More Than Just a Game

A Hypergame-Theoretic Inquiry into Access and Benefit-Sharing in Digital Sequence Information

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"Between the idea
And the reality
Between the motion
And the act
Falls the Shadow"

T.S. Elliot - *The Hollow Men*

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AI Statement

I used ChatGPT as a supportive tool for coding tasks, debugging and as a writing assistant, helping me to formulate my arguments more clearly and compactly.

Abbreviation List

ABS – Access and Benefit Sharing

AI – Artificial Intelligence

ATK – Associated Traditional Knowledge

CBD – Convention on Biological Diversity

COP – Conference of the Parties, where the countries of the United Nations gather, for biodiversity or the climate

DSI – Digital Sequence Information

EPA – Engineering and Policy Analysis (Master Programme)

GRULAC – Group of Latin American and Caribbean Countries, 33 countries

INSDC – International Nucleotide Sequence Database Collaboration

IP – Intellectual Property

IPLCS – Indigenous People and Local Communities

IR – International Relations

JUSCANZ – Japan, the US, Switzerland, Canada, Australia, Norway and New Zealand

MAT – Mutually Agreed Terms under the Nagoya Protocol, refer to bilateral agreements between companies and countries

MTA – Material Transfer Agreement, the agreement on a particular piece of genomic information being transferred from one country to another

PIC – Prior Informed Consent under the Nagoya Protocol, refers to prior information being full and transparent and countries having the ability to opt in or out

USD – United States Dollar

View 1 (V1) – Open Access Global Commons

View 2 (V2) – Sovereign Resource

View 3 (V3) – The compromise between these two as a multilateral treaty

WIPO – World Intellectual Property Organization

Management Summary

The governance of Digital Sequence Information (DSI) has become one of the most contested issues under the Convention on Biological Diversity (CBD). While genetic resources have traditionally been governed through access and benefit-sharing (ABS) rules under the Nagoya Protocol, the rise of DSI has disrupted this framework. Disagreements persist over whether DSI should be treated as a global commons, openly accessible for research, or as a sovereign resource subject to national control. The 2024 Cali Fund represents a partial compromise, yet unresolved questions over contributions, allocation, and enforcement leave governance fragmented and fragile.

This thesis addresses these challenges by developing a hypergame model of DSI negotiations. Classical game theory explains stability under a shared strategic reality, but international negotiations often unfold under asymmetric perceptions: actors disagree not only on payoffs but also on the very game being played. The hypergame model formalises this divergence, enabling analysis of misperceptions, belief revision, and strategic surprise. Applied to DSI governance, the model evaluates how providers and users interact when they adopt different framings (DSI as commons or sovereign resource) and different international relations paradigms (liberalism or realism).

The findings show that asymmetric perceptions systematically destabilise cooperation. Although openness often offers the greatest collective benefit, sovereignty tends to emerge as the more stable equilibrium, as mistrust undermines liberal–liberal cooperation. Divergent perceptions generate risks of exploitation and defensive retreat, leading to non–Pareto-optimal outcomes. Over time, governance trajectories reinforce mistrust, producing cycles of sovereignty with only rare moments of convergence. These dynamics underscore the fragility of cooperation in the absence of credible institutions.

The research makes two contributions. Scientifically, it advances strategic analysis by formalising perceptual divergence as a central feature of negotiations. By linking hypergame theory with international relations paradigms and a concrete case study, it formalises how instability can stem from incompatible worldviews rather than material interests alone. For policymakers, it highlights the need to reduce misperceptions, build trust, and prevent liberal signalling from being exploited as realist strategy. Transparency in contributions, enforceable compliance mechanisms, and coordination across overlapping regimes (CBD, FAO, WHO, WIPO, BBNJ) are crucial to avoid fragmentation.

But it points to even more, namely voluntary agreements and transparency alone are unlikely to sustain cooperation, since both seem to think the other realist. Enforceable mechanisms with repercussions for non-compliance are required, with user countries bearing first responsibility, as providers already cede administrative control. Options include mandatory corporate compliance or phased financial contributions, shifting enforcement to user countries and their private sectors. At the same time, user countries should retain an exit option through a contractual pathway that reduces funding for providers that reject the multilateral framework in favour of bilateral arrangements.

In conclusion, without credible safeguards, DSI governance risks devolving into sovereignty-based fragmentation. With careful institutional design, capacity-building, and early trust-building, however, a cooperative framework remains possible. The hypergame approach offers a new lens for understanding these dynamics, providing insights not only for biodiversity governance but also for other global challenges where perceptions diverge and misalignments threaten cooperation.

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1. Problem Definition

The global governance of genomic biodiversity is changing. Following extensive negotiations under the Convention on Biological Diversity (CBD), the international community agreed in 2022 to establish the Cali Fund, a multilateral mechanism intended to address access and benefit-sharing from the use of *Digital Sequence Information* (DSI) on genetic resources (CBD, 2025). This development signals growing recognition of the economic, environmental, and political significance of DSI. Yet despite this momentum, profound disagreements persist regarding how such DSI should be governed, by whom, under which normative framing and what exactly constitutes DSI (Medaglia, 2020; Laird & Wynberg, 2018, Bagley, 2022).

1.1 Defining DSI

DSI refers to digital representations of genetic material, like sequences of DNA or RNA extracted from plants, animals, microorganisms, or humans (Theissing et al., 2023; Laird & Wynberg, 2018; Medaglia, 2020). The term "digital sequence information" (DSI) was introduced in CBD decision XIII/16 and Nagoya Protocol NP-2/14 (Laird & Wynberg, 2018; Bagley, 2022; Secretariat of the Convention on Biological Diversity, 2011). A protocol set up in 2011 with the following objective: "…the fair and equitable sharing of the benefits arising from the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding, thereby contributing to the conservation of biological diversity and the sustainable use of its components.".(Morgera et al., 2014; Bagley, 2022; Secretariat of the Convention on Biological Diversity, 2011).

However, scientific communities more commonly use terms like genetic sequence data or nucleotide sequence information, reflecting differences in material scope and rapid technological change (Laird & Wynberg, 2018). In policy discussions, terminological variation often signals divergent interpretations of what falls under the Nagoya Protocol, and thus if DSI should be classified as a genetic resource and be accompanied by access and benefits schemes that are mandatory in the Nagoya Protocol (Bagley, 2022). Different international bodies use varying terms, such as "sequence data," "resources in silico," or "genetic sequence data", indicating the lack of harmonized language across legal and scientific frameworks, and a true definition of DSI (Laird & Wynberg, 2018).

1.2 Rising use and geopolitical tensions

Datasets containing DSI underlie a growing range of applications: from supporting conservation planning, ecosystem monitoring, and climate resilience strategies, to enabling innovation in sectors such as pharmaceuticals, agriculture, biotechnology, and synthetic biology (Theissinger et al., 2023; Laird & Wynberg, 2018; Medaglia, 2020; Bagley, 2022). As such, DSI serve both *global public goods functions* and *private commercial interests*, creating tensions between open science, proprietary innovation, and national sovereignty.

A striking example of the problems, was the development of Regeneron's Ebola drug, Inmazeb™, used a virus sequence from a 2014 Guinean Ebola survivor, uploaded by the Bernard Nocht Institute to GenBank without restrictions, and its further use needed no benefit-sharing agreement like they would have for a physical sample (Hammond, 2019). Even though Guinea provided the genetic material that made the drug possible, Regeneron, a US-based pharmaceutical company, doesn't have to share any profits from the patents or share the products, so access to the now patented vaccine depends on the goodwill of the U.S., instead of a fair ‘Nagoya inspired’ deal (Hammond, 2019; Bagley, 2022). Once Ebola entered the US, it was deemed a ‘National Security Risk’ and America was treated first, the other countries had to wait (Bagley, 2022). Regeneron made millions, the USA has power and can distribute the drug to whoever they see fit for whatever price they see fit and Guinea was dependent and still suffering from Ebola, or paying high prices for the use of the patented drug (Hammond, 2019; Bagley, 2022).

Crucially, while the capacity to collect, process, and commercialize genomic data is highly uneven, concentrated in technologically advanced countries and private firms, much of the world’s biodiversity, approximately 75% of the world’s biological resources, is located in the Global South (Hogg, 2024; Forsdick et al., 2023; Vilaça et al., 2024; Medaglia, 2020; Bagley, 2022; Fajinmolu et al., 2025). This creates geopolitical asymmetries between data providers and data users, as arguably, the one that use the resource are not always the ones that ‘own’ the resource (Lawson et al., 2024). This also raises the question if DSI should be treated as a resource of a country, a sovereign resource, or as an international open access knowledge database that focusses on improving the world. Arguments can be made for both, as it is location bound, yet once digitalized it loses its locality (Bruynseels, 2020). So, should genomic data be treated as a knowledge commons, freely accessible to maximize global benefits? Or should it be governed as a sovereign resource, subject to national control and compensation?

1.3 International relations as a lens

These competing framings reflect deeper ideological tensions between liberal multilateralism and realist geopolitics in the field of International Relations (IR). The scope of International Relations encompasses the complex interactions among the world’s sovereign states (Sørensen et al., 2021). It focuses primarily on the detailed analysis of events and situations that have an impact on multiple states, and thus also the development of cooperation or defection in DSI (Moravcsik, 1997; Sorensen et al., 2021).

From a realist perspective, the international level is a level constructed by anarchy. States are primarily motivated by their self-interest and the need to maintain their autonomy, especially regarding their own security and survival (Waltz, 1979). Realism in international relations begins with four key assumptions: the state is the primary and most powerful actor; it acts as a unified entity, especially in times of conflict; decision-makers behave rationally in pursuit of national interest; and the international system is anarchic, lacking a central authority (Sørensen et al., 2021). In times of crisis, unlike domestic systems with police or courts, there is “no one to call” globally, states must rely on themselves (Duguri et al., 2022; Moravczik, 1992). Kenneth Waltz, argued that all states operate under the constraints of anarchy and act based on relative power (Waltz, 1979).

Liberalism, among others, criticizes these assumptions and says that countries can work together in order, thus non-anarchic, too. Neoliberal institutionalism, often shortened to 'neoliberalism' within international relations (IR) theory, focuses on how international organizations facilitate cooperation among states by reducing the temptation to defect from agreements (Sørensen et al., 2021). In the context of IR, liberalism emphasizes that cooperation can yield significant benefits for all parties, provided there is trust that others will uphold their commitments (Moravczik, 1997; Sørensen et al., 2021). Defection is more likely when a state can cheat and avoid consequences, but when an impartial third party, such as an international organization, monitors compliance and shares information, the risk of cheating decreases (Sørensen et al., 2021). This monitoring function makes cooperation more reliable and encourages all signatories to honour agreements (Moravczik, 1992). According to liberal theorists, states are primarily concerned with absolute gains, where all participants benefit, though not necessarily equally, rather than relative gains, which focus on how much more one state benefits compared to another (Sørensen et al., 2021; Moravczik, 1992).

From a Liberal perspective, interdependencies can and will foster cooperation, potentially leading to better solutions and outcomes for both, where trust is the epitome of cooperation (Moravcsik, 1997). So the question comes regarding digital sequence information comes down to, should we work together towards a world order that is better than before, liberal, or should a country get a fair price and the most benefit from its sovereign resource in comparison to the others, realist. These conceptions are not merely discursive but actively shape actors' preferences, institutional designs, and negotiation strategies. Leading into the third paradigm, in International Relations constructivism, which poses that anarchy is what states make of it (Wendt, 1992). The paradigms countries use in their logic are the ones that shape the eventual outcome of the world politics and International Relations outcomes, according to Wendt (Wendt, 1992). So, shortly stated if a country thinks realist, it will act realist, if it thinks liberal, it will act liberal.

1.4 Differing views in practice

Research performed by Bagley, on the actual negotiations, has identified three different practical views countries seem to have on how DSI should be integrated in the Nagoya Protocol and implications for ABS (2022).

- **View 1** holds that DSI isn't a genetic resource but can result from one and be addressed in mutually agreed terms (MAT). Beyond that, it's seen as a global non-monetary benefit that doesn't require further sharing. Supporters, mostly from developed countries and research circles, argue that ABS rules on DSI would harm innovation and conservation.
- **View 2** argues that DSI falls within the definition of "genetic resources" and should therefore be subject to Prior Informed Consent (PIC) and Mutually Agreed Transfers (MAT) requirements under the Nagoya Protocol.
- **View 3** sees DSI as separate from "genetic resources" but acknowledges it results from their use. It argues that commercial use of DSI should involve monetary benefit-sharing, since its non-monetary (the availability of data) benefits alone don't meet Nagoya Protocol obligations.

As of 2024 with the entrance of the Cali Fund, the 3rd view seems to be assuming the part of a compromise between the countries however this third view does seem to be in between the other two and a the outcome of a compromise on a spectrum between 1 and 2. At the 15th Conference of the Parties (COP15) to the Convention on Biological Diversity, countries agreed to establish a new multilateral fund under the Global Environment Facility, aimed at ensuring benefit-sharing from the use of digital sequence information (DSI) on genetic resources (Secretariat of the Convention on Biological Diversity, 2025). The fund, referred to as the Global Biodiversity Framework Fund or CALI Fund, is intended to support biodiversity conservation in countries that provide genetic resources but often lack the capacity to extract value from them. It was agreed that contributions should come from a range of actors, including the private sector, particularly from companies that benefit commercially from access to DSI (Secret of the Convention on Biological Diversity, 2025).

While the establishment of the fund has been agreed upon, the document also makes clear that important aspects remain unresolved (Secret of the Convention on Biological Diversity, 2025). The specific financial contributions, the rules for determining who pays, and how the funds will be allocated are still subject to negotiation. The parties have yet to determine the exact mechanisms by which monetary benefits will be collected or how they will be equitably distributed, leaving significant details open for future decision-making (Secretariat of the Convention on Biological Diversity, 2025, pp. 4–5). This makes it a voluntary mechanism up until now. Countries can choose to fully contribute to the fund, aligning with a global commons approach, or they can choose to close off access and contributions, reflecting a more sovereign control stance.

The ambiguity and contestation around these framings in DSI, and the strategic use of cooperation language to pursue national interests (realist), or pursue the greater good (liberal) generate conditions for misaligned incentives from differing countries, possibly resulting in unwanted unfair and suboptimal outcomes for all countries involved (Kovach et al., 2015). For example, consider a scenario in which Country A mis assumes that Country B will act liberally and support the greater good. On this basis, Country A opens access to its resources. However, Country B instead follows an inherently realist logic, pursuing its own interests and withdrawing once it has obtained what it needs. This illustrates how the framing of DSI, and whether countries approach negotiations from a liberal or realist perspective and how they perceive the other country to be, directly shapes their behaviour and influences the prospects for fair and effective governance of DSI.

1.5 Bridging the gap between framing and governance reality

While existing literature on Digital Sequence Information (DSI) highlights important legal and institutional tensions, such as the conflict between open data principles and access-and-benefit-sharing obligations (Klünker & Richter, 2022), or the implications for certain groups (Wynberg et al., 2021), it does not provide analytical tools to systematically capture framing contests. Studies tend to describe discursive or normative disagreements, but they do not model how divergent framings of DSI, such as its treatment as a “global commons” versus a “sovereign resource,” shape fairness perceptions or strategic behaviour in negotiations.

In policy studies more broadly, framing analysis has been used to explore how competing interpretive schemes influence strategic interaction (e.g., Goffman, 1974; Kaplan, 2008). Yet this tradition has not been applied to the DSI debate, where the lack of shared assumptions about the nature of the resource fundamentally affects governance outcomes and possibly, strategies. By integrating hypergame theory with international relations paradigms, this research addresses this gap and demonstrates how framing contests can be formalised as part of strategic analysis.

This thesis addresses this gap by applying a novel combination of overarching frames of DSI, paradigms of International Relations theories and hypergame-theoretic scenario analysis to explore how actors could behave under shared or asymmetric framings of DSI. Hypergame theory is a branch of game theory that conceptualizes situations of cooperation or strategic action from the perspectives of the actors involved, it does not assume one game that is viewed the same by all actors involved, this will be further clarified in the methods chapter (Kovach et al., 2015).

This thesis conceptualizes DSI governance as a set of hypergames investigating how strategic choices evolve under varying perceptions of liberalism and realism. By constructing a structured scenario space, the research maps the potential for misaligned motives and their influence on the development of the DSI commons for different actors. While focusing on states (providers vs. users) in the ongoing CBD negotiations and the CALI Fund, the analysis also considers how lower-level actors like companies influence national strategies and how higher-level international organizations respond, highlighting the complexities arising from the interaction between states and private actors.

