolation of country-level patterns.

Key Observations:

- Countries with Falling Poverty (Brazil, India, Indonesia):**
Large emerging economies that have invested in conditional cash transfers, education, or rural development.
- Low-Poverty Countries (Norway, Netherlands, Finland):**
These countries rarely show significant lines on this graph due to already low or negligible headcounts.

Implication

Clear identification of country trajectories makes it easier to match social policy outcomes to economic strategies or external shocks.

Appendix D

D. Military expenditure and Social Sustainability in NATO countries

NATO's 2 % GDP military expenditure benchmark has long served political and strategic signal of alliance commitment. (NATO)

The following section presents a series of graphs of social sustainability indicators of NATO countries and compares them military expenditure.

https://colab.research.google.com/drive/1QXiz_sHx6iA6c8dxHUIREWxeAcOrAsqh

D.1 Percentage of NATO Countries Met or Exceeded 2% GDP target (2014-2023)

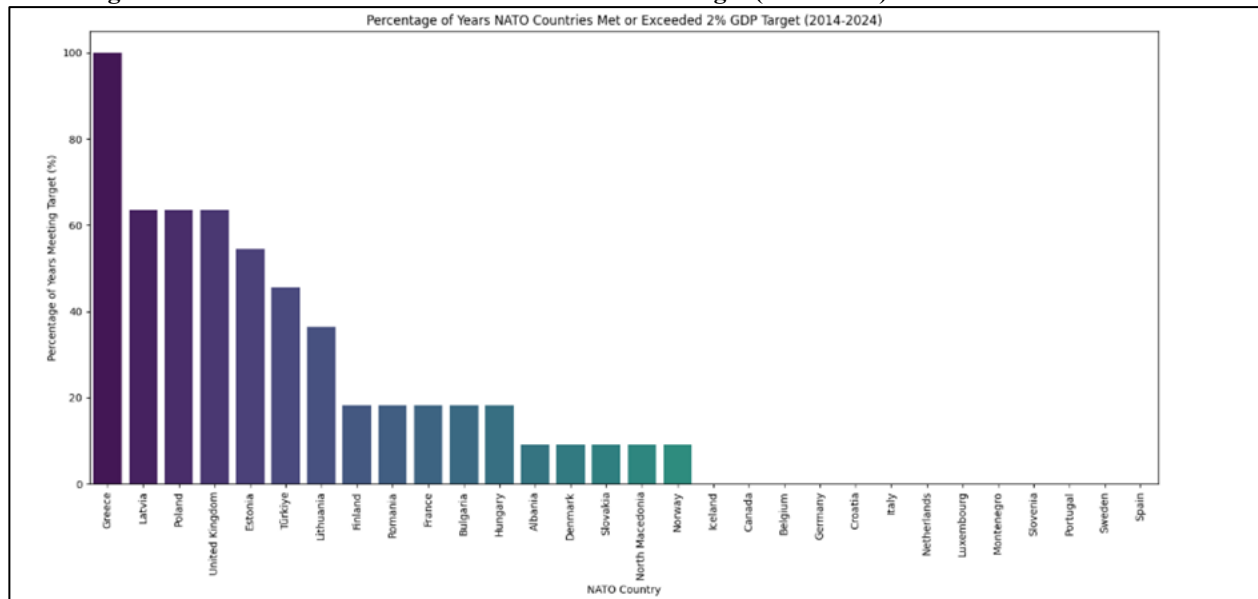


Figure 27: Percentage of NATO Countries Met or Exceeded 2% GDP target.

The figure 27 bar chart represents consistency of NATO members in meeting the alliance's recommended benchmark (2% target).

Key Observations:

- Countries like Greece, Latvia, Poland met the target more than 60% time during the decade (2014-2023)
- Countries like Spain, Portugal, Belgium fell consistently low.

Interpretation:

A higher percentage of compliance may signal stronger alignment with NATO defence policies, but it does not necessarily correlate with better social outcomes. The wide disparity suggests differing national priorities between defence spending and domestic welfare commitments.

D.2 Military Expenditure as Share of GDP over time for NATO countries vs. 2% Target