1.6 Research Objective

This thesis aims to conceptually and strategically analyse the governance of genomic biodiversity data (DSI) under competing political framings. It develops and applies a dynamic hypergame-theoretic framework to examine how state actors and relevant non-state actors (e.g., private firms) behave under alternative framings of genomic data: (1) as an open-access global knowledge commons, and (2) as a sovereign natural resource. This analysis is further situated within different International Relations paradigms, focusing on (1) liberalism, which emphasizes absolute gains from DSI for countries, and (2) realism, which prioritizes relative gains from their sovereign resource.

This research systematically models governance as a dynamic hypergame to examine how actors' framing assumptions and asymmetric perceptions of each other's paradigms shape strategic choices, institutional outcomes, and benefit-sharing mechanisms. Particular emphasis is placed on the implications of asymmetric framing, whereby actors operate under divergent normative assumptions, and the consequences this has for cooperation and resource allocation. For instance, outcomes differ substantially when one country adopts framing 1 while its counterpart adheres to framing 2, or vice versa. The broader objective is to identify the conditions under which governance of digital sequence information (DSI) can be fair, effective, and durable, despite the opacity of real-world strategic behaviour and the persistent challenges of ensuring transparency and compliance. In addition, the study seeks to highlight potential risks for future benefit-sharing arrangements and to anticipate how evolving geopolitical dynamics may shape the development of international governance surrounding DSI.

1.7 Relevance

1.7.1 Scientific Relevance

While digital sequence information is increasingly debated within legal, political, and ethical scholarship, many analyses fail to capture the dynamic and perceptual complexities driving real-world negotiations (e.g. Sett et al., 2024 for scientists; Wynberg et al., 2022 for farmers & Rohden & Scholz, 2021 for the political process). Traditional models often assume shared understandings or complete information, falling short in politicized and uncertain domains like Digital Sequence Information (DSI). This thesis addresses this explanatory gap through a hypergame-theoretic approach, integrated with International Relations paradigms and constructivist framing. The strength of this approach lies in its ability to explicitly model and analyse:

1. Different perceptions and expectations: Unlike standard game theory, hypergame theory does not assume that all players see the game in the same way or share the same motives (Kovach et al., 2015). This is especially important for DSI, where actors disagree on ownership, benefit-sharing, and intentions. It helps explain outcomes that might look "irrational" but in fact come from different understandings of reality.

2. Framing as part of the game: Instead of treating DSI framings (global commons vs. sovereign resource) as fixed, they are modelled as strategic choices that change preferences and how the game is perceived. This shows how debates over framing directly shape strategic behaviour.

3. Learning and (mis)trust over time: The dynamic model tracks how players update their beliefs after "strategic surprises." This helps explain cycles where cooperation builds on trust or, alternatively, where mistrust locks actors into poor outcomes.

Main contributions of the thesis:

1. Linking framings, worldviews, and hypergames: Research on DSI often notes discursive conflicts but lacks tools to model them. This thesis builds a new framework that integrates framing assumptions into the structure of the game, giving more insight into how coordination problems develop under uncertainty.

2. Looking across levels of governance: DSI involves global negotiations, national governments and companies. This thesis examines how these layers interact, especially how global rules are enforced in practice through domestic policies and corporate behaviour and what this does for trust and behaviour for the parties. This improves the model's ability to explain real governance challenges.

3. Exploring alternative futures: Rather than predicting a single outcome, the thesis maps possible governance pathways and the mechanisms through which they could emerge, shaped by framings and actor preferences. This contributes to debates on post-2022 CBD implementation and introduces a novel use of scenario exploration in global environmental politics.

This thesis contributes to the intersection of institutional analysis, strategic modelling, and global biodiversity governance by applying hypergame theory to the problem of DSI governance. Whereas most studies focus on legal or normative aspects of benefit-sharing, this research offers a structured strategic view of how actors' choices, interests, and framings interact over time. It examines cross-level feedbacks, strategic interdependencies, and shifting governance logics, treating the framing of genomic data as a factor that actively shapes actor rationality, perceived payoffs, and game structure. In doing so, it advances the integration of institutional framing, collective action dilemmas, and game theory in environmental governance and international negotiations.

1.7.2 Relevance to Engineering and Policy Analysis (EPA)

The thesis aligns with EPA's focus on analysing complex, multi-actor systems under deep uncertainty. It fits within the program's methodological ambition to integrate formal modelling, conceptual clarity, and policy relevance in the analysis of socio-technical problems.

This work makes a significant contribution to EPA's mission by addressing a deeply uncertain and politicized policy domain: the global governance of Digital Sequence Information (DSI).

Specifically, it demonstrates methodological relevance by:

- Developing a structured hypergame with dynamic and strategic feedback loops.
- Integrating qualitative institutional framings with formal, hypergame-theoretic logic to model ambiguity and interpretive conflict.

- Offering scenario-based models that reveal how different actor configurations, framings, and strategic moves could influence the viability and equity of global DSI governance.

Beyond methodological advancements, this research contributes to theoretical ambition within EPA by applying and extending International Relations paradigms to a cutting-edge governance challenge, offering insights into how fundamental beliefs about state behaviour shape technological and environmental policy.

From a practical policy relevance standpoint, this thesis delivers strategic insights for policymakers and negotiators involved in DSI governance, particularly within the Convention on Biological Diversity (CBD) context and discussions surrounding mechanisms like the CALI Fund. By explicitly modelling asymmetric perceptions and the consequences of misaligned strategic choices, the research provides a framework for:

- Diagnosing sources of policy stalemate: It highlights how mutual misperceptions can lead to suboptimal outcomes, even when underlying interests might align.
- Anticipating strategic responses: The hypergame scenarios offer policymakers a tool to foresee how different actors might react based on their perceived realities, rather than an objective 'truth'. This aligns with an EPA approach that values understanding strategic behaviour and process dynamics over solely prescriptive advice.
- Informing negotiation strategies: By revealing the mechanisms through which trust erodes or cooperation becomes fragile, the findings can guide efforts to build more robust and transparent governance arrangements for DSI. This speaks to the "process style" and "interactive style" of policy analysis, emphasizing the importance of understanding conflicting views, strategic behaviour, and fostering learning among actors.

Ultimately, this thesis provides a robust decision-analytic framework that can inform the understanding and potential design of DSI governance mechanisms, particularly under diverging interests and norms, reinforcing EPA's commitment to tackling complex, real-world policy dilemmas.

2. Research Questions

This chapter sets out the positioning of framing within the research design and formulates the central research question guiding the thesis. It begins by situating framing as a dynamic mechanism within the hypergame-theoretic analysis of DSI governance, linking it to broader International Relations paradigms. The chapter then introduces the main research question, highlighting its novelty and contribution. Following this, four sub-questions are presented in sequence: first, the mapping of strategic choices and payoff structures; second, the role of asymmetric perceptions in shaping negotiation outcomes; third, the temporal dynamics of belief revision and governance trajectories; and fourth, the multi-level interactions between global negotiations and national actor behaviour. The chapter concludes with a summary showing how these elements together align into a coherent framework for addressing the overarching research problem.

2.1 Positioning of Framing in the Research Design

While political framings of genomic data, as either a global knowledge commons or a sovereign national resource, play a central role in shaping institutional negotiations, this thesis positions framing as a mechanism within a broader hypergame-theoretic analysis of Digital Sequence Information (DSI) governance. Framing is not treated merely as an input variable, but as a dynamic factor that shapes preferences, defines rationality, and introduces asymmetries into games at both the international and national level. By embedding framing within formal models, the thesis retains analytical structure while still enabling reflection on deeper political dynamics in the discussion and implications. In the discussion and further analysis of the frames and its implications, the paradigms of International Relations will be integrated.

2.2 Main Research Question

How do asymmetric perceptions of Digital Sequence Information (DSI) framings and underlying International Relations paradigms lead to strategic misalignments and influence the stability of governance outcomes in global negotiations, in the context of the Convention on Biological Diversity (CBD) discussions?

This question addresses a current governance problem at the intersection of biodiversity, technology, and international equity. While the CBD negotiations represent an institutional step forward in global benefit-sharing, its successful implementation depends on resolving tensions between strategically divergent actors, specifically concerning competing framings of what DSI constitutes. The novelty of the question lies in:

- Applying a dynamic hypergame-theoretic structure to clarify how governance dilemmas evolve.
- Focusing on framing and negotiation as a strategic move, not merely a background assumption.
- The handling of the relatively new and complex phenomenon of Digital Sequence Information Governance (Scholz et al., 2023).

2.3 Sub-Questions

Sub-question 1: *What are the core strategic choices and corresponding payoff structures for 'provider' and 'user' states under different DSI framings (knowledge commons vs. sovereign resource) and International Relations paradigms (liberalism vs. realism)?*

This first sub-question explores the fundamental elements that constitute the strategic games in DSI governance, mapping the actors' primary strategic options and how their perceived benefits are structured under varying conceptual lenses. Including the entry of a structural sensitivity analysis, for possible varying game structures.

Sub-question 2: *How do asymmetric perceptions of DSI framings and underlying IR paradigms influence actor preferences, negotiation strategies, and lead to suboptimal or exploitative outcomes in hypergame scenarios?*

This second sub-question anchors the research in constructivist policy theory, exploring how framing shapes perceptions of legitimacy, obligation, and entitlement. The key innovation here is to treat framing not only as an ideational variable but also as a strategic move with distributional consequences. Understanding these framings is essential to interpret the positions actors take in the games and to construct payoff structures in the models. It also helps identify how one framing can be instrumentalized to advance self-interest under the guise of cooperation.

Sub-question 3: *What are the dynamic trajectories of belief revision and system-wide transitions in DSI governance hypergames for understanding pathways to stable DSI outcomes over time?*

This third sub-question builds the temporal dimension of the thesis. It justifies the use of staged games by acknowledging that governance evolves, that trust (or its absence) accumulates, and that institutional inertia can lock in or prevent cooperation. It enhances the explanatory power of the game models and allows for reflection on path dependency, learning, and institutional drift.

Sub-question 4: *How do the interdependencies between the CBD negotiations, other negotiations and national-level actor behaviours (states and private firms) complicate strategic interactions and impact the transparency and enforceability of DSI governance agreements?*

This question explicitly links national-level incentive structures to global strategic choices, and contextualizes the hypergame analysis. It adds an institutional political economy layer, recognizing that countries are not unitary actors and that private firms are major stakeholders in DSI extraction and use. The interplay between domestic policy constraints and international negotiations is central to understanding why some countries push for nationally binding access-and-benefit-sharing mechanisms while others focus on international cooperation.

2.4 Summary of Alignment

Together, the sub-questions provide a comprehensive exploration of the main research question:

- Sub-question 1 maps out the strategic choices and payoff structures, providing the inputs for the hypergame analysis.
- Sub-question 2 clarifies how misperceptions lead to specific, often suboptimal, outcomes in hypergame scenarios.
- Sub-question 3 builds a temporal architecture for applying hypergame theory to real-world transitions, offering dynamic insights.

- Sub-question 4 reveals the multi-level institutional mechanisms and practical constraints, especially regarding the interactions between states and private actors in real-world DSI governance.

3. Method & Data Collection

This chapter presents the overall research design developed to examine how asymmetric perceptions of digital sequence information (DSI) framings and international relations paradigms influence strategic misalignments and the stability of governance outcomes. The design integrates formal hypergame modelling with interpretative analysis informed by liberal and realist perspectives, complemented by qualitative interviews. This mixed approach was selected to capture both the structural dynamics of strategic interaction and the perceptual asymmetries that underlie misalignment, while maintaining clarity regarding scope and limitations.

3.1 Research Design and Sub-Question Linkages

The research design is organised around four sub-questions (SQs), each addressed through a distinct methodological approach. SQ1 maps the strategic options and associated ordinal payoff structures. SQ2 investigates asymmetric perceptions by means of static hypergame analysis. SQ3 advances this by modelling dynamic trajectories of belief revision. SQ4 situates and assesses the results through qualitative evidence drawn from semi-structured interviews. This sequencing creates coherence: the formal models establish the structural baseline, while the qualitative material both grounds the assumptions and tests their plausibility.

3.1.1 Methods, Data, and Validation per Research Question

The following section provides a brief overview of the data sources employed for each sub-question, clarifying how different forms of evidence are matched to specific analytical objectives.

SQ1 – Strategic options and payoffs.
Payoffs were constructed through qualitative interpretation of theoretical frameworks and review of developments in DSI governance. Where possible, realist and liberal priorities were drawn from literature and policy documents, then validated through interviews by asking respondents to articulate what they considered most important. For the realist theory, Waltz and Gilpin are used to build out a qualitative ranking of outcomes (1979;1987). For the Liberal theory, the commons framework set out by Ostrom and later added on towards by Dagan & Heller is used (1990/2007; 2000). Outcomes were ranked ordinally on a four-point scale (1 = least preferred; 4 = most preferred). Equal payoffs were assigned if players exhibited no clear preference between two outcomes. Assumptions most open to debate were explicitly tested in sensitivity analysis.

SQ2 – Asymmetric perceptions.
To assess the effects of divergent framings, static hypergames were constructed by combining an objective "reality" with players' subjective perceptions. Equilibria were calculated under both payoff-based and risk-based decision rules using a custom Python implementation that builds on the *nashpy* library. The full hypergame framework and its operationalization can be found in chapter 5. This allowed systematic cataloguing of exploitation, misalignment, and suboptimal outcomes.

SQ3 – Dynamic trajectories.
The static hypergames were extended into a two-stage framework where strategic surprises triggered belief revision. Transition grids were analysed to identify possible shifts in equilibria and to explore the stability of governance outcomes, again a full operationalisation

of this dynamic aspect can be found in Chapter 5. The dynamics do not aim to predict real trajectories but to illustrate plausible paths of misalignment and convergence.

SQ4 – Qualitative contextualization.
Semi-structured interviews were conducted between 7 July and 7 August with four participants: a provider representative, a user representative, a DSI governance expert, and a WIPO patent negotiator. These roles were chosen to capture provider and user perspectives, a meta-level expert view, and insights into connections between benefit-sharing and intellectual property negotiations. Interviewees were recruited through email with support from the research supervisor. No claim of saturation is made, but the sample offers a balanced overview within the scope of this project. Data were anonymized and stored securely under TU Delft guidelines.

3.2 Coding and analysis

All modelling code was developed from the ground up in Python 3.12.0. The code was tested against simple baseline problems for internal consistency before being applied to hypergames. Figures and outputs were created by the author, and the modelling approach was inspired by but not directly copied from existing hypergame literature.

The codebase follows PEP 8 conventions and is organised in a modular structure, with separate scripts for functions (calculating attributes of outcomes), an analysis run file (which allows for quick analysis for whole hypergame combinations), a visualization file and a combinatorial analysis file (allowing for the sensitivity analysis). The determination of Nash equilibria was conducted through a dedicated module, nashpy, which implements the algorithmic procedures for identifying both pure and mixed strategy equilibria. Supporting modules rely on standard scientific computing libraries, including NumPy for efficient array operations and Pandas for structured data handling. The visualisation of results was carried out using Matplotlib. To promote transparency and enable reproducibility, the complete source code will be made available in a public GitHub repository upon completion of the thesis, including a read_me file for further use by others in the hypergame field.

3.3 Data Collection and Interview Methods

To complement the formal modelling, qualitative data were collected through four semi-structured interviews with key stakeholders. These interviews provided contextual insights into the priorities and perceptions of different actor groups, serving both to ground assumptions used in the payoff structures and to enrich the interpretation of model results.

Interview selection and roles
Interviewees were deliberately chosen to reflect complementary perspectives: (1) a provider country representative, (2) a user country representative, (3) a DSI governance expert, and (4) a WIPO patent negotiator. This composition ensured inclusion of provider and user perspectives, a broader meta-level view, and a connection to parallel negotiations on intellectual property. Participants were recruited via email with guidance from the supervisor. While no claim of saturation can be made, the four interviews were deemed sufficient to capture diverse viewpoints relevant to the scope of this study and the combination with more formal modelling.

Practical details

Three interviews were conducted online via Microsoft Teams and lasted approximately one hour each. A fourth interview was conducted in written form, due to time constraints on the part of the interviewee. Interviews were held in English or Dutch, depending on the preference of the participant. Conversations were audio-recorded via a mobile device, manually transcribed by the author, and subsequently analysed to extract main insights. Relevant quotes are used throughout the thesis to support arguments and highlight specific observations.

Interview themes

Semi-structured interviews were chosen for this component of the research because they offer the flexibility to explore the multi-layered nature of international negotiations surrounding Digital Sequence Information (DSI). As Putnam's (1988) "two-level games" framework highlights, negotiators must balance international bargaining with domestic constraints, and subsequent scholarship has shown that these domestic arenas now include a diverse range of non-state actors (da Conceição-Heldt & Mello, 2017). By interviewing a representative of a provider country, a representative of a user country, a DSI governance expert, and a negotiator engaged in the patenting discussions at WIPO, the research aims to capture perspectives that span both state and non-state influences. The semi-structured format allowed for comparability across interviews while leaving room to probe specific themes such as perceptions of fairness, strategic misalignments, and the influence of scientific or commercial pressures, all of which are central to understanding the strategic landscape in which the hypergames are embedded.

In methodological terms, semi-structured interviews are well suited to examining complex governance processes because they combine structure with openness (Kvale & Brinkmann, 2009; Bryman, 2016). This ensures that core topics relevant to the hypergame analysis are consistently addressed, while still enabling respondents to introduce unanticipated but policy-relevant insights. In this thesis, the qualitative data generated by the interviews serve three main purposes: first, to inform where actors might realistically be located on the hypergame spectrum; second, to contextualize why certain equilibria or negotiation surprises emerge; and third, to enrich the policy implications of the analysis by highlighting the interplay between state strategies and broader stakeholder dynamics. In this way, semi- 46 structured interviews contribute not just descriptive accounts, but explanatory depth, grounding the theoretical modelling in the practical realities of DSI governance

No rigid question list was applied; instead, the interviews followed a semi-structured approach organized around key topics. These included: perspectives on DSI, institutional difficulties in governance, trust dynamics, provider–user relations, patenting challenges, links to the CALI Fund, and the involvement of the private sector. This ensured comparability while allowing flexibility to pursue contextual insights raised by each interviewee.

Ethics and data management

All participants provided written informed consent prior to the interviews, and verbal consent was confirmed again at the start of each session. Names and country affiliations were anonymised. Transcripts are securely stored on a drive under the supervision of TU Delft, in accordance with TU Delft Human Research Ethics Committee guidelines.

Validation

Validation was achieved through multiple strategies. First, sensitivity analysis tested the robustness of payoff assumptions. Second, triangulation with semi-structured interviews ensured that constructed payoffs reflected the effects of issues for real actors. Third, transparency of coding and documentation strengthens reproducibility, with data and scripts to be shared upon completion. Together, these measures support the reliability of insights while remaining clear about scope.

Table 1: Sub question linked to data source

Sub-Question	**Method**	**Data Sources**	**Validation**
SQ1: Strategies & payoffs	Literature review; qualitative interpretation; ordinal payoff construction	Policy/literature documents; theoretical frameworks; interviews	Sensitivity analysis; interview validation
SQ2: Asymmetric perceptions	Static hypergame modelling; equilibria computation	Python models; *nashpy*	Internal consistency checks; Sensitivity Analysis; scenario cataloguing
SQ3: Dynamics	Two-stage belief revision model; transition analysis	Model outputs (transition grids)	Logical consistency; comparison with qualitative cases
SQ4: Contextualization	Semi-structured interviews; thematic interpretation	4 anonymized interviews; triangulation with documents	Triangulation with modelling

4. Theoretical Foundations and Framing Dynamics

This chapter establishes the theoretical and conceptual foundation for analysing Digital Sequence Information (DSI) governance through a hypergame lens. It proceeds in four steps. First, it situates states as the central actors in the negotiations, outlining how the provider–user distinction, despite its limitations, captures the structural asymmetries that shape bargaining positions in the Convention on Biological Diversity (CBD). Second, it introduces the competing framings of DSI; open-access global commons (View 1), sovereign national resource (View 2), and hybrid compromise (View 3), it explores their strategic implications, particularly in relation to the Cali Fund. Third, it anchors these framings within the broader paradigms of International Relations theory; Realism, Liberalism, and Constructivism, demonstrating how each paradigm explains divergent state preferences and behaviours. Finally, the chapter links these framings and paradigms to the game-theoretic modelling framework used in later chapters, showing how misaligned perceptions generate strategic complexity.

4.1 Countries as actors in play

From both liberal and realist perspectives, states are the primary actors in international negotiations. In the context of Digital Sequence Information (DSI) governance, this implies that sovereign states, particularly the 196 parties (with 168 signatures) to the Convention on Biological Diversity (CBD), are the central players in the strategic interaction (Secretariat of the Convention on Biological Diversity, 2025). While all CBD member states formally participate in the negotiations, modelling each as an independent player within a hypergame-theoretic framework would lead to excessive analytical granularity, requiring extensive data that are neither available nor helpful to the aims of this study. A more structured approach is therefore adopted, grounded in interest-based typologies.

The central division in current policy discourse separates countries into 'providers' and 'users' of genetic resources, a distinction that maps loosely onto the broader developed–developing country divide. However, this binary classification has attracted criticism. As highlighted by Schulz et al. (2021), many DSI user countries primarily access genetic data derived from their own territories or via open repositories, challenging the assumption that users systematically exploit resources from provider states. Nevertheless, this critique overlooks the trajectory of global initiatives such as the Earth BioGenome Project, which aims to digitise the genomes of all known species (Earth Biogenome Project, 2022). Given that biodiversity is unevenly distributed, with the majority concentrated in the Global South (Fajinmolu et al., 2025). The future DSI repositories will increasingly rely on sequence data originating in developing countries.

Furthermore the critique, as raised by Scholz et al. (2021), concerns the observation that the majority of DSI uploads originate from institutions based in developed countries. On the surface, this appears to challenge the provider–user distinction by suggesting that so-called user countries are also the main contributors to global DSI repositories. However, this interpretation confuses the *act of uploading* with the *origin/provision of the genetic resource*. Due to infrastructural disparities, sequencing and data deposition often take place in high-income countries, even when the underlying biological samples are sourced from biodiversity-rich regions in the Global South (Villaca et al., 2024; Nehring et al., 2022). Compounding this issue is the fact that many DSI uploads omit critical metadata such as the country of origin (84% omits a country of origin), rendering it difficult to trace provenance accurately (Scholz et al., 2022). Rather than invalidating the provider-user distinction, this dynamic underscores its importance: countries with rich genetic resources often not only lack the capacity to use and analyse DSI data but also lack the capacity to sequence and upload their own biodiversity data, while technologically advanced (user) states dominate the sequencing and data-sharing infrastructure (Helmy et al., 2016). The critique of Scholz therefore highlights, not undermines, the asymmetries that the provider–user framing seeks to capture.

At the same time, not all developing countries are biologically rich or politically mobilised in DSI negotiations. The term 'provider', then, is better understood not as a synonym for ‘developing country’, but as denoting states with high biodiversity and limited domestic capacity to exploit DSI technologically or commercially. These countries typically face a structural asymmetry: they control valuable resources but lack the means to convert them into downstream innovations, themselves.

By contrast, 'user' countries, often developed nations, possess advanced bioinformatics infrastructure, R&D capabilities, and intellectual property regimes that enable them to translate DSI into patents, products, and profits.

These distinctions are institutionally mirrored in the negotiation groupings of the United Nations system. The provider bloc largely corresponds to the African Group, GRULAC, and the Asia-Pacific Group, whereas user countries are typically aligned under the EU and JUSCANZ umbrella. For instance the US, is a megadiverse country, and a global powerhouses in biotech (Martin et al., 2021). In even other cases states will occupy intermediate positions, or float somewhere in the middle of the two categories. Brazil and India, for instance, are both biodiversity-rich provider and are emerging biotech actors, contributing in the top five most productive institutions (Martin et al., 2021; WEF, 2024) . Such countries are likely to adopt ambivalent or bridging positions in the negotiations, reflecting both their resource ownership and growing technical capacity.

This also was reflected in the Interviews with a global north and a global south representative in the negotiation process.

“Yes, we operate as the EU within the CBD negotiations and often have support from North America and JUSCANZ. These are the developed, wealthier countries with which we generally share a similar position. On the other side, you see GRULAC, Africa, and Asian countries acting more collectively… Developing countries perceive an inequality: they feel that hardly any benefits are being shared and argue that developed countries, thanks to digital access, have an advantage. Therefore, they believe that compensation is necessary.”

USER REPRESENTATIVE (APPENDIX C.2)

“Well, there is always a general division between the Global North and the Global South, but the lines are not always clear-cut On one side, the African Union pushed for a stronger mechanism and greater control over data, including support for a single global database. On the other side, you had many countries from the Global North who opposed any kind of geographical tagging or centralised database.”

PROVIDER REPRESENTATIVE (APPENDIX C.1)

In light of these dynamics, this analysis adopts the provider–user distinction as its primary framing. Although imperfect, this dichotomy captures the fundamental asymmetry in capabilities and interests that underpins the politics of DSI and the current negotiation process. It is particularly suited to a forward-looking analysis: as the digitalisation of biodiversity accelerates, the stakes for equitable access and benefit-sharing will become even more salient. And the growth of information will likely have to come from new places, in other words developing countries. The provider–user framework thus offers a conceptually clear and analytically tractable basis for constructing the hypergame model of DSI negotiations.

4.2 The Frames in DSI

The global debate over Digital Sequence Information (DSI) governance revolves around three core framings (Bagley, 2022). This research primarily focuses on the strategic implications of two prominent, often competing, perspectives: DSI as a Global Knowledge Commons (View 1) and DSI as a Sovereign National Resource (View 2). The third, View 3, emerges as a pragmatic compromise that attempts to bridge these foundational differences.

4.2.1 View 1: DSI as an Open-Access Global Knowledge Commons

View 1 conceptualizes DSI as a non-material, open-access global public good. Proponents, often from developed countries and research communities, argue that imposing access and benefit-sharing (ABS) rules on DSI would impede innovation and conservation efforts (Bagley, 2020; Gaffney et al., 2020; Rohden & Scholz, 2022; Annex C.2 & C.3). This perspective emphasizes that DSI provides global non-monetary benefits that do not necessitate further sharing beyond open access, since they benefit all involved (Bagley, 2020). Open access to DSI fosters a global scientific ecosystem, accelerating innovation through cumulative effort and leading to societal returns such as faster vaccine development and improved agricultural resilience, which is already benefit sharing.

A global knowledge commons is "a shared, collectively governed resource of knowledge and information that spans national and disciplinary boundaries, is jointly used and maintained by a community of diverse stakeholders, and is vulnerable to social dilemmas such as enclosure, overuse, or underuse, particularly in the digital age." (Hess & Ostrom, 2006). In the case of view 1 the community would be the world, and the knowledge commons Digital Sequence Information in public databases.

Open access refers to the free, online availability of data, without financial, legal, or technical barriers (Suber, 2006). It removes *price barriers* by ensuring that content is accessible without subscription or payment, and it eliminates *permission barriers* by granting users the legal rights to use the data (Suber, 2006). Provider Countries would open up their resource in order to have access to the global databases, while user countries would upload DSI to public databases so everyone has access to it. In order for there to be a true global open access commons, the capacity would have to be built for the providers, under view 1 this could be done with voluntary help of the users.

> *"We, as a user country, also find non-monetary benefit-sharing extremely important for capacity building, through international collaboration in projects, exchanges, and similar initiatives. These forms of cooperation are often undervalued, but they are much more important for creating a more level playing field."*
>
> USER REPRESENTATIVE (APPENDIX C.2)

In this view both the provider and the user would then benefit from the access to the infrastructure they have together. With reduced or no transaction costs, and faster scientific progress as a result. In order for this to work, the benefit will flow to both provider and user countries to the sharing and making available of the products, the means to use the data, and the sharing and making available of the open access resource (DSI).

Implications for Actors under View 1*:*

- Provider Countries (aligned with V1): A provider choosing V1 openly shares its DSI in global repositories without restrictions, imposing no conditions like Prior Informed Consent (PIC) or Mutually Agreed Terms (MAT). It counts on the benefits to flow back through progress, and new products that will be available through the development of the data infrastructure.

- User Countries (aligned with V1): A user aligned with V1 gains rapid access to diverse datasets, accelerating innovation and maintaining long-term system efficiency. Crucially, user countries also treat derived products and databases as a global commons, refraining from extensive patenting and actively supporting capacity building for provider countries to ensure equitable participation and mutual progress.

4.2.2 View 2: DSI as a Sovereign National Resource

In contrast, View 2 posits DSI as a sovereign resource requiring compensation. This perspective argues that DSI falls within the definition of "genetic resources" and should therefore be subject to Access and Benefit Sharing (ABS), Prior informed consent and Mutually Agreed Terms requirements under the Nagoya Protocol. States adhering to View 2 prioritize sovereign control in the world of DSI governance. There are multiple ways in which countries can apply view 2.

The provider side

Prior Informed Consent (PIC) and Mutually Agreed Terms (MAT) are core principles of the Convention on Biological Diversity (CBD) and further elaborated in the Nagoya Protocol, where benefit-sharing is regulated for genetic resources (2011). PIC requires that a provider country explicitly authorizes access to its genetic resources in advance, based on full information about their intended use (Greiber et al., 2012). MAT are the negotiated conditions under which access is granted, including agreements on how benefits from the use of those resources will be shared fairly and equitably (Greiber et al., 2012).

A fact-checking study commissioned by the CBD found that countries adopt different strategies to ensure access and benefit-sharing (ABS) from the use of their digital sequence information (DSI), some focus on access while others focus on benefits (2020). Some explicitly incorporate DSI into their ABS frameworks by defining it in law as *genetic information*, *genetic heritage*, or *sequence information*, thereby requiring prior informed consent (PIC) and mutually agreed terms (MAT) for its use (CBD, 2020). Others interpret existing concepts such as *genetic resources*, *intangible components*, or *associated knowledge* to extend ABS obligations to DSI, often enforced through permits or contractual clauses (CBD, 2020). In addition to legislation, states may rely on permits, MAT, and Material Transfer Agreements (MTAs) to regulate access and impose conditions such as restrictions on sequencing, disclosure requirements, recognition of state rights in publications, or limits on commercialization (CBD, 2020). Brazil, requires registration of DSI-related activities and mandates monetary or non-monetary contributions once research leads to commercialization, while India and Malawi impose obligations case by case (CBD, 2020). Countries such as Peru, Costa Rica, and Kenya are developing monitoring systems, including digital tools to track patents and publications using their DSI (CBD, 2020).

All in all every country will have its own way of regulating sovereign ABS under view 2, leading to a plethora of potential regulations for users to take into consideration. Some of them requiring more transaction costs than others, but each difference making it harder and more difficult to use for the user countries (Sett et al., 2024).

The User side

On the other hand, not only provider countries have the option of asserting sovereign control over the development of DSI in the world. First of all User countries, as discussed before, also mostly upload the resource online (Scholz et al., 2023). They too have the option of closing off the use of the resource to other countries, in the same way as the provider countries. However, User countries operating (and their companies) under v2 may also treat the outcomes of the resource use as, their own sovereign resource.

A central factor shaping the practical consequences of each governance outcome is the structure of the global DSI database ecosystem, and the geopolitical control embedded within it. DSI flows through a multi-layered and highly interconnected data landscape. At its foundation lies the International Nucleotide Sequence Database Collaboration (INSDC), composed of GenBank (US), ENA (EU), and DDBJ (Japan) (Rouard et al., 2025). These repositories form a globally synchronised, open-access archive of nucleotide sequence data, which is essential for scientific transparency, reproducibility, and innovation. However, their governance and infrastructural control reside in US, EU, and Japanese institutions (Rouard et al., 2025). This means that, even under "open" access models, the Global North effectively controls the technical infrastructure through which much of the world's DSI is stored and distributed. Decisions about database standards, metadata, and future architecture thus remain in the hands of a few countries, regardless of where the data originate.

Around this core, more than 3,000 public databases further enrich DSI through curation, annotation, and integration (Rouard et al., 2025). These databases, mostly based in North America, Europe, and a few East Asian countries, depend on the INSDC for primary sequence data and typically exchange information openly. Beyond this public sphere, private and corporate databases often operate as "one-way" repositories, absorbing data from public sources but restricting reciprocal flows (Rouard et al., 2025). These private databases on the one hand, could increase through corporate workflows. Furthermore, the same form of one-way repositories, could start applying to the public databases, with more and more demands before access from provider countries is possible.