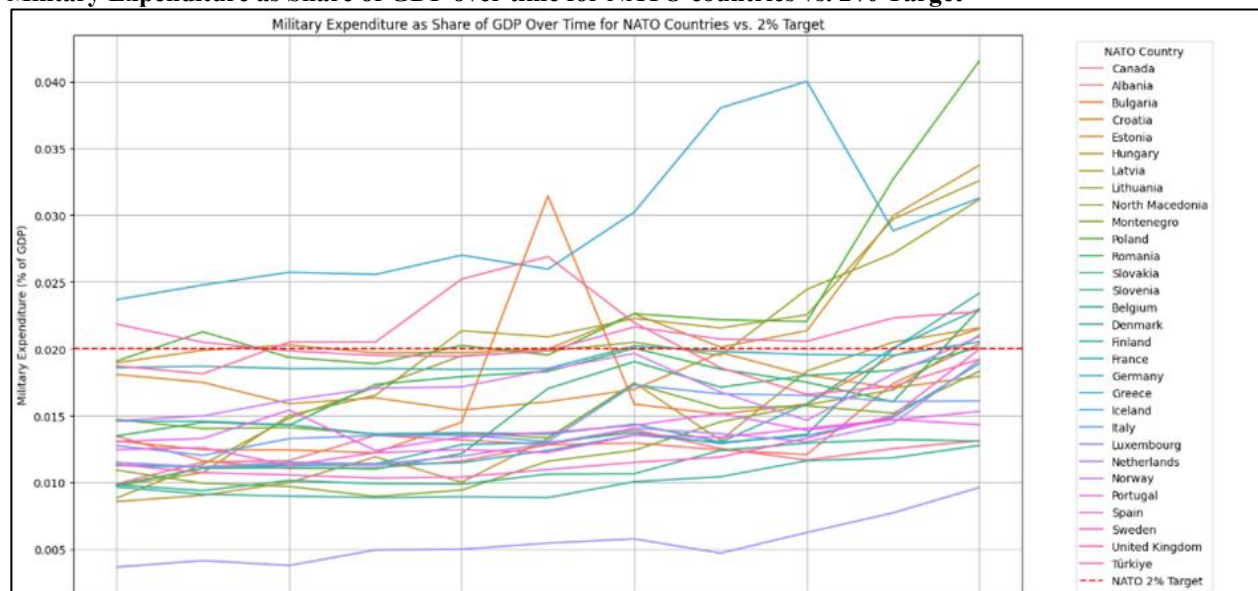


Figure 28: Military Expenditure as Share of GDP over time for NATO countries vs. 2% Target

The figure 28 represents the military expenditure as share of GDP overtime for NATO countries compared with the NATO 2 % target.

Key Observations:

Countries like Poland, Estonia and Lithuania show an increase in the military expenditure as share of GDP after 2020 due to increased security threats (Tian et al., 2024). Other countries maintain moderate levels of expenditure.

Interpretations

Countries increasing their military expenditure budget to respond geopolitical tensions but there is no trend observed in NATO countries overall which implies that these trends are depended more on the social economical state of the country.

D.3 Correlational Heatmap: Military expenditure versus Social Sustainability for NATO Countries

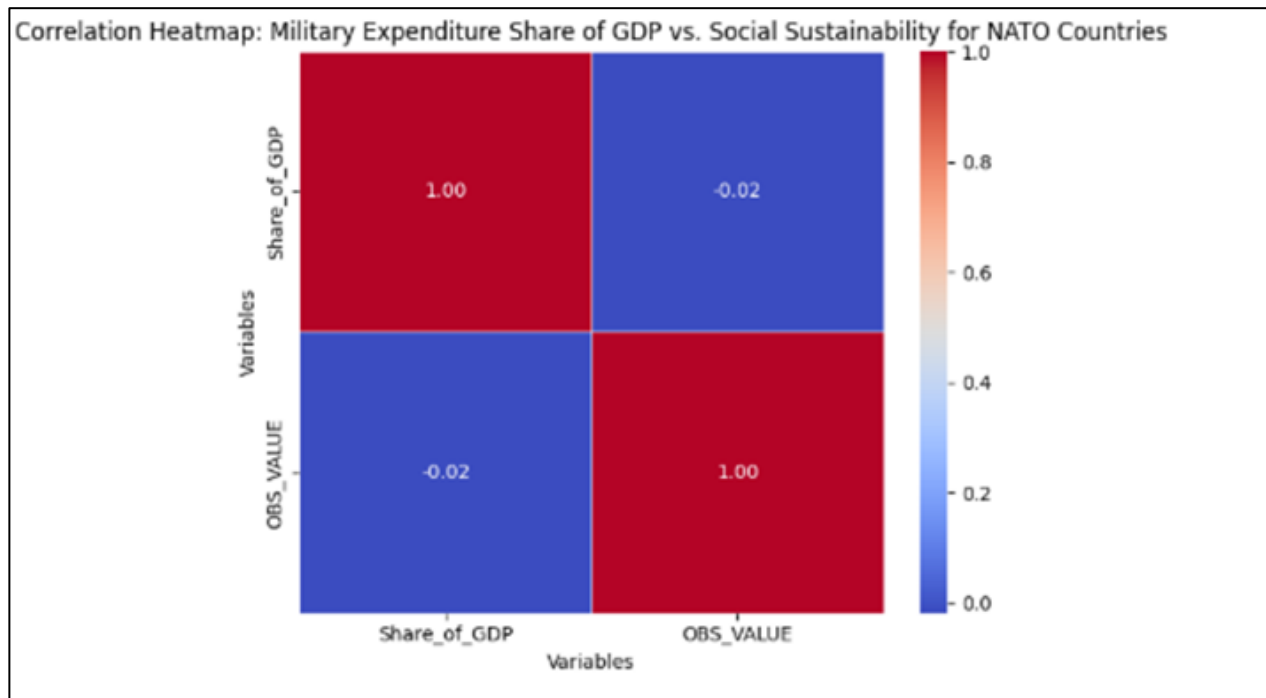


Figure 29: Correlational Heatmap: Military expenditure versus Social Sustainability for NATO Countries