> *"I hope that most countries will see the databases as a public good. As governments, we co-finance it to some extent, and certain conditions will probably be attached."*
>
> USER REPRESENTATIVE (APPENDIX C.2)

Patents and Trade Secrets

The products that follow the use of the resource too, can be seen in a more sovereign way and a less sovereign way. The way these products are protected, defined or kept secret, is the domain of Intellectual Property rights. The legal protection of Digital Sequence Information (DSI) under current intellectual property (IP) regimes, especially patents, copyright, and trade secrets, is unclear and inconsistent (Seitz, 2020).

Patent law is different per country, but generally excludes natural discoveries like genetic sequences unless they are linked to a human-made invention (Seitz, 2020). Since the 2013 *Myriad* case in the U.S., naturally occurring DNA sequences are no longer patentable, synthetically altered do apply. The EU Biotechnology Directive allows some exceptions, such as gene sequences isolated from the body, but still requires novelty, inventive step, and industrial applicability (Seitz, 2020). While DNA sequences might be compared to software code or literary works, such protection is weak or untested in law, especially if the sequences reflect natural functions rather than human creativity. So companies under view 2 could keep the applications from DSI to themselves, and try to maximise profit, but they could not necessarily prevent the use of these sequences by other countries.

Yet this is where trade secret protection comes in to play for DSI, if the information is kept confidential. A trade secret is a form of intellectual property right that protects confidential business information which derives commercial value from not being publicly known (WIPO, 2025). To qualify as a trade secret, the information must be known only to a limited group of people, provide a competitive advantage, and be subject to reasonable efforts to maintain its secrecy, such as non-disclosure agreements and access controls (WIPO, 2025). Protection is typically grounded in national unfair competition law or specific legal provisions, and it prohibits unauthorized acquisition, disclosure, or use of the secret. However, independent discovery, reverse engineering, or parallel development of the same information by others is allowed (WIPO, 2025).

Once the data is in a public database, it cannot legally be made privatized trade secret again, yet many companies already have private (secret) databases (WIPO, 2025; Rouard et al., 2025). In view 2, user countries would not shy away from this, as it protects and improves the countries products as sovereign resources. The role of specific gene sequences in biotechnological inventions can be significant. If companies in user countries choose to protect these sequences or their applications through trade secret protection, rather than disclosing them via patents or public databases, they can strategically withhold key information. This approach allows them to maintain exclusive commercial control over the resulting innovations without triggering transparency or benefit-sharing obligations. As a result, provider countries face greater difficulty assessing the commercial value derived from their genetic resources, weakening their ability to monitor use and claim equitable benefits. In this way, trade secrecy can serve as a mechanism for user countries to limit their legal and ethical responsibilities, while maximizing their technological and economic advantage. As was also identified in an interview with a WIPO negotiator and patenting expert (Appendix C.4).

Implications for Actors under View 2:

- Provider Countries (aligned with V2): A provider choosing V2 restricts access to its DSI through domestic ABS laws, requiring PIC, MAT, or bilateral agreements, and storing DSI (partially) in national databases.
- User Countries (aligned with V2): A user aligned with V2 enforces control over downstream applications via patents, proprietary licensing, and closed databases. This perspective prioritizes securing intellectual property. And when the price for it is paid

4.2.3 The Relationship to View 3 and the Cali Fund: A Hybrid Compromise

While Views 1 and 2 represent distinct, often opposing, approaches, View 3 emerges as a hybrid compromise. It acknowledges DSI's origins in national biodiversity while simultaneously aiming for multilateral benefit-sharing and open access to Digital Sequence Information. View 3 explicitly argues that commercial use of DSI should involve monetary benefit-sharing, recognizing that non-monetary benefits alone do not fulfil Nagoya Protocol obligations

(Bagley, 2020). Essentially, View 3 synthesizes the open-access principles of View 1 with the sovereignty-based claims of View 2.

Cali fund

The establishment of the CALI Fund is (partially) how View 3 is taking shape in practice. The Cali Fund is a global fund adopted under the Convention on Biological Diversity (CBD) by Decision 16/2 during COP-16 in November 2024 and launched on 25th of February 2025 (CBD, 2025). It forms the monetary part of a multilateral mechanism for the fair and equitable sharing of benefits arising from the use of digital sequence information on genetic resources (DSI) (CBD, 2025). This mechanism aims to balance open access to DSI with benefit-sharing, particularly in support of biodiversity-rich and provider countries, including indigenous peoples and local communities (IPLCs) (CBD, 2024).

The following summary of the content of the Cali Fund or decision 16/2 is based directly on the source (CBD, 2024). Firstly, it is crucial to note that the CALI Fund currently functions as a voluntary mechanism. The decision is not made instead of national regulation but aims to co-exist with national regulation. This means that countries are not obligated to adhere to the decision, and that implementation or additional ABS measures are up to the country itself, in other words 'voluntary'. The main function of the fund is to on the one hand collect funding from users of DSI, while on the other hand distributing the funding towards developing countries and indigenous people. While the decision is agreed upon in principle, important aspects are still not decided or made clear.

Table 2: Ambiguities in the Cali Fund

Issue	**Details**
Contribution rate	Indicative rate of 1% of profit or 0.1% of revenue from DSI use. • Uncertainty remains over whether "revenue" means all revenue or only DSI-related revenue. • "DSI-related" itself is not yet fully defined.
Scope of companies	Not yet fully clear who exactly must contribute. • Sectors mentioned: pharmaceuticals, nutraceuticals, cosmetics, animal and plant breeding, biotechnology, sequencing equipment, AI-driven scientific services. • Companies must contribute if they directly or indirectly benefit from DSI in commercial activities. • Thresholds: entities exceeding two of three financial thresholds—USD 20m in assets, USD 50m in sales, USD 5m in profit (averaged over three years). • Conditions apply only if company activities involve DSI. • Final contribution rates, scope, and enforcement mechanisms will be decided at COP-17.

Issue	Details
Allocation of funds	Not yet fully defined. • Funding will primarily support developing countries, LDCs, SIDS, and economies in transition, aligned with national biodiversity strategies. • At least 50% of funds should support the self-identified needs of Indigenous Peoples and local communities, including women and youth, through government authorities or institutions they identify. • Funds may be disbursed through national entities (e.g., biodiversity funds) or international/regional entities, provided they meet financial governance and transparency standards. • Allocation formula still to be created, likely based on biodiversity richness, geographical origin of genetic resources, and capacity needs. • An Ad Hoc Technical Expert Group on Allocation Methodology will design the disbursement mechanism.
Transparency and tracking	Mechanisms for tracking DSI use by companies and ensuring transparency have not yet been addressed in the decision.

In summary, the Cali fund represents a multilateral mechanism with a lot of moving room and undecided factors that, when it works and countries and companies adhere to it, could allow open access to exist in harmony with regulated access and benefit sharing from the sovereign perspective. However, at the same time countries could still develop national policies regulating ABS through a 'view 2' sovereign manner and user countries could not report on used DSI, could not make it mandatory, or even not incentivize companies to contribute to the fund, signalling a more bilateral future. All pointing to the fact that the Cali Fund is a compromise between the views, as was also identified in the interviews (Annex C). The negotiations took over 30 extra hours to reach its current form, it does not clearly signal a view 1 future or clearly signal a view 2 future.

"There are still many ifs, ands and buts about the decision, as it is a compromise. Quite literally, everyone was at the table until deep into the night trying to get their specific point included. No one is truly happy with the outcome, but you could be even less happy. This is what was ultimately decided as a compromise."

USER REPRESENTATIVE (APPENDIX C.2)

The WIPO and the Connection to the Cali Fund

The same can be said for the reporting and trade secret part of DSI, although patents are a part of another treaty (a treaty is more binding then a decision) and WIPO, it is important to also mention this treaty for it shows the ability for provider and user countries to monitor or cover up use of DSI through trade secrecy and private databases. Just stating that some companies have to pay 1% without ever being able to know who the some are, could prove insufficient. To be able to see which part of the profits is made through what use of DSI is important. One way to do this, could be through patents. What follows is an analysis of the new treaty regarding patents and genetic resources, including DSI.

The WIPO Treaty on Intellectual Property, Genetic Resources and Associated Traditional Knowledge, adopted in Geneva on May 24, 2024, establishes a global disclosure requirement in the patent system concerning the use of genetic resources and associated traditional knowledge (Callo-Muller et al., 2024; WIPO, 2024). The treaty's aim is to improve transparency and the quality of patents by ensuring that when inventions are based on Genetic Resources or ATK, applicants must disclose the country of origin or source of the materials or knowledge used, if none of the information is known, a declaration must be made affirming that (Art. 3). If a patent thus uses DSI, it is based on genetic resources and should be reported.

However, the treaty, just like the Cali Fund, leaves several aspects open or ambiguous. It does not require patent offices to verify the accuracy of disclosures (Art. 3.5), which may limit its enforceability. Although Article 5 outlines sanctions and remedies, it does not allow the revoking of patents for failure to disclose, unless fraudulent intent is proven under national law (Art. 5.3–5.4). Enforcement, is thus again mostly a national endeavour, leaving room for countries to operate between view 1 and 2 to their liking. Additionally, disclosure applies only to applications filed after the treaty's entry into force.

Trade secrecy, through private databases, is thus still possible for companies, depending on National Legislation. Each contracting party to the treaty also, retains the freedom to implement the treaty's provisions according to their own national legal systems. Leaving them the room to couple it towards obligations in paying access and benefit or not.

How V1 and V2 Take Shape in V3:

The voluntary nature of the CALI Fund and the unresolved aspects mean that the fundamental tensions between View 1 and View 2 continue to play out within the framework of View 3.

- V1 elements in V3: Countries can choose to fully contribute to the CALI Fund, and open up their resource, thereby aligning with the open-access, global commons approach of View 1. This represents an actor opting into the multilateral, cooperative spirit.
- V2 elements in V3: Conversely, countries can choose to close off access and contributions to the CALI Fund, reflecting the sovereign control stance of View 2. This signifies an actor prioritizing national control and bilateralism over multilateral engagement.

Therefore, the dynamics modelled in the View 1 versus View 2 hypergames directly inform how strategic tensions and alignments might manifest under the hybrid regime of View 3. The outcome of View 3, and mechanisms like the CALI Fund, depends on whether actors' perceptions and strategic choices, influenced by their underlying liberal or realist paradigms, drive them towards contribution and multilateralism (aligning with V1) or towards withdrawal and bilateral control (aligning with V2).

4.3 Theoretical paradigms in International Relations

This section outlines three foundational paradigms in international relations, Realism, Liberalism, and Constructivism, to establish the analytical lens through which global negotiations over Digital Sequence Information (DSI) are examined. These paradigms offer distinct explanations for state behaviour, grounded respectively in power dynamics, institutional cooperation, and the social construction of interests. Realism emphasises relative power and strategic self-interest in an anarchic international system. Liberalism, by contrast, highlights the role of institutions, mutual benefit, and absolute gains in fostering cooperation. Constructivism moves beyond material interests to focus on how identities, norms, and perceptions shape state preferences and actions. By situating the DSI debate within these theoretical frameworks, this section provides the foundation for the hypergame analysis that follows. It is important to note that, these discussions of paradigms are in no means exhaustive, but aim to be explained sufficiently to be able to serve as lenses.

4.3.1 Realism as relative power

Realism grounds itself in the strive for power and selfish interests between states, in an international system shaped by anarchy. It has roots all the way back to Machiavelli and Thomas Hobbes, but has been most famously adapted by Morgenthau and later Waltz in International Relations theory. Morgenthau, and other classical realists, sought this in human nature's lust for power (Korab-Karpowicz, 2017). Waltz, sought it in the international structure of politics (Waltz, 1979; Korab-Karpowicz, 2017). In this thesis, the driving factor behind the motives is deemed off less importance, the thesis will follow Waltz's and Gilpin's story line in defining realism.

Structural realism, or neorealism, as developed by Kenneth Waltz in *Theory of International Politics* (1979), presents a foundational paradigm in international relations theory. Waltz's innovation lay in shifting the explanatory focus from human nature to the structural constraints imposed by the international system. As he argues, "the structure of the international system limits the cooperation of states" and compels them to act primarily in pursuit of their own survival and security (Waltz, 1979, p. 105).

In Waltz's theory, it is not merely the motives of states that lead to competition but the *structure* of the system itself. "Units (states) are distinguished by their capabilities, not their functions," and "the distribution of capabilities across units" determines the balance of power (Waltz, 1979, pp. 93–97). This leads to a tendency toward balance-of-power politics, even in technical fields like Digital Sequence Information (DSI), where scientific cooperation may be framed as neutral or benevolent, as the following quote highlights.

> *"Also, even if we wanted to adopt advanced technologies, where would we get the resources? Where would we get the necessary research kits? They would have to be bought in euros or dollars. This decision does not solve that issue directly, and we were realistic about that."*
>
> PROVIDER REPRESENTATIVE (APPENDIX C.1)

When applied to the global governance of DSI, structural realism offers a compelling explanation for the persistence of geopolitical tensions. Despite rhetorical commitments to open science or multilateralism, states that hold realist paradigms perceive DSI as a strategic resource that can augment or diminish national power. As such, they are disincentivized from accepting institutional arrangements that could expose them to relative disadvantage. This reflects Waltz's assertion that "states seek to ensure their survival; as a result, they aim to maximize relative gains, not absolute gains" (1979, p. 105).

From a realist perspective, as articulated by Robert Gilpin in *The Political Economy of International Relations* (1987), states seek dominance not only through military power but also through control of the political economy and technological advancement. Within realist theory, technological capacity and economical power constitute a strategic instrument of influence, enabling states to shape international structures and maintain advantages over rivals (Gilpin, 1987).

In practice, DSI is, thus, not a neutral input for research but a strategic asset in an emerging global contest over bioeconomic and technological dominance. States that possess the capacity to sequence, store, and analyse DSI can convert it into intellectual property, biotechnological products, regulatory power (Bagley, 2022; Appendix C.3 & 4). Patenting rights over DSI-derived and exclusive possession of innovations in biotechnology, particularly in pharmaceuticals, synthetic biology, and agricultural inputs, translate directly into economic inflows and geopolitical influence (CBD/WGDSI/2/2/Add.2/Rev.1, 2024; Rappert, 1996). As Capri (2025) documents, firms like 23andMe have licensed genomic data to pharmaceutical companies for hundreds of millions of dollars. This commercialisation pathway transforms DSI into a currency of strategic development, particularly for countries aiming to consolidate their technological edge. As was confirmed by an expert in a conducted interview.

"Genetic material is increasingly viewed as a strategic resource. Countries are becoming more aware of its value, and companies are becoming more dependent on it. As a result, both formal and informal cooperation can be observed between governments, companies, and research institutions."

EXPERT DSI GOVERNANCE (APPENDIX C.3)

Realist concerns extend beyond profit. Strategic asymmetries in data infrastructure and access allow a small group of states to dominate the global DSI architecture. Major repositories such as GenBank (United States), ENA (European Union) and the DDBJ (Japan) are hosted in high-income countries, giving them disproportionate influence over data governance and access protocols (Rouard et al., 2025). This infrastructural control can generate dependency: if a country or bloc controls the primary DSI platforms, others are forced to engage on their terms. In realist logic, such asymmetries are not accidents but instruments of power, levers that can be used in broader geopolitical bargaining (Gilpin, 1987).

Crucially, developments seem to emphasize that states value control over these data. In techno-nationalist systems such as China's, firms are required under national security laws to share all collected data with the state, blurring the line between public research and state intelligence (Capri, 2025). As highlighted by five Members of the European Parliament in a joint *Euroviews* article, Chinese genomics giants such as BGI and Mindray operate under the authority of China's National Intelligence Law, which compels them to share collected data with state agencies upon request (Lexmann et al., 2024). The authors explicitly warn that genetic data, much like energy, constitutes a strategic resource: "DNA data is the new gold," they write, noting China's ambition to dominate the genomics sector by 2049 through its national champions, BGI and MGI (Lexmann et al., 2024). It also emphasizes again that companies seem to be stuck in a grey zone, between the commercial market and in extreme cases the authority of the state (Capri, 2025). In this context, genomic infrastructure is not neutral. The members of the EU parliament even call for a shift from the EU's current "de-risking" posture to full decoupling in the genomics domain, mirroring realist prescriptions that prioritise autonomy, hard security, and control over foundational capabilities (Lexmann et al, 2024).