The figure 29 is a correlational heatmap comparing Military expenditure versus Social Sustainability. The correlational constant is -0.02 indicating a slight negative correlational.

Interpretation

This implies no statistically significant linear relationship between how much a country spends on its military and its performance on social sustainability.

D.4 Military expenditure versus Social Sustainability for NATO Countries

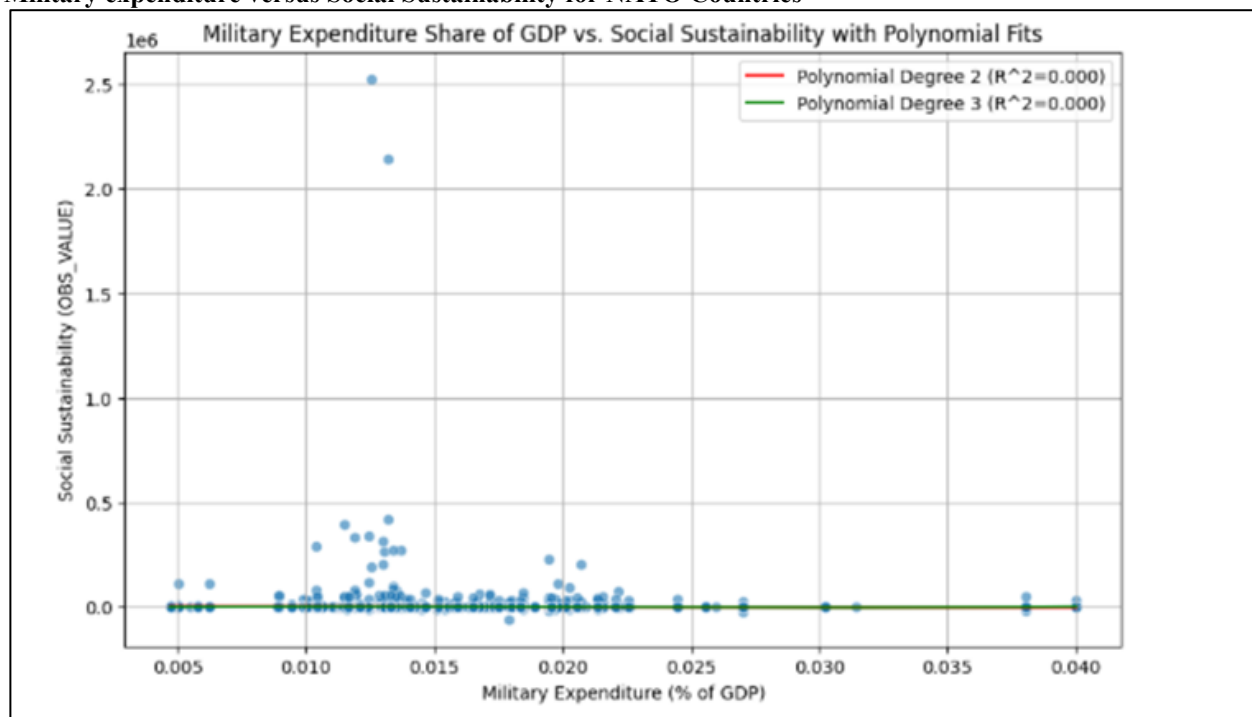
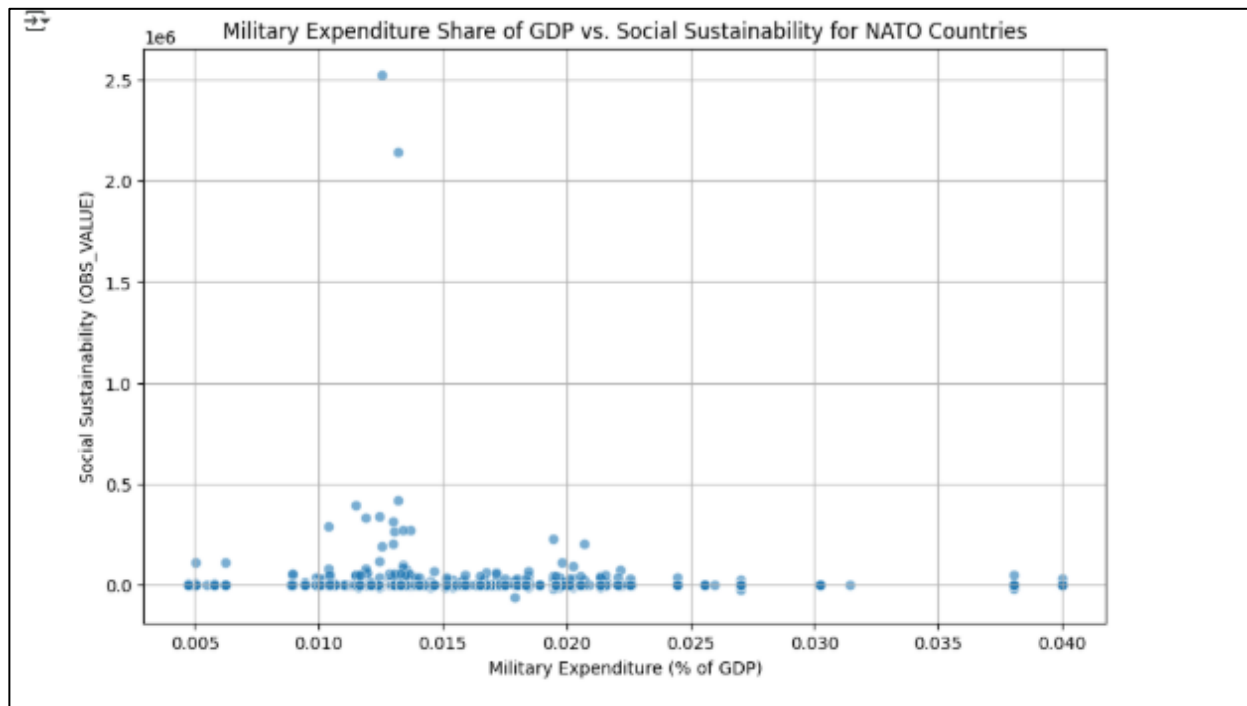