In 2024, both the United States and Canada significantly tightened their regulations on the international sharing of genomic and sensitive health data due to national security concerns. The US Congress passed the 'BIOSECURE Act', which prohibits federally funded agencies from procuring biotechnology equipment or services from "biotechnology companies of concern" and restricts the sharing of genomic data with “foreign adversaries” (including China, Russia, Iran, and North Korea) (Xue et al., 2024). The Act defines “biotechnology” broadly, encompassing sequencing platforms, PCR machines, and related analytical tools (Xue et al., 2024). Canada, while previously more cautious, introduced the ‘Policy on Sensitive Technology Research and Affiliations of Concern’ in May 2024 (Xue et al., 2024). This policy prohibits academic partnerships with foreign institutions deemed to pose a national security risk, especially in biotechnology and healthcare. It builds on Canada's National Security Guidelines for Research Partnerships, which had previously encouraged risk awareness but not named specific countries. Canada’s new stance, more aligned with the US approach, explicitly aims to shield sensitive genomic research from exploitation (Xue et al., 2024).

In both cases, the core logic of these restrictions is rooted in the protection of national interest and the mitigation of vulnerabilities. The United States’ ‘BIOSECURE Act’ and ‘Executive Order’, along with Canada’s ‘Sensitive Technology Policy’, treat health and genetic data not simply as useful information, but as strategic assets that could be exploited by adversarial states. The notion that genomic data constitutes a vector for geopolitical advantage, whether through technological dominance, bioweapon development, or discriminatory surveillance, is a distinctly realist framing. These measures reflect the perception that interdependence can generate relative losses in power, and that openness in scientific collaboration must be tuned down when it conflicts with sovereignty and security.

Provider countries face a strong disadvantage in the negotiations. Once they contribute DSI to a shared database, placed under control of User countries, they cannot revoke it, nor can they reliably enforce benefit-sharing. The non-rival and non-excludable nature of DSI means it can be endlessly reused by technologically capable actors without direct accountability to the origin state (Capri, 2025). This results in a diminishing pool of leverage: once the data is uploaded, the provider’s bargaining position erodes.

On the other hand, advances in synthetic biology and AI allow for the creation of modified or entirely synthetic genetic sequences that cannot be traced back to their original source (Sett et al., 2024). This undermines benefit-sharing if governance frameworks remain fragmented (Sett et al., 2024). Companies could bypass DSI obligations by synthesizing new sequences, such as optimized enzymes or vaccine components, that differ significantly from natural ones (Sett et al., 2024). Without harmonised global rules, synthetic DSI will escape jurisdictional claims, making benefit-sharing ineffective. So potentially waiting too long for provider countries, could lead to a loss of relative power too.

States are also motivated by relative scientific advancement, as became evident from the interviews (Appendix C.1 & 2). Scientific advancement and development is thought to lead to new technological innovations (capabilities), and economic influence (Jefferson et al., 2018). A relative gains approach would view scientific breakthroughs as not simply valued for their absolute developmental contribution but for their capacity to keep pace with or outpace geopolitical competitors. For such countries, the fear is not only exploitation, but irreversible exclusion, indicating that other actors will continue to extract value from shared DSI while they remain locked out of downstream innovation. In this sense, investment in scientific infrastructure is not merely a development goal but a strategic imperative to safeguard future relevance and reduce asymmetrical dependence.

Taken together, these concerns frame DSI as a contested resource in a world defined by strategic competition. States governed by realist logics will prioritise control, denial, and unilateral advantage over openness, equity or absolute benefit. This understanding of relative gain, infrastructural asymmetry, and long-term leverage will form the basis for interpreting the actions and preferences of actors with a realist paradigm in the hypergame scenarios that follow.

Table 3: Realism and Game Theory

Realist Principle	**Explanation**
Anarchy	The international system lacks a central authority, compelling states to act in self-help.
Power as Central Goal	States prioritise the accumulation and preservation of relative power for survival.
Relative Gains	States are concerned not just with their own gains, but how much more or less they gain relative to others.
Zero-sum Logic	A gain for one state is often seen as a loss for another, especially in security matters.

4.3.2 Liberalism as absolute progress and benefit

Liberal theories of international relations emphasize the potential for mutual gain, global cooperation, and institutional solutions to collective challenges. Scholarly liberal institutionalist theory, as articulated by Moravcsik, asserts that "the greater the mutual gains from social cooperation, the greater the incentives for political accommodation" through institutional framework. Moreover, Keohane's *After Hegemony* argues that multilateral institutions can sustain cooperation even in the absence of hegemonic power, one large state dominating the others (1984). In the governance of Digital Sequence Information (DSI), this perspective centres on the principle of absolute benefit: the idea that all states, regardless of power or capacity, can advance together through openness, knowledge sharing, and equitable systems of benefit redistribution.

Liberal approaches view DSI not as a resource to be controlled only for national advantage, but as a global liberal commons, whose open-access use can maximize economic and scientific value across borders (Paul, 2010). Open access to DSI fosters a global scientific ecosystem in which innovation accelerates through cumulative effort. Advocates highlight the substantial societal returns from this model: faster vaccine development, improved agricultural resilience, novel enzymes for green industrial processes, and more targeted responses to biodiversity threats. Sett et al. (2024) illustrate how vaccine platforms, cold-active enzymes, and plant disease resistance all depend on integrated, cross-border DSI access, none of which could be achieved through nationally siloed databases or bilateral legal agreements. In this sense, the true power of DSI emerges only when scientists can compare, combine, and reanalyse data from across species, geographies, and regulatory frameworks. Resulting in a higher absolute global benefit.

This cooperative vision is also economically persuasive. As highlighted in the CBD's commissioned estimates, sectors relying on DSI, such as pharmaceuticals, agricultural biotechnology, and industrial processing, generated more than USD 1.5 trillion in 2024, with projections exceeding USD 2.3 trillion by 2030 (CBD/WGDSI/2/2/Add.2/Rev.1, 2024). Bilateral benefit-sharing systems, in contrast, create friction: they are administratively burdensome and create uncertainty for cross-national research (Scholz et al., 2022; Sett et al., 2024).

The Liberal Knowledge Commons

One way to define the collective use of a resource by a group is through the commons. The tragedy of the commons describes a situation where individuals, acting in their own self-interest, overuse and deplete a shared resource, even though this outcome is harmful to everyone in the long run. Because no single actor bears the full cost of their actions, the resource is exploited unsustainably, leading to collective loss.

However, DSI is not a commons in the classical sense, it is a knowledge commons. In traditional commons (like fisheries or grazing land), the tragedy arises from overuse: individuals exploit a finite resource until it collapses. In knowledge commons, however, information is non-rivalrous, one person's use doesn't diminish another's in principle (Olstrom, 2007). The danger is not depletion but underproduction or enclosure. If knowledge is overly privatized then collaboration, innovation, and collective benefits are stifled. This has been termed a "tragedy of the anti-commons": too many overlapping rights and restrictions prevent effective use of information (Heller, 1998; Heller, 2013; Ghosh, 2007).

A long time, this tragedy was seen as the undeniable outcome of a non-privatised commons (Dagan & Heller, 2000). However, in 'Governance of the commons' Olstrom sets out rules for the use of a commons, and explains how it can work and how it has worked in local communities. She identified design principles for successful commons governance, that build on strong internal rules, trust and shared norms, limiting exit and exclusion of outsiders (Olstrom, 1990). However, Olstrom's approach is based upon communitarianism, and possesses no right to exit, nor the right to enter for all based on individual will (Dagan & Heller, 2000).

The liberal commons builds further on the commons that was set a part by Olstrom in 1990. It builds on strong internal rules, trust and shared norms, limiting exit and excluding outsiders. A liberal commons, as defined by is an institutional arrangement that combines the cooperative benefits of shared resource use with the liberal value of individual autonomy (Dagan & Heller, 2000). It enables a bounded group to jointly manage and benefit from a resource while guaranteeing members a secure right to exit. Unlike traditional commons, which may restrict liberty, and private property, which undermines cooperation, the liberal commons seeks to reconcile both goals through law, institutional design and trust (Dagan & Heller, 2000).

Back to Digital Sequence Information

In the context of digital sequence information (DSI), a liberal commons is a governance framework that preserves open, cooperative access to genetic data while ensuring that provider countries and participants retain autonomy, credible exit options, and equitable opportunities to benefit. It treats DSI as a shared global resource whose value is maximized through unrestricted scientific use, but whose legitimacy depends on behaviour and institutional safeguards that guarantee inclusive participation and benefit redistribution.

While liberal countries value openness and cooperation, they do not do so unconditionally (Dagan & Heller, 2000; Moravcsik, 1987). Absolute gain does not mean unilateral concession. Liberal countries seek tangible returns for their participation in the global DSI ecosystem, whether through scientific partnerships, technological access, or commercial revenue. Their motivation is not to enrich others at their own expense, but to develop alongside the rest of the world. If open access leads to the unchecked appropriation of Digital Sequence Information, such as through one-sided patenting, non-attributed data use, or unreciprocated technological extraction, liberal actors in this research will view the system as illegitimate.

"We are not asking anyone to stop doing research or innovation. We just want the process to generate benefits for both sides. Before, we got nothing..... When we agree to share resources, we are effectively giving up some control, especially administrative control. In any international agreement, there is always a degree of lost sovereignty. If we are asked to simply give away our regulatory control, we expect clear benefits in return. Without that, where is the incentive to cooperate?"

PROVIDER REPRESENTATIVE (APPENDIX C.1)

Liberalism is not about being exploited; it is about entering institutions where shared progress is credible, verifiable, and mutually reinforcing (Dagan & Heller, 2000; Moravcsik, 1987). For provider countries, this includes capacity building, equitable participation in R&D, and assurance that benefits, both monetary and non-monetary, flow back in ways that support their long-term development. The liberal vision of DSI governance thus depends not only on open data, but on institutional safeguards and trust that ensure openness leads to enduring, inclusive growth.

Table 4: Liberalism

Liberal Principle	**Explanation**
Non-zero-sum Logic	States can achieve absolute gains; mutual cooperation may benefit all parties, even if unequally.
Trust and Reciprocity	Repeated interactions build trust and foster cooperation, reducing incentives to defect.
Institutions Matter	International institutions facilitate cooperation by reducing uncertainty, enforcing agreements, and sharing information.
Absolute Gains	States focus on increasing their own welfare, rather than comparing relative power with others.
Interdependence	States are economically and politically interconnected, making unilateral defection costly.
Rules and Norms	Institutionalised norms constrain behaviour and promote predictable outcomes.

4.3.3 Constructivism

Beyond the material and interest-driven logics of Realism and Liberalism, Constructivism offers a crucial third lens, positing that "anarchy is what states make of it" (Waltz, 1992). This paradigm emphasizes that the fundamental structures of international politics are social, rather than strictly material (Wendt, 1992). It argues that states' identities, interests, and perceptions are not fixed, but are instead shaped by their interactions, shared ideas, and prevailing norms (Wendt, 1992). In this view, how states think about each other and the international system directly influences how they act and how they will change their views.

In the context of DSI governance, this means that even if certain states possess inherent liberal or realist tendencies, their actual behaviour in negotiations is also influenced by their interpretations of the situation and their counterparts' motives. As Ruzicka and Keating (2015) observe, trust in international relations is often discursively constructed. States may strategically employ the language of cooperation to signal identity alignment or institutional legitimacy, even if their underlying strategic interests diverge. This supports the constructivist claim that framing is not merely expressive, but performative, actively shaping how policies are perceived and enacted.

This thesis integrates Constructivism by exploring how countries, acting according to their perceived Liberal or Realist paradigms, interact with each other in the DSI governance landscape. The hypergame framework, by explicitly modelling these asymmetric perceptions, allows us to analyse how states' constructed realities, their beliefs about themselves and their opponents, influence their strategic choices and, ultimately, the collective outcomes. This approach reveals how states, through their interpretive lenses, "make" their own anarchic (or cooperative) reality in the DSI commons.

The research systematically explores all sixteen possible configurations arising from the intersection of framing choices and paradigm beliefs across both actors, structured into four core games: Liberal–Liberal, Liberal–Realist, Realist–Liberal, and Realist–Realist. How this is operated and modelled in the research will be explained in the following Methodology section.

Crucially, countries operating under a Realist paradigm may interact with countries following a Liberal paradigm, and each may hold divergent beliefs about the other's true underlying paradigm. These varied perceptions, combined with their chosen DSI framings, collectively shape the 'combined reality' of their strategic interaction. This approach allows for a deeper understanding of how misaligned perceptions of underlying motives can lead to outcomes that might seem unexpected or suboptimal from a single, objective viewpoint

Table 5: Liberalism vs. Realism

Dimension	**Liberalism**	**Realism**
Core Logic	Non-zero-sum cooperation is possible under the right institutional conditions.	Politics is a zero-sum game driven by self-interest and survival.

Dimension	Liberalism	Realism
View of Cooperation	Cooperation can be sustained through trust, reciprocity, and institutions.	Cooperation is temporary and fragile; self-help dominates.
Role of Institutions	Institutions reduce uncertainty, enforce rules, and facilitate cooperation.	Institutions have limited impact; states act based on power, not rules.
Assumption of Rationality	Actors are rational but capable of learning, trusting, and building regimes.	Actors are rational, power-maximising, and distrustful.
Power Concern	Focus on **absolute gains;** how much all parties benefit.	Focus on **relative gains;** how one's gains compare to others'.
Trust	Possible and desirable, especially when institutions lower transaction costs.	Naïve and dangerous; leads to vulnerability in anarchic systems.

5. The Hypergame Framework

This section introduces the analytical framework used to model strategic interactions in Digital Sequence Information (DSI) governance, with a particular focus on bounded rationality, divergent perceptions, and evolving belief systems. Drawing on theories of resource dependency and game theory, it first outlines why strategic interdependence matters in policy settings where outcomes are jointly determined by multiple actors with partially conflicting interests. The section then presents hypergame theory as a methodological extension capable of capturing asymmetries in perception and strategic framing. In this research, hypergames are applied to model how states with differing paradigms, Realist or Liberal, engage in negotiations over DSI, shaping both their own preferences and beliefs about their counterparts. The section also explains how framing choices and belief updates are operationalised in the model, and how these interactions are analysed through three payoff matrices per game. Finally, the approach is situated within real-world governance by incorporating a the broader context through semi-structured interviews, that bridges open-access and sovereign-resource logics, and by integrating insights from non-state actors through interview-based contextualisation. Together, these elements provide a structured yet flexible method for exploring the strategic dilemmas and potential pathways in the evolving global governance of DSI.

5.1 A Simple Game for Clarification

The following part is for the reader that is relatively new in game theory it is based on Osborne & Rubinstein's 'A course in game theory' (1994). Definitions stem from this book and the first explanation is loosely based on their first explanation. The figures, are the work of the author.

The Normal form of a game takes the shape of a matrix, referring to combination of choices of actors. In the following figure x, an explanation of what means what will follow.

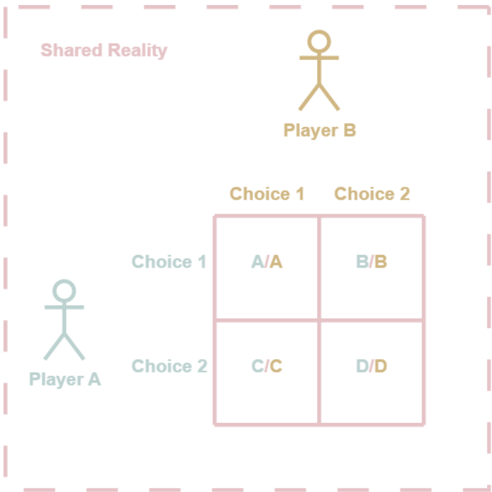

Figure 1: A Normal Game

The first element of game theory is the players, there need to be at least two cognitive agents that try to base their choices on the outcome they desire the most, in order for game theory to be able to be explanatory. Which brings into play the second important element of game theory, the choices players are able to make. There need to be at least two choices, in order for strategic rationality through game theory to make a difference, if there is no choice there is no dependence and thus nothing to analyse.

The third element is the payoffs players grant to outcomes of combination of choices, in our simple game the combination of Choice 1 by player A and Choice 2 by player B Leads to a payoff of A for player A and a payoff of A for player B. A in this case could mean anything and could represent different numbers for both players. There are different ways to use payoffs, they can represent absolute values of something, such as an amount of money that is being made in a certain outcome or the amount of time that is spent doing an activity, it could even be a combination of the two or a school grade. Another way to use payoffs in game theory is by ordinally ranking the outcomes, in this case we would have four outcomes so we would rank them 1 through 4, with four the highest and 1 the lowest, or the other way around it depends on the modellers choice.