Figure 30: Military expenditure versus Social Sustainability for NATO Countries**Figure 31:** Military expenditure versus Social Sustainability for NATO Countries

The figure 30 & 31 scatterplot shows dense cluster of countries with low to moderate spending and wide variation in social sustainability outcomes.

Both linear and polynomial regression fits yield $R^2 = 0.000$, confirming no predictive value between military expenditure and social sustainability score.

Interpretation

Higher military expenditure negatively correlates with better social sustainability in the country.

These factors are heavily influenced by the social economic state of the country.

D.5 Military expenditure as a share of GDP versus Life security and Guarantee for NATO Countries

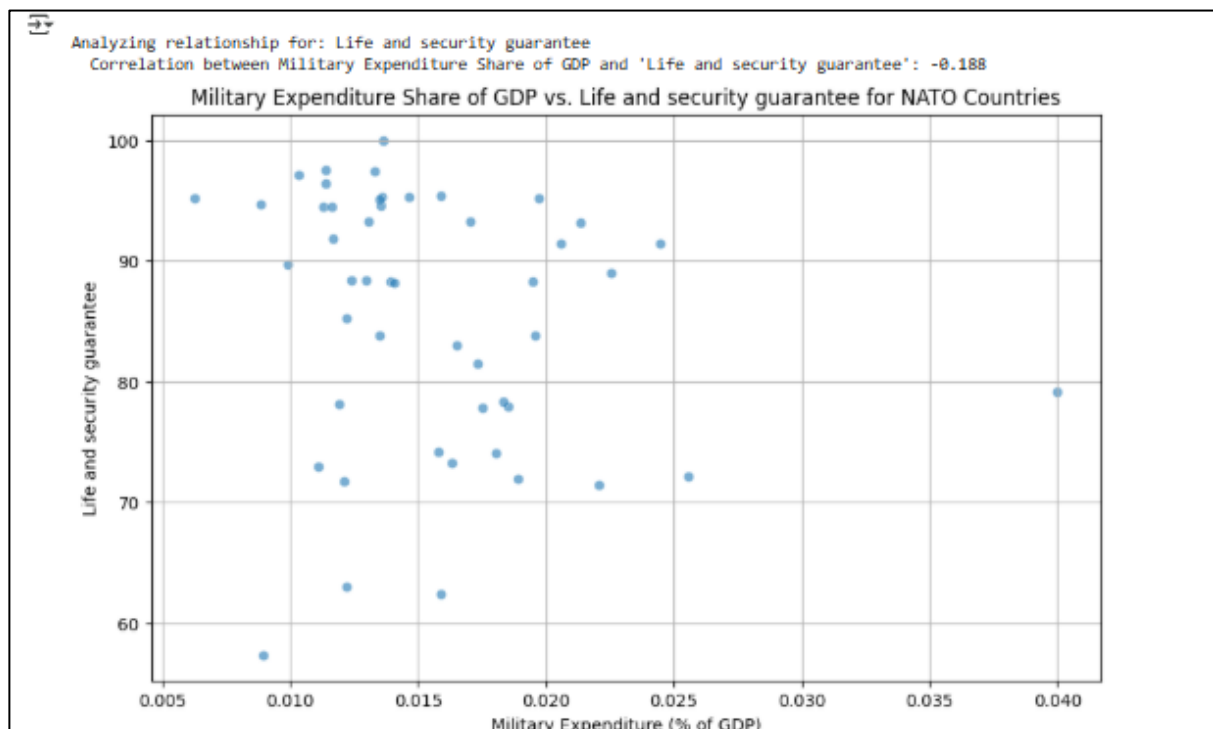


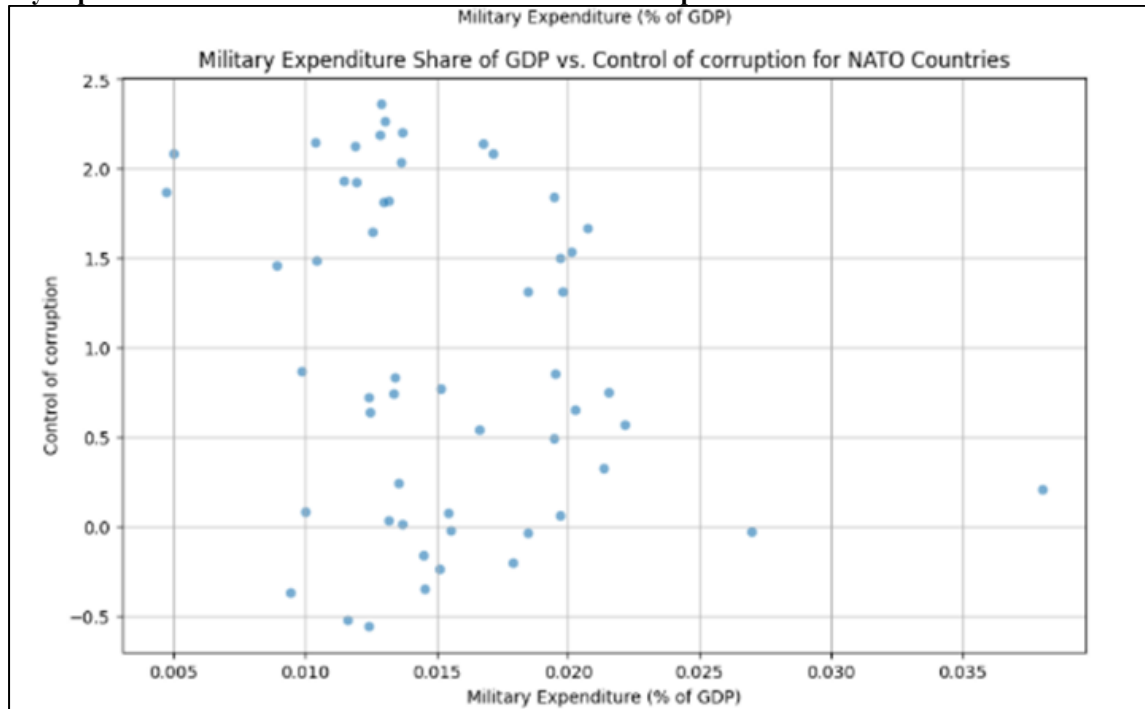
Figure 32: Military expenditure as a share of GDP versus Life security and Guarantee for NATO Countries

This scatter plot illustrates that countries with moderate to low military expenditure tend to exhibit higher life security.

Interpretation

The graph shows that countries with moderate to low military expenditure report higher life security and guarantee (above 90%).

D.6 Military expenditure as a share of GDP versus Control of Corruption for NATO Countries

**Figure 33: Military expenditure as a share of GDP versus Control of Corruption for NATO Countries**

The above scatterplot shows the relationship between military expenditure as a share of GDP versus Control of Corruption for NATO Countries.

The control corruption index ranges from -2.5(weak control) to positive 2.5(Strong control).

Interpretation

The scatterplot reveals a strong negative correlation between higher military expenditure and corruption control. Countries with both high and low control of corruption scores appear across the range of military expenditure, indicating that increased defence budgets do not inherently correlate with better governance.