Game theory then tries to predict the rational outcome(s) of a game through the calculation of differing equilibria and through using the players as rational vehicles trying to make the optimal decision in these strategic dependent situations. Two concepts are especially of importance and have played a big part in the analysis of games in game theory.

- **Pareto optimality** refers to a situation where it is impossible to make someone better off without making someone else worse off (Osborn & Rubinstein, 1994). So imagine player A, thinks equilibrium choice 1, choice 1 is better then all the other equilibria, then it would be pareto optimal even if player B thinks it is the worst outcome.
- **Nash equilibrium** is a set of strategies, one for each player in a strategic (non-cooperative) game, such that no player has an incentive to unilaterally change their strategy, assuming all other players keep their strategies unchanged (Osborn & Rubinstein, 1994). In other words, each player is making the best decision they can, taking into account the decisions of the others. No player can gain a better outcome by changing only their own strategy.

5.2 Resource dependency

Many are instinctively put off by the language of game theory, so it is important to clarify from the outset that the term "game" does not imply an actual game, it can refer to life and serious matters. In this context, a game refers to a situation involving two or more actors or 'players' whose decisions jointly shape the outcome, each pursuing their own goals (Bennet, 1995). These interdependent decision settings pose distinctive challenges for both decision-makers and analysts.

Resource dependency drives strategic interactions between actors. Theories of resource dependency explain how organizations respond to complex and uncertain environments. The decisions of individual actors produce shared outcomes, positive or negative, which, in turn, deepen the interdependencies among organizations and between an organization and its broader environment (Hermans et al., 2018). No single actor has full control over the outcome. Instead, each must anticipate and respond to the choices of others (Bennet, 1995).

For example, actor 1's preferred course of action may depend on what actor 2 does, and vice versa. If both actors are aware of this interdependence, they will not only try to predict each other's behaviour, but also attempt to influence it.

The result is a strategic setting where decisions are made in anticipation of others, and outcomes emerge from these mutual adjustments (Hermans et al., 2018; Bennet, 1995). This dynamic also gives rise to threats, bluffing, and strategic deception, however, in most situations, interests diverge only partially. There is almost always some scope for joint gains or shared benefits, if not through full cooperation, then at least by managing the conflict within bounds (Bennet, 1995). Strategic interaction is thus not only about conflict, but also about cooperation and collaborative advantage (Huxham & Macdonald, 1992). Promises, commitments, and trust matter alongside threats and bargaining. In cases of partial interest divergence, conflict and cooperation are not opposites, they are intertwined and must be analysed together (Lax & Sebenius, 1986).

5.3 Limits and focus

A big proportion of game theory has focussed on identifying the analysis of the rationally best choice out of many options in a mathematically optimal way (Hermans, 2014:Bennet, 1995). An alternative perspective views models not as tools for prescribing optimal solutions, but as instruments for clarifying the underlying structure of complex situations, including their dilemmas and trade-offs (Osborne & Rubinstein, 1994). Game theory provides a structured approach to analysing strategic interactions among multiple actors, making it particularly useful for evaluating policy dilemmas where governance depends on interdependent decisions (Hermans et al., 2018). The goal is to enhance understanding of the decisions actors face, the interdependencies among their choices, and the strategic tools they may use such as threats, promises, negotiation, or communication to advance their interests. Hermans et al. (2014) emphasize that game theory is particularly valuable for unpacking the "black box" of policy implementation, as it can explain why seemingly cooperative policies fail due to strategic shifts, hidden incentives, and evolving power dynamics. This approach does not abandon rational analysis, but applies it with more modest expectations (Bennet, 1995). By recognizing the legitimacy of multiple outcomes, it enables analysts to trace how different conclusions are supported by distinct lines of reasoning.

However, when analysing specific conflicts, the descriptive limitations of simple game models are well documented. Even setting aside debates about the plausibility of their assumptions, such as those concerning actor preferences, their structure often fails to capture key dimensions known to influence real decisions (Bennet, 1995; Osborne & Rubinstein, 1994). These missing elements can be grouped into four categories:

- Differing perceptions: Key actors may operate with fundamentally different understandings of the situation.
- Dynamics: The sequence and timing of decisions, as well as evolving preferences, capabilities, or perceptions, often shape outcomes.
- Combinatorial complexity: Each actor may face a wide array of interdependent choices, compounded by the presence of multiple players.
- Linked issues: Strategic choices are often embedded in broader negotiations across multiple issues, involving overlapping arenas such as alliances, governments, and committees.

All of these will try to be accounted for in the following research, through the following methods, however some limitations will remain. namely:

- Differing perceptions: Will be adjusted for using the concept of hypergames and differing metatheories about actors and their perspectives on the world. Which will be further clarified in the following paragraph.
- Dynamics: Will be accounted for by creating a two stage game, that aims to take into account future developments in the field of DSI. Opting for a beginning stage in the development of DSI, in other words referring to the state as it is now and a later stage in the development.
- Linked Issues: Will be accounted for by contextualizing the games and referring to the possible interactions between the state, the private actors and other intergovernmental negotiations. By not only focussing on the international negotiation but also on possible strategic dilemma's concurring on national levels between countries, companies and regulators.
- Regarding combinatorial complexity, this research will rely on simplified models that constrain the number of choices available to actors. While this approach reduces realism, it is justified by the study's primary objective: to illustrate strategic behaviour, identify potential dilemmas, and explore plausible future developments under uncertainty. The simplification is considered acceptable provided the research is not interpreted as predictive, but rather as an exploratory tool for understanding strategic dynamics.

Eductive versus Evolutive Game Theory

To fully clarify the analytical posture of this research, it is of use to distinguish between two modes of game theoretic analysis: the *eductive* and the *evolutive*. This distinction, articulated, among others, by game theorist Ken Binmore (1987), separates analyses based on how actors are presumed to reach an outcome (equilibrium). This thesis adopts an eductive approach.

An eductive analysis assumes that an outcome (equilibrium) is achieved through a process of deliberate and careful reasoning (Binmore, 1987 ; Osborne & Rubinstein, 1994). Actors are not simply stumbling on in the dark; they are sophisticated agents who engage in introspection and attempt to simulate the reasoning processes of their counterparts. The core of an eductive process lies in belief formation and revision: "if I think that you think that I think..." becomes a central dynamic (Binmore, 1987). Binmore argues that perfect rationality is unattainable in such situations due to computational limits and self-referential reasoning (an infinite loop of "if I think that you think that I think..."). He critiques the Bayesian (normal) approach for assuming arbitrary prior beliefs, instead emphasising the need to model how beliefs (or stop mechanisms in computers) are formed through structured reasoning (1987). This mode of analysis is thus suited for the understanding of a high-stakes negotiations among a small number of strategic actors, where decisions are shaped by perception of the other and the anticipation of future moves.

The hypergame framework, which will be thoroughly explained in the following part, employed in this thesis is, by its nature, an eductive tool. It formalises and aims to internalize the very process of reasoning under uncertainty and asymmetric perception, that players face. By modelling actors with distinct IR paradigms (Liberal vs. Realist), allowing them to hold beliefs about each other and to revise beliefs through strategic surprise, the model operationalises the introspective logic at the heart of eductive theory.

In contrast, an evolutive analysis posits that equilibrium emerges from a process of adaptation and trial-and-error over many iterations (Binmore, 1987). It is typically applied to scenarios involving large populations of less sophisticated actors whose strategies are "weeded out" over time through competitive pressure. Such a framework might be appropriate for modelling market dynamics or biological competition, making it more suitable for the analysis of global DSI development through for instance market development for businesses. However, the state actors involved are (arguably) not engaging in a repetitive, low-stakes game; they are making calculated, path-dependent decisions in a complex political environment. Their strategies in negotiation are (at least partially) the product of conscious deliberation, historical context, and geopolitical calculation.

The choice of an eductive framework allows the analysis to move beyond simple payoff optimisation and to explore the procedural aspects of rationality: how actors construct their understanding of the strategic landscape, how misperceptions might lead to suboptimal outcomes, and how beliefs matter and evolve in response to interaction.

5.4 Hypergames and the use of metatheories:

This brings us to a particular type of game theory which will be applied in this research, although in a slightly novel way, called a hypergame. A hypergame is built upon the concept of bounded rationality (Bennet et al., 1977; Kovach et al., 2015). Bounded rationality refers to the idea that a player's ability to make fully rational decisions is constrained by limited information, cognitive capacity, and time (Simon, 1990). Introduced by Herbert Simon as a refinement of classical decision-making models, bounded rationality accounts for why players in game theory or decision theory may not always choose the optimal strategy. This concept does not imply irrationality; rather, it acknowledges that players aim to act rationally but are restricted by their mental and informational limitations (Kovach et al., 2015 ; Simon, 1990). True rationality would require infinite cognitive resources, like the earlier example by Binmore suggested with the two supercomputers, something real-world actors do not possess (1987). Instead, players rely on the information at hand, their available cognitive resources, and often face time pressures, making decisions that are rational within those bounds (Simon, 1990; Binmore, 1987). Schelling introduced the concept of focal points (now often called *Schelling points*) to explain how actors can coordinate in such situations where multiple rational equilibria exist. A focal point is a solution that stands out as natural, special, or salient to the players, enabling them to converge on the same choice simply because each expects the other to do so (Schelling, 1960). Different players may view different focal points as natural, arriving at different conclusions about the same situation, reflecting their distinct perceptions of the game or environment.

Hypergame theory breaks down a single strategic interaction into multiple perceived games, allowing analysts to reason across these varying perspectives to better understand and potentially improve outcomes (Kovach et al., 2015). Each player forms a belief not only about the structure of the game but also about how others perceive the available actions and preferences. Bryant further emphasized that the perceived set of players can differ among actors, reflecting real-world divergences in awareness and interpretation (1984). In a hypergame, each player may thus operate based on a distinct understanding of who is involved, what options are available, and what outcomes are preferred. Leading to potentially completely different payoff and outcome matrixes for both players, this asymmetrical situation might lead to potentially surprising outcomes and equilibria for both players, that might seem irrational on a first glance.

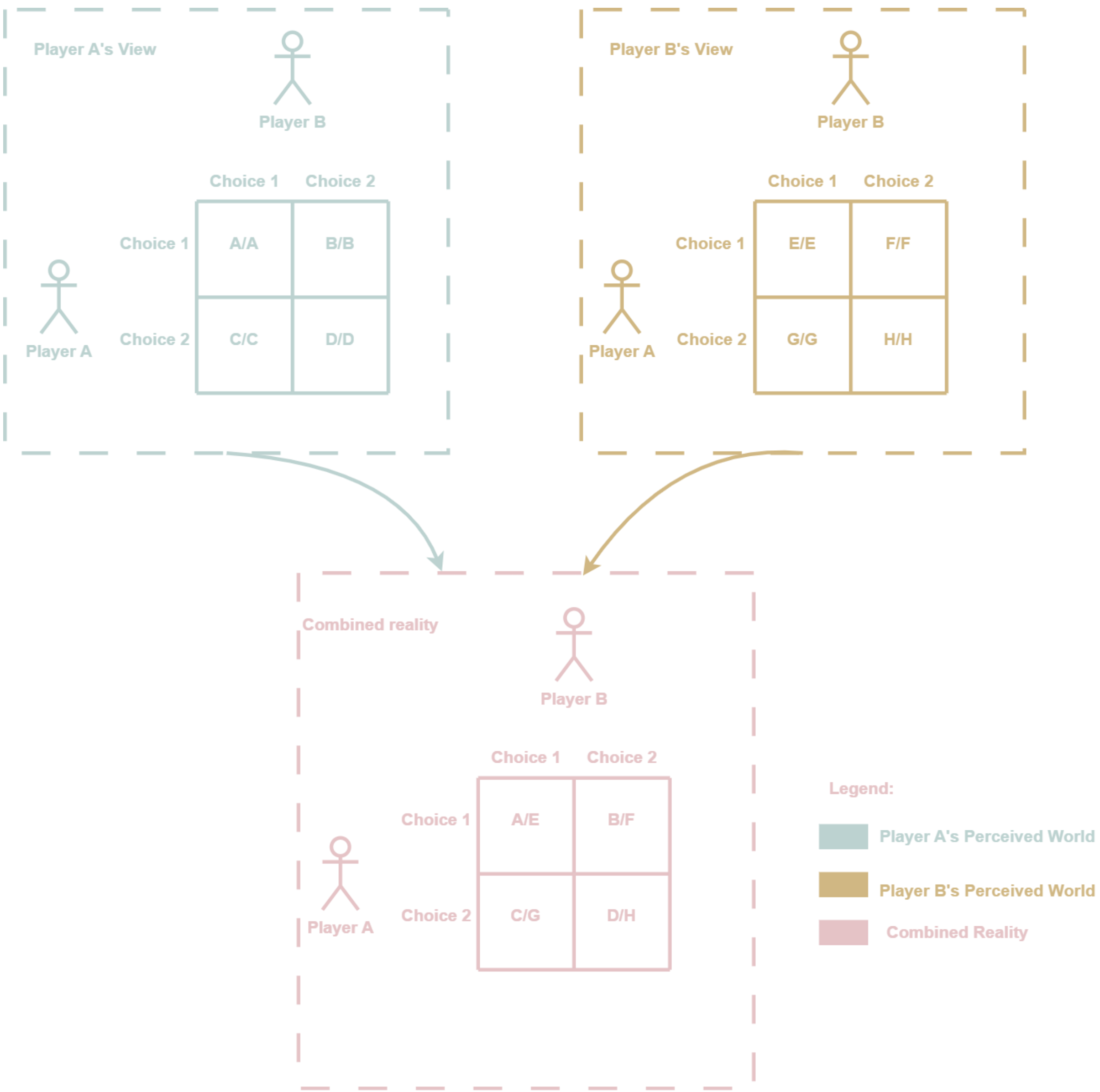

Figure 2: A Hypergame

This diagram illustrates the core difference between a normal game and a hypergame. In a normal game both actors see the combined reality fully, they see only the pink part of the diagram. Because, all actors share the same understanding of the situation, they operate using a common outcome model, with their decisions based on agreed actions and predictable results. Both players know the rules, the available strategies, and the likely outcomes, leading to clear and aligned decision-making. In contrast, a hypergame captures situations where actors perceive the game differently. Each player acts based on their own version of reality, using distinct perceived models to guide their decisions, in other words, the blue and the brown part. While they engage in the same objective environment, their interpretations of the rules, strategies, or goals diverge. This mismatch in perception can lead to unexpected strategies, misunderstandings, and outcomes that traditional game theory cannot anticipate, as they can both not see the combined reality.

This distinction highlights why hypergame theory is useful for analysing complex negotiations like those surrounding DSI governance. Unlike classical game theory, which assumes actors have correct and shared knowledge of each other's motivations, hypergame theory accounts for perception errors and the strategic consequences of misjudging the opponent's paradigm. By modelling these dynamics, this research can better explore how misunderstanding and framing contests affect international cooperation, fairness, and long-term governance outcomes, through bounded rational choice.

In this research the overarching views of what they value and what they think the other values, will also be incorporated. The paradigms, Liberalism and Realism, will define what the actors prefer and what they believe the other will prefer. A hypergame as used in this research will, thus, look like the following figure x.