D.7 Military expenditure as a share of GDP versus Share of Human Development Index for NATO Countries

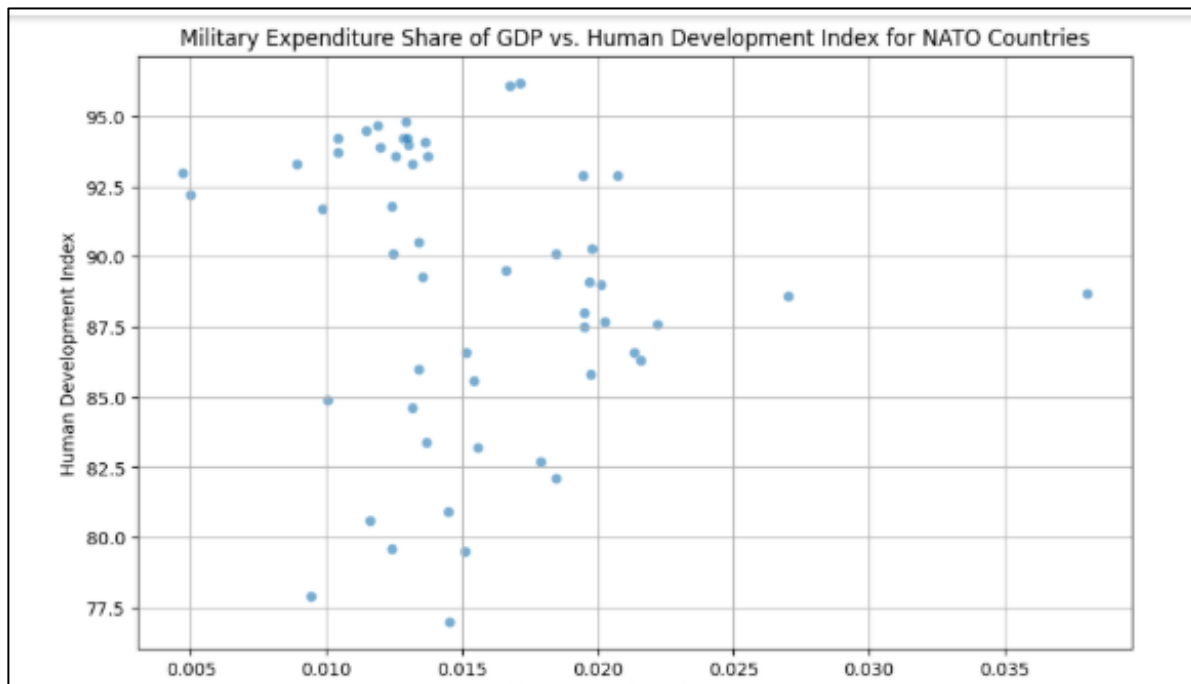


Figure 34: Military expenditure as a share of GDP versus Share of HDI for NATO Countries

The above scatterplot shows the relationship between military expenditure as a share of GDP versus of Human Development Index (HDI) for NATO Countries.

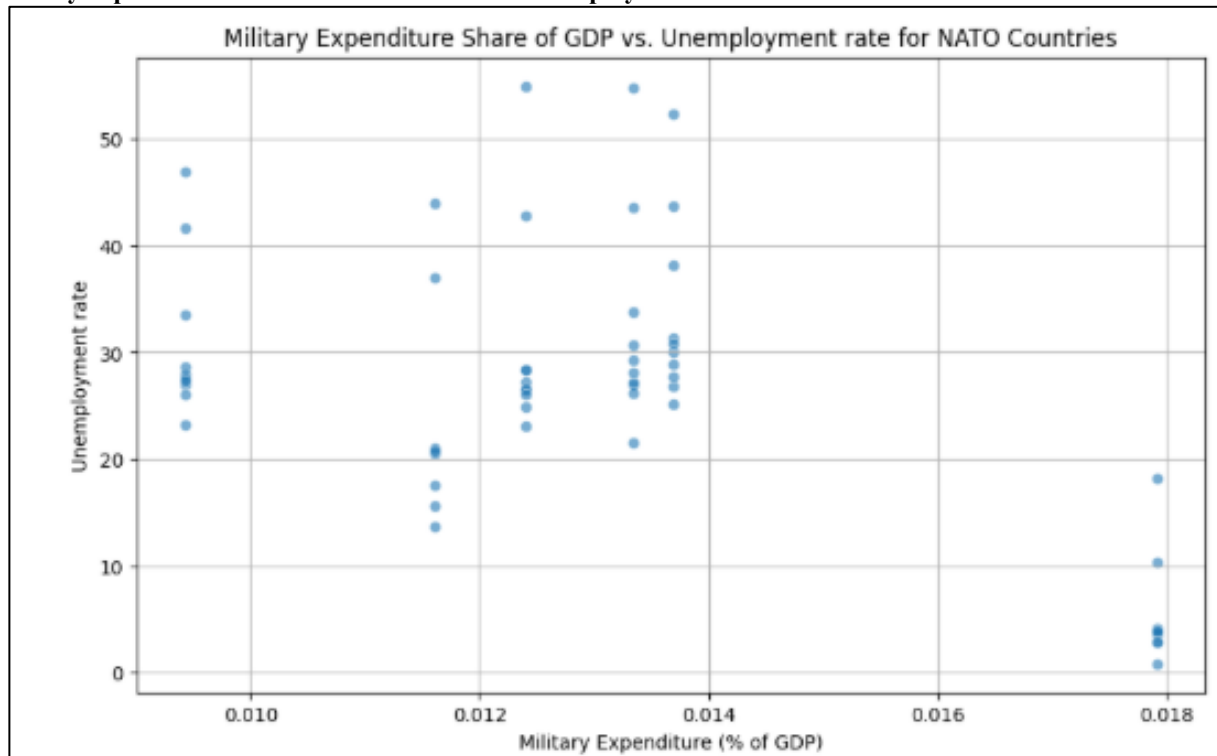
The human development index combines literacy rate, life expectancy, income into a single index. (United Nations, 2024)