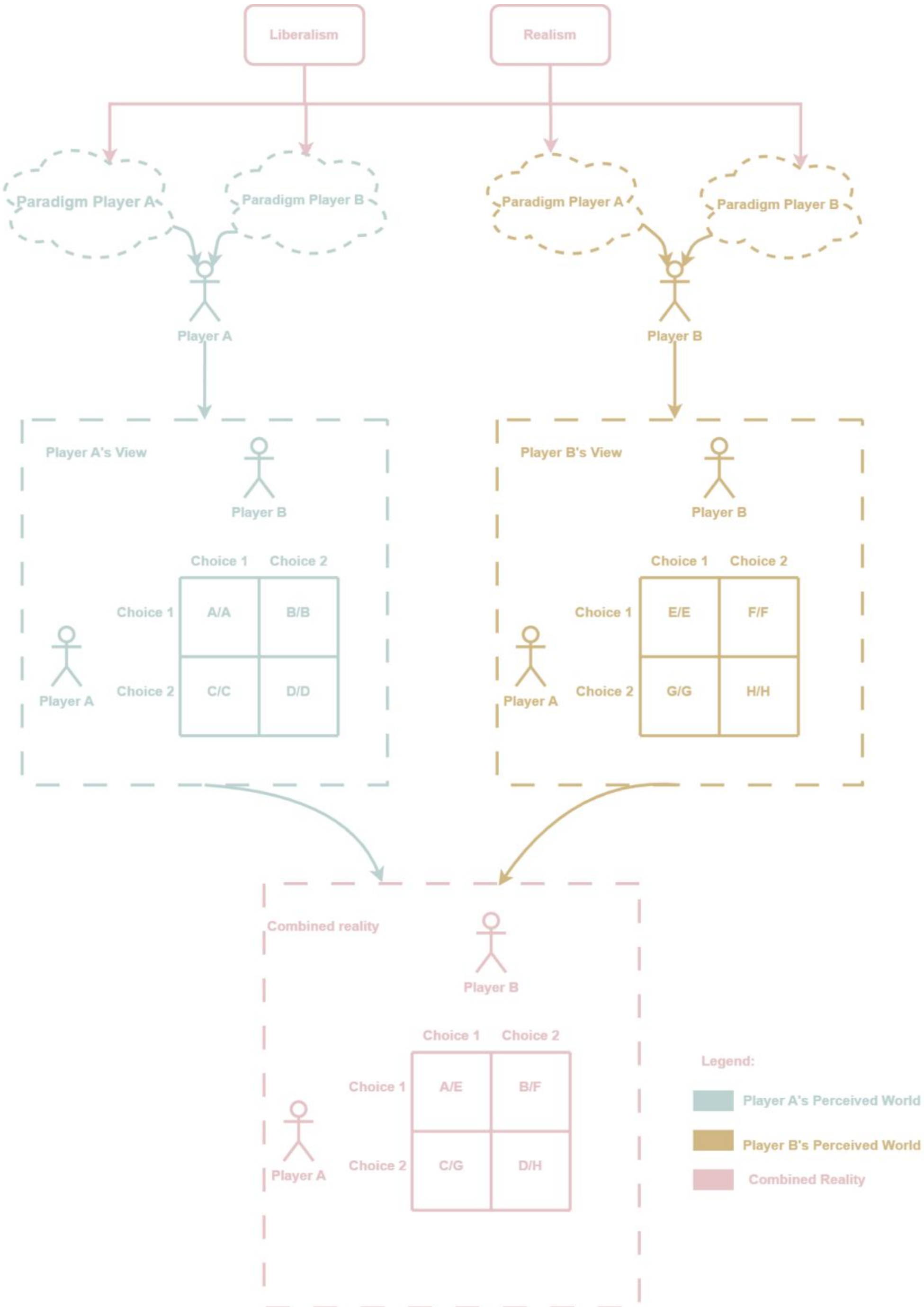

Figure 3: A hypergame Fuelled by paradigms (Own Work, 2025)

5.5 More than one hypergame

To be more specific, this research models strategic interactions in DSI governance as a series of hypergames, where actors engage not only through material choices but also through framing strategies and belief systems. In this design, each actor's primary decision variable is how they frame Digital Sequence Information (DSI) within the Cali Fund, whether to present and act in a View 1 manner (a global open-access knowledge commons) or View 2 (a sovereign resource requiring compensation). This choice serves as a strategic signal and action, intended to shape the expectations and responses of other actors.

However, actors operate under conditions of bounded rationality and incomplete information. Each forms a belief regarding the underlying paradigm, liberal or realist, that motivates the other party. This belief determines how an actor interprets the opponent's framing choice and how it constructs the payoff matrix. For example, if an actor perceives its counterpart to follow a realist paradigm, it may distrust cooperative signals and anticipate opportunistic behaviour, even if the counterpart frames DSI as open access. Conversely, if it assumes a liberal counterpart, cooperative framings are likely to be taken at face value, fostering trust-based strategies.

The combination of (1) framing as a deliberate strategic move, (2) paradigm belief as a cognitive lens, and (3) payoff structures shaped by both, creates a hypergame environment characterised by asymmetric perceptions, potential misalignment, and strategic deception. The model systematically explores all sixteen possible configurations arising from the intersection of framing choices and paradigm beliefs across both actors, structured into four core games: Liberal–Liberal, Liberal–Realist, Realist–Liberal, and Realist–Realist.

Table 6: Setup of the Experiments

Game Names	**Provider's Perceived Game**	**User's Perceived Game**	**Interaction Type**
G1	Liberal – Liberal	Liberal – Liberal	**Game**
G1-G2	Liberal – Liberal	Liberal – Realist	Hypergame
G1-G3	Liberal – Liberal	Realist – Liberal	Hypergame
G1-G4	Liberal – Liberal	Realist – Realist	Hypergame
G2-G1	Liberal – Realist	Liberal – Liberal	Hypergame
G2	Liberal – Realist	Liberal – Realist	**Game**
G2-G3	Liberal – Realist	Realist – Liberal	Hypergame
G2-G4	Liberal – Realist	Realist – Realist	Hypergame
G3-G1	Realist – Liberal	Liberal – Liberal	Hypergame
G3-G2	Realist – Liberal	Liberal – Realist	Hypergame
G3	Realist – Liberal	Realist – Liberal	**Game**
G3-G4	Realist – Liberal	Realist – Realist	Hypergame

G4-G1	Realist – Realist	Liberal – Liberal	Hypergame
G4-G2	Realist – Realist	Liberal – Realist	Hypergame
G4-G3	Realist – Realist	Realist – Liberal	Hypergame
G4	Realist – Realist	Realist – Realist	**Game**

5.6 Dynamics of belief

To capture the evolution of strategic behaviour, the hypergames are analysed dynamically, allowing for the possibility of belief updates, learning, or entrenchment of misperceptions over time. This dynamic approach aims to reflect the real-world more where actors might adjust strategies based on observed actions, institutional developments, or shifts in geopolitical context.

In the repeated hypergame framework, agents engage in a series of interactions where each encounter is based on their own subjective view of the game, rather than on an objective, one-shot scenario (Sasaki et al, 2014). Each round, or hypergame, results in a hyper Nash equilibrium, and agents only modify their views when an outcome conflicts sharply with their expectations, what is termed cognitive dissonance. If such dissonance is never encountered, their subjective views remain unchanged, leading to a stationary state where the hypergame persists. The mechanism is akin to the falsificationist approach in science, where a theory holds until it is disproven by evidence, suggesting that an agent's perspective endures as an unfalsified hypothesis based on past experiences (Sasaki et al., 2014).

A static hypergame analysis reveals potential misalignments, but a dynamic model requires a mechanism for evolution. In this model, the catalyst for change is strategic surprise. A surprise occurs when an actor observes a counterpart's move inconsistent with the expected rational outcomes derived from the pure-strategy Nash equilibria of the game they perceive. The core assumption is that actors treat each other as rational. Therefore, an unexpected move is interpreted not as irrationality, but as evidence that the player's perception of the opponent's paradigm was flawed. This surprise triggers a process of belief revision.

The model implements a specific and conservative belief revision rule: an actor, when surprised, maintains their own core paradigm but revises their belief about their opponent's paradigm. This reflects a cognitive bias where one's own worldview is considered stable, and contradictory evidence re-evaluates others rather than oneself. This rule is implemented as follows:

- **Maintain Self-Paradigm**: The actor's own paradigm (Liberal or Realist) remains unchanged.
- **Flip Opponent-Paradigm**: The actor's perception of the opponent's paradigm is inverted (e.g., a perceived Liberal becomes a perceived Realist).

This shift in perception fundamentally alters the game the actor believes they are in, leading to a new payoff matrix for the next round of interaction. For instance:

- If a provider in G1 (Liberal-Liberal) is surprised by the user's move, their belief transitions from G1 to G2 (Liberal-Realist).

- If a user in G3 (Realist-Liberal) is surprised by the provider's move, their belief transitions from G3 to G1 (Liberal-Liberal).

When these individual revisions occur, the entire hypergame transitions. If both actors are surprised simultaneously in a G1-G3 hypergame, the system evolves to a new G2-G1 state for the subsequent round.

5.7 Example Analyses of a Hypergame

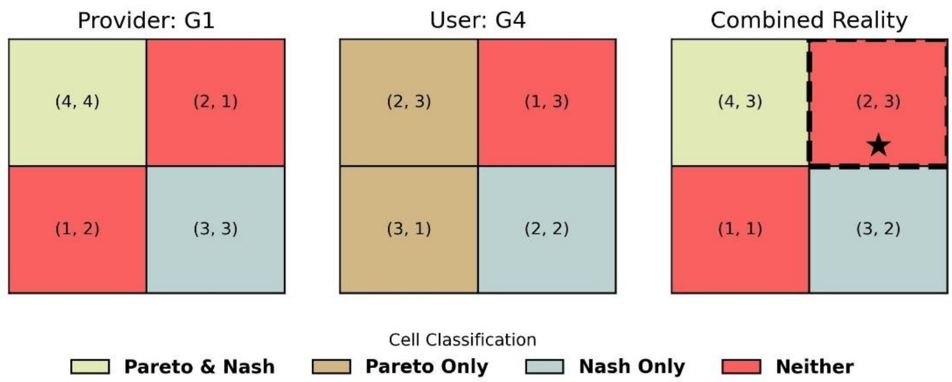

Figure 4: Example analysis of a hypergame (G1-G4 payoff-based)

This figure presents three side-by-side payoff matrices, each representing how different actors perceive the strategic interaction. It is the main developed figure through which the hypergames will be analysed.

Each 2×2 matrix displays payoffs as ordered pairs: (Provider payoff, User payoff). The colour coding highlights key strategic properties of each outcome:

- **Nash + Pareto:** An outcome that is both a Nash Equilibrium (stable, no incentive for unilateral deviation) and Pareto Optimal (efficient, no one can be made better off without making someone else worse off) from the perspective of the player(s) considered. This represents a highly desirable and stable outcome.
- **Pareto Only:** The outcome is Pareto Optimal but not a Nash Equilibrium. Players might agree it's efficient, but one or both could have an incentive to deviate unilaterally, making it potentially unstable.
- **Nash Only:** A Nash Equilibrium that is *not* Pareto Optimal. This outcome is strategically stable, but socially suboptimal; there might be other outcomes where both players could be better off.
- **Neither (Dominated):** An outcome that is neither Pareto Optimal nor a Nash Equilibrium. This outcome is both inefficient and unstable, typically representing a poor choice for all involved.

Left Matrix: Provider's Perceived Game

This shows the game from the provider's subjective viewpoint, reflecting their assumptions about outcomes and the user's choices.

- **Nash Equilibrium:** An outcome is a Nash equilibrium if the provider believes they would not want to deviate from their chosen strategy, given what they expect the user to do, and vice versa.

- **Pareto Optimality:** An outcome is Pareto optimal if, from the provider's viewpoint, no other outcome would improve the provider's payoff without reducing the user's payoff (as the provider perceives it).

This matrix reveals how the provider evaluates their own optimal strategies and perceived trade-offs, independent of the user's actual intentions or preferences.

Centre Matrix: User's Perceived Game

This displays the game from the user's subjective understanding, shaped by their beliefs about the provider's motivations and the resulting payoffs.

- **Nash Equilibrium:** A strategy pair is a Nash equilibrium if the user believes they are making the best decision, and (if they consider the provider's rationale) that the provider is doing the same.
- **Pareto Optimality:** An outcome is Pareto optimal if, from the user's perspective, no other outcome would improve their payoff without harming the provider, as the user perceives it.

This game illustrates how the user's framework shapes their expectations and what outcomes they consider rational or desirable.

Right Matrix: Combined Reality

This crucial matrix is constructed by taking the provider's perceived payoff for themselves and the user's perceived payoff for themselves. It represents the *actual* strategic landscape resulting from their joint actions, regardless of individual misperceptions. It is the only matrix that reflects what each party truly values for themselves in that specific interaction.

- **Nash Equilibrium:** Here, a strategy pair is a Nash equilibrium if each player's action is the best response with respect to their *own actual payoff* (as represented in this combined view).
- **Pareto Optimality:** An outcome is Pareto optimal in the combined matrix if no other outcome would improve one actor's actual payoff without harming the other's actual payoff.

This matrix allows for an analysis of the actual incentives faced by both players, even if these incentives are hidden from their individual subjective views. It uncovers the underlying structure of mutual benefit or strategic tension that might not be apparent to either actor alone. The star (★) symbol in this matrix, surrounded by a dashed black border, indicates the outcome that is *selected* by the players based on their individual strategies and the chosen decision-making rule (e.g., risk-dominant or payoff-dominant).

- Risk dominant entails that if a game has multiple Nash-equilibria, the player will choose the one with the least risk. In other words, with the highest payoff if the opponent doesn't choose the same equilibrium.
- Payoff-dominant entails that if a game has multiple Nash-equilibria, the player will choose the equilibrium with the highest payoff.

Why This Matters: Analysing All Three Matrices Side-by-Side

Comparing these three matrices offers insights:

- **Diagnosing Strategic Misalignment:** We can identify situations where Nash equilibria differ across the perceived games and the combined reality, indicating fundamental misunderstandings.
- **Identifying Missed Opportunities:** We can uncover outcomes that are Pareto optimal in the combined reality (mutually beneficial) but are not perceived as such by either actor, leading to suboptimal choices.
- **Detecting Hidden Instability:** We can reveal scenarios where players believe they are coordinating effectively, but their actions are actually moving them toward unstable or dominated outcomes in the combined reality.

6. Defining and Analysing the Basic Games

This section defines the four interaction outcomes, each representing a distinct combination of strategic choices regarding Digital Sequence Information (DSI) access and control. These outcomes serve as the empirical foundation for the hypergame matrices used throughout the analysis. For each outcome, the corresponding material configuration is described in terms of governance instruments (e.g., repository access, intellectual property, and benefit-sharing mechanisms), allowing abstract strategies (View 1 or View 2) to be grounded in concrete institutional practices. The section then summarizes the payoff values based on how each outcome is evaluated under different paradigm combinations: Liberal–Liberal, Liberal–Realist, Realist–Liberal, and Realist–Realist (full analysis in Appendix A). Each of these four game configurations is analysed in turn, with attention to how actors assess strategic benefit, exposure, and institutional credibility based on their paradigm. The resulting payoff matrices define the core structure of the hypergame model and enable the identification of Nash equilibria, Pareto optima, and strategic asymmetries across varying belief alignments.

6.1 The Four Outcomes

This section defines the four possible interaction outcomes in the standard game used throughout the hypergame analysis. Each outcome represents a distinct combination of access and control strategies applied to digital sequence information (DSI) by countries acting simultaneously as providers and users. By disaggregating these outcomes into behavioural and institutional components building onto the theoretical foundations chapter, it becomes clear what each strategy entails in practice, both in terms of data input (access to DSI) and output (control over results). This framing provides the empirical grounding for the game matrices used in subsequent sections. It enables clearer interpretation of strategic choices, Nash equilibria, and payoff asymmetries by linking abstract decisions (V1 or V2) to specific instruments such as patents, open repositories, or ABS legislation. Understanding the material structure of each outcome is essential for evaluating which configurations are stable, efficient, or vulnerable under different perceptions and paradigms.

6.1.1 (V1, V1) – Mutual Openness with Effective Multilateral Benefit-Sharing via the Cali Fund

In this configuration, both countries adopt View 1 behaviour within the View 3 compromise. They refrain from proprietary control and deposit DSI in the INSDC core (GenBank/ENA/DDBJ) and interoperating public databases; access is open, without PIC/MAT or bilateral licences. Downstream, both actors keep derived outputs broadly accessible, limiting restrictive IP to genuinely novel applications and pairing patents with open licensing or benefit-sharing commitments that preserve reuse by providers.

Monetary sharing is routed through the Cali Fund, which, at this stage, remains voluntary. User countries set domestic measures to encourage corporate contributions and issue compliance certificates. Contributions follow indicative rates (1% of profit or 0.1% of revenue from DSI use), with scope oriented to sectors such as pharmaceuticals, nutraceuticals, cosmetics, plant/animal breeding, biotechnology, sequencing equipment, and AI-enabled scientific services. Entity thresholds (e.g., assets/sales/profit tests) guide who should pay. Disbursement prioritises developing countries, with at least half channelled to IPLCs (including women and youth) via national or accredited entities meeting fiduciary and transparency standards. Allocation through the fund is clear and specified, following the protocols set apart. There is no need for heavy reporting and no need for extensive tracking of exactly what sequence came from where.