Interpretation

The scatter plot indicates a mild inverse relationship between military expenditure as a share of GDP and Human Development Index (HDI).

Several nations with military expenditures under 1.5% of GDP show HDI scores above 90. Conversely, outlier countries with higher military budgets (above 2.5%) show no clear advantage in human development outcomes.

This supplements the peace dividend hypothesis.

D.8 Military expenditure as a share of GDP versus Unemployment rate for NATO Countries**Figure 35:** Military expenditure as a share of GDP versus Unemployment rate for NATO Countries

The scatterplot shows the relationship between military expenditure as a share of GDP and Unemployment rate for NATO Countries.

Interpretation

There is a high discrepancy between the data which indicates no linear pattern.

The unemployment rate among NATO states varies significantly, ranging from single digits to over 50%. Such variability suggests that military spending does not directly drive employment outcomes in a consistent manner across the alliance.

Literature Maps

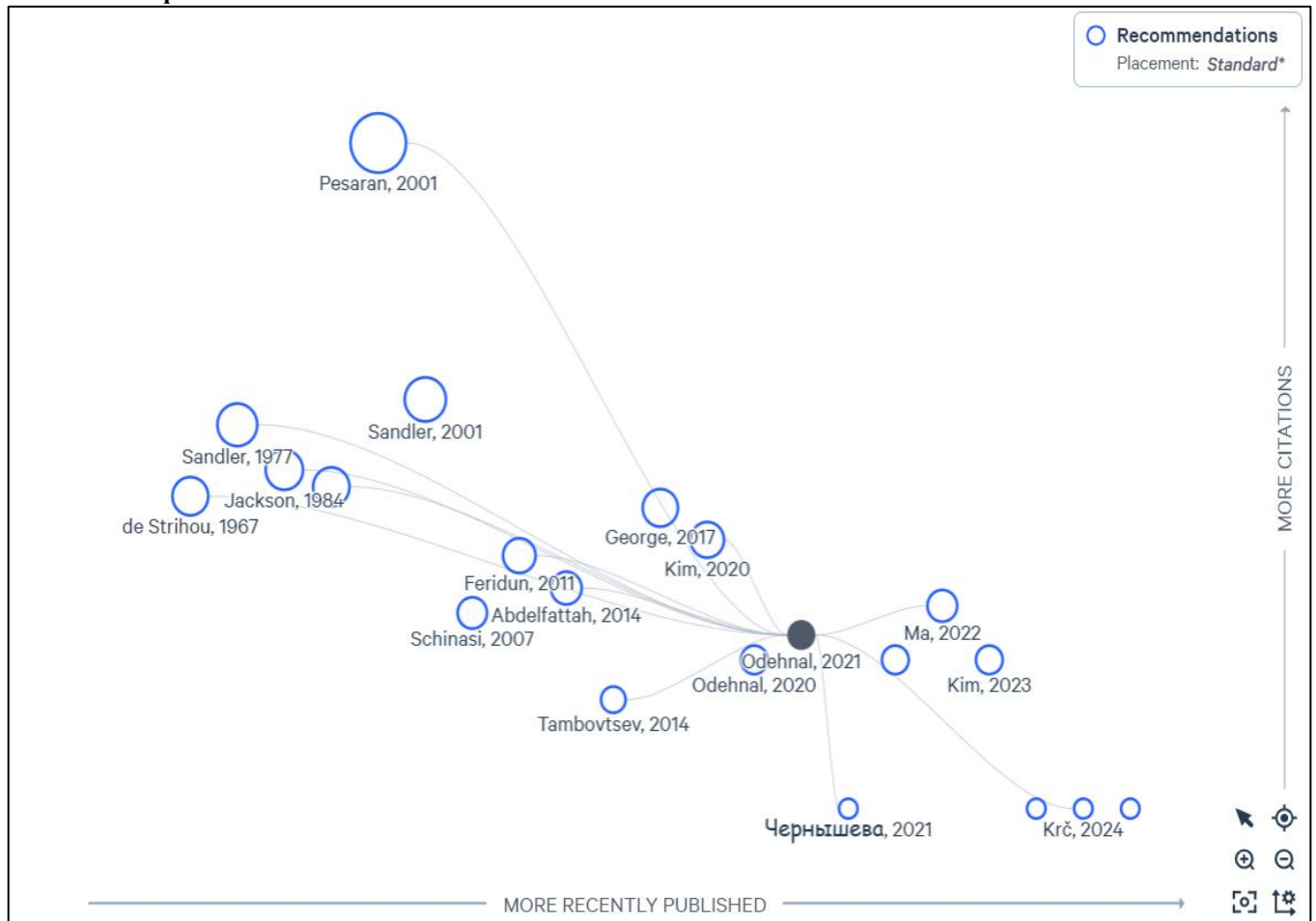


Figure 36: Citation Network Visualization.

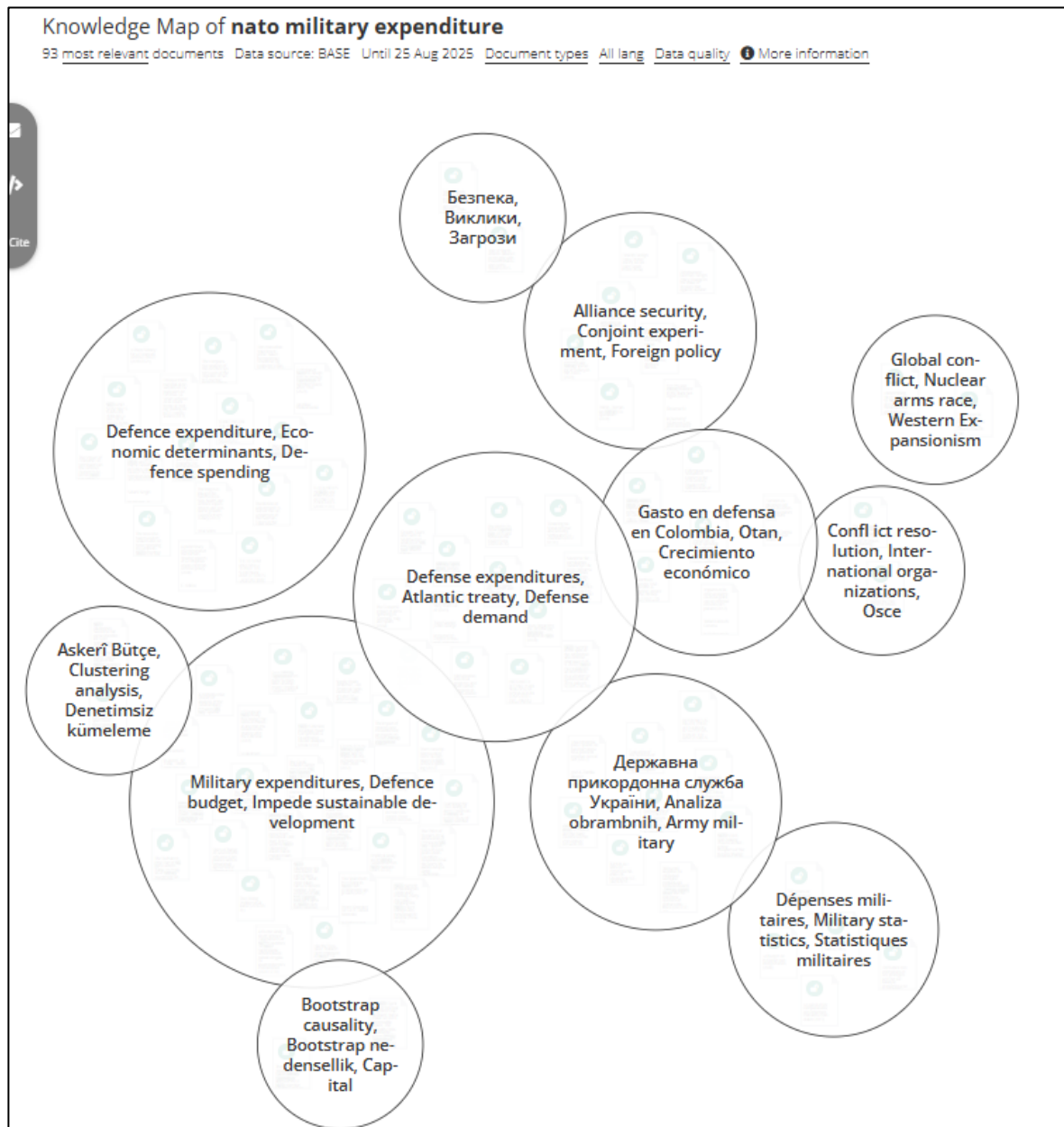


Figure 37: Knowledge Maps of NATO Military Expenditure (Open Knowledge Maps, 2025)