Because governance is not fully equal and utopic in every way, two asymmetries persist. First, database asymmetries persist: infrastructure and standards are largely governed by institutions in the US/EU/Japan, even as providers increase capacity. Second, transparency on downstream use is only partially supported by adjacent IP instruments. The new WIPO treaty introduces disclosure of origin for inventions based on genetic resources (including DSI-based inventions by interpretation), but office verification is limited and sanctions stop short of routine revocation; trade secrecy and closed corporate databases can therefore still obscure some value flows, however this remains proportionate. These gaps make non-monetary channels, like capacity building, knowledge and technology exchange, and joint projects, extra important complements that reduce the asymmetry between providers and users, they widen participation, and improve global cooperation.

If implemented credibly, this outcome institutionalises reciprocity with low transaction costs: providers remain contributors and become beneficiaries (via fund redistributions and capacity investments), users sustain rapid innovation from open data, and both sides align incentives around a predictable, multilateral pathway rather than bespoke bilateral deals. Residual risks, voluntary compliance, delayed inflows relative to domestic incentivisation, and incomplete visibility over corporate use, are mitigated through: (i) early, transparent national signalling on who should pay and how much (with a backstop to mandate if voluntary uptake fails); (ii) clear certification; (iii) audited, public reporting by disbursing entities; and (iv) visible pipelines of funded biodiversity and capacity projects. As the provider and user representatives note, the aim is to keep the system simple and predictable enough to prevent closure, while making benefits practical and trackable:

"Our goal was to create a mechanism that would allow for the distribution of benefits in a straightforward way—without adding significant administrative burdens on the parties involved. That was particularly important for us because conducting scientific research in the Global South is already extremely difficult."

PROVIDER REPRESENTATIVE (APPENDIX C.1)

"If the multilateral mechanism functions well, they will not have to handle it separately each and every one. That is the ideal, to prevent more countries from closing off."

USER REPRESENTATIVE (APPENDIX C.2)

6.1.2 (V1, V2) , Exploitation with Undermined Multilateralism

In this configuration, the provider behaves as a View-1 actor inside the View-3 compromise: it keeps DSI openly accessible via INSDC repositories (GenBank/ENA/DDBJ), imposes no PIC/MAT or bilateral licences, and refrains from downstream control. The user, by contrast, acts as a View-2 actor downstream: it appropriates value through patents, exclusive licensing, proprietary or "one-way" databases, and, where possible, trade secrecy. Although the Cali Fund formally exists, contributions from the user side are voluntary, minimal or inconsistent, and partly obscured by corporate strategic manoeuvring and delays between vague non encouraging domestic incentivisation and visible inflows. The result is structural asymmetry: the system's infrastructure remains open, but benefit flows are one-sided.

Institutional features amplify this imbalance. Database governance and standards remain concentrated in Global North infrastructures, while transparency over commercial use is only partially supported by the new WIPO disclosure regime (limited verification and sanctions; continued scope for trade secrets). In practice, providers can see some of the data that is being accessed, but not reliably verify how value is created or shared. This weakens the credibility of multilateralism: the provider bears openness; the user captures rents, under-contributes to the fund, and withholds key information.

"At its core, the Cali Fund is supposed to act as a bridge between private capital and the parties—specifically for DSI that falls within the agreed scope. But here is the issue: the mechanism only works if the countries where these companies are based take concrete steps to ensure those companies actually contribute. It is also up to those countries to define what the benefits are and what incentives should be offered to companies to encourage participation."

PROVIDER REPRESENTATIVE

"For the time being, it is not the intention of the EU to issue regulations or introduce enforcement measures. Our focus is instead on informing national stakeholders. Should the worst-case scenario occur in which no money flows into the fund, then at each review moment we will need to assess where adjustments are required. Legally, governments are not currently obliged to do anything; no national legislation needs to be amended on the basis of the decision."

USER REPRESENTATIVE

6.1.3 (V2, V1) , Controlled Provider, Open User with Asymmetric Institutional Participation

In this configuration, the provider acts under View 2 while the user behaves under View 1 within the View-3 compromise. The provider withdraws access from the multilateral sphere by imposing domestic, bilateral, ABS controls, PIC/MAT, permits, bilateral contracts, and (could partially) relocate DSI to national or pay-walled platforms with country-specific terms. Despite the Cali Fund's existence, the provider does not channel data or benefits through the multilateral mechanism and engages only minimally in the creation of fund-supported projects. Instead aiming to gain money for its own state, and not necessarily biodiversity or IPLC related. In effect, access conditions are pre-negotiated case by case, raising transaction costs and fragmenting the knowledge base.

The user country takes the opposite approach. It deposits DSI in global repositories (INSDC and interoperating public databases), keeps downstream outputs broadly reusable, and contributes financially to the Cali Fund. Patents are used sparingly and transparently for genuinely novel applications, often paired with open licensing or non-monetary collaboration (capacity building, technology and knowledge transfer). Because the provider withholds its DSI and bypasses the multilateral route, it is largely insulated from the user's IP choices, but it also forgoes the gains of cumulative, open science.

Systemically, the outcome is a partial commons. Open user data and funding flow into the multilateral channel, yet provider data remain siloed behind sovereign gates. Interoperability suffers, research reproducibility and meta-analysis degrade, and the value of open infrastructures declines as key inputs are missing. Governance asymmetries persist: standards and infrastructure remain concentrated in Global North nodes, while transparency over commercial use is only partly improved by the new WIPO disclosure regime (the user side); meanwhile, the provider's closure deprives the fund of politically salient proof that openness "pays back," weakening incentives for other states to remain open.

"We would prefer to avoid an arms race, but if things really get out of hand then it might become necessary. What we want, however, is for it to be opened up and for us to exchange as much material as possible."

USER REPRESENTATIVE

6.1.4 (V2, V2) , Mutual Control and Systemic Fragmentation

In this configuration, both countries adopt View 2 behaviour inside the View 3 compromise. The provider restricts access through domestic ABS controls (PIC/MAT, permits, bilateral contracts) and (partly) relocates DSI to national or pay-walled platforms with country-specific terms. The user asserts control downstream via patents, exclusive licensing, proprietary ("one-way") databases, and, where permitted, trade secrecy. DSI governance is thus channelled through domestic frameworks, bilaterally, rather than open international repositories, with access conditions defined ex ante and enforced nationally.

Although the Cali Fund is formally in place, it functions weakly in this outcome. Contributions remain voluntary; scope, rates (e.g., 1% profit or 0.1% revenue), sectoral coverage, entity thresholds, and enforcement modalities are not yet fully operationalised. Neither side meaningfully uses the fund for contribution or redistribution; instead, states transact via bilateral or contractual pathways. On the transparency flank, the new WIPO disclosure regime improves signalling only at the margins: verification limits, constrained sanctions, and the continued availability of trade secrets leave substantial space for obscuring value creation from DSI.

The result is systemic fragmentation. Public infrastructures (INSDC and interoperating open databases) are bypassed or constrained; interoperability declines as jurisdictional rules multiply; transaction costs rise through case-by-case negotiations; and reproducibility and meta-analysis suffer as key inputs become inaccessible. Governance asymmetries persist, standards and core infrastructure remain concentrated in a few Global North nodes, yet the overall commons is diminished for all participants. Mutual control reduces asymmetric vulnerability (neither actor is exposed), and both players have full control over their resource.

"If we were to require permits for everything, we would be undermining our own policies. Administrative approval can take between two to six months, before research even begins. That would discourage scientific activity entirely. What we needed was a mechanism that was simple and fair, one that did not punish countries like ours."

PROVIDER REPRESENTATIVE

"There really needs to be a plan to maintain the momentum. Otherwise everything will be shut down; if this does not work, then we will lock everything up, and that is something we definitely do not want because in that case no one gains anything."

USER REPRESENTATIVE

6.2 The Four Standard Games

The following section discusses the Four Standard Games, outlining their rational strategic outcomes and the dilemmas they present. Each game is accompanied by a normal form representation with colour-coded outcomes to guide interpretation of the analysis. In addition, a concise table is provided for each case, summarising the payoffs assigned to each outcome for both players. For a full account of the reasoning underlying these payoff allocations, readers are referred to Appendix A.

6.2.1 Game 1: Provider Liberal- User Liberal

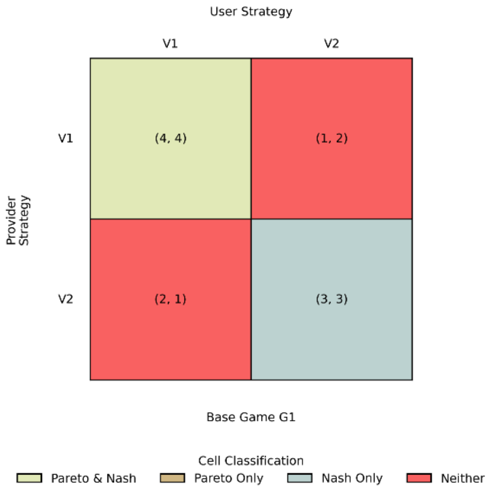

Figure 5: Game 1

From the G1 perspective, the most desirable outcome is mutual openness (V1, V1), which is Pareto optimal and maximises cooperative gains by ensuring broad access to DSI and reinforcing innovation. However, both actors also recognise that mutual sovereignty (V2, V2) constitutes a second Nash equilibrium. Although this outcome delivers lower payoffs, it provides strategic symmetry and reduces the risk of unilateral exploitation, particularly given the irreversible nature of DSI sharing. The result is a coordination problem: (V1, V1) stands as the payoff-dominant option, offering the highest collective benefit, while (V2, V2) is the risk-dominant fallback when trust in the other's commitment to openness is uncertain.

Ultimately, G1 shows that idealistic (liberal) alignment is an insufficient condition for cooperation. Without mechanisms to anchor the payoff-dominant outcome, actors may still retreat to sovereignty-preserving strategies, even if its non-pareto optimal. However, in a case where both actors know that the other is liberal and uncertainty is not a big factor, this Nash equilibria seems less likely.

Table 7: Game 1, payoffs

Outcome	Provider	User	Analysis
(V1, V1)	4	4	Mutual openness maximises global benefit and national capacity-building for both
(V1, V2)	1	2	Provider exploited; user undermines long-term global stability and future access
(V2, V1)	2	1	Provider loses trust and openness; user gains moderately due to retained infrastructure
(V2, V2)	3	3	Strategic parity without trust; reduced overall benefit, but stable under fragmentation

6.2.2 Game 2 Provider Liberal – User Realist

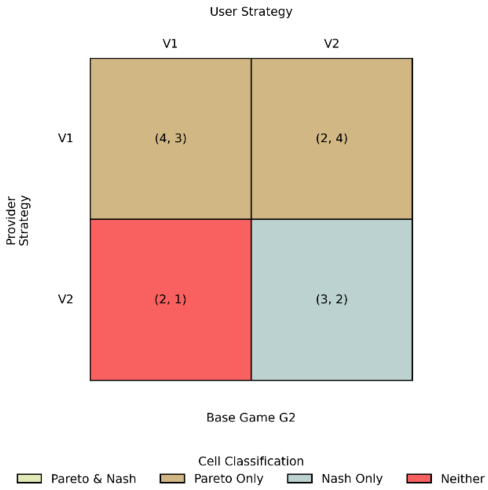

Figure 6: Game 2

This game has a single Nash equilibrium: systemic fragmentation (V2,V2) Although mutual openness (V1,V1) is Pareto optimal, it is not selected because the provider cannot reasonably trust the user to maintain this cooperative stance. The user perceives sovereign control (V2) as a preferable response to the provider's openness, making (V1,V2) a more attractive configuration from the user's realist perspective. Given that both actors recognise the user's underlying realist paradigm, they converge on mutual sovereignty (V2,V2) as the only strategically stable outcome. Consequently, despite the existence of a more efficient configuration, the equilibrium reached is strategically defensible but suboptimal in terms of collective welfare. In both the risk-based and payoff-based strategies, the game converges on the same equilibrium: mutual sovereignty (V2,V2).

Table 8: Game 2

Outcome	Provider	User	Strategic Logic
(V1, V1)	4	3	Mutual openness maximises global benefits; user restrains but still benefits
(V1, V2)	2	4	Provider exploited; user captures full value through asymmetric control
(V2, V1)	2	1	Provider limits openness; user cooperates and is penalised, worst case
(V2, V2)	3	2	Mutual assertion; stable but inefficient; sovereignty preserved, cooperation lost

6.2.3 Game 3 Provider Realist – User Liberal

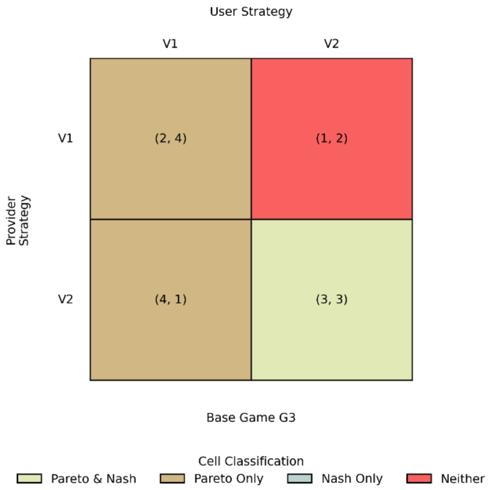

Figure 7: Game 3

In this game, the rational outcome, systemic fragmentation (V2,V2), is both a Nash equilibrium and Pareto optimal. Unlike previous configurations, neither actor has an incentive to deviate from this outcome. As it offers each a relatively high and equal payoff of 3, and there is no outcome where both could do better.. The user expresses a preference for mutual openness (V1,V1) while the provider strongly favours (V2,V1), seeking control while the other leaves it open. However, the outcome where the provider closes down, while the user opens up (V1,V2) is strictly dominated, as it is the least preferred option for both parties.

This configuration reflects a relatively balanced strategic environment, where mutual sovereignty yields an efficient and equitable outcome. Importantly, the strategic convergence is consistent across both risk-based and payoff-based reasoning, as (V2,V2) remains the sole Nash equilibrium under either decision-making logic.

Table 9: Game 3 payoffs

Outcome	Provider	User	Strategic Analysis
V2, V1	4	1	Provider exploits liberalism for strategic control; user isolated
V1, V1	2	4	Global benefit maximised; provider regrets missed leverage
V1, V2	1	2	Provider exploited; user captures short-term control, undermines trust
V2, V2	3	3	Strategic symmetry; cooperation blocked, but stability preserved

6.2.4 Game 4 Provider Realist – User Realist

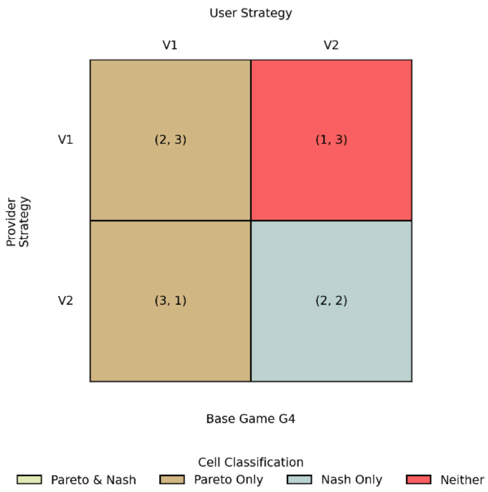

Figure 8: Game 4

This game has a single Nash equilibrium: systemic fragmentation (V2,V2) Although mutual openness (V1,V1) is Pareto optimal, it is not selected because the provider cannot reasonably trust the user to maintain this cooperative stance. The user perceives sovereign control (V2) as a preferable response to the provider's openness, making (V1,V2) a more attractive configuration from the user's realist perspective. Given that both actors recognise the user's underlying realist paradigm, they converge on mutual sovereignty (V2,V2) as the only strategically stable outcome. This convergence reflects a lack of trust in the sustainability of cooperation, particularly from the provider's side. Consequently, despite the existence of a more efficient configuration, the equilibrium reached is strategically defensible but suboptimal in terms of collective welfare. In both the risk-based and payoff-based strategies, the game converges on the same equilibrium: mutual sovereignty (V2,V2).

Table 10: Game 4 Payoffs

Outcome	Provider	User	Strategic Logic
(V1, V1)	4	4	Mutual openness maximises global benefits; user restrains but still benefits
(V1, V2)	2	3	Provider exploited; user captures full value through asymmetric control
(V2, V1)	2	2	Provider limits openness; user cooperates and is penalised, worst case
(V2, V2)	3	2	Mutual assertion; stable but inefficient; sovereignty preserved, cooperation lost

6.3 Variation in the standard structures for sensitivity analysis

Since the standard preference structures rest on qualitative analysis and underlying assumptions, selected assumptions were subjected to alternative specifications. This was carried out through a sensitivity analysis, as outlined in the methodology section. The resulting variations were identified through targeted analysis and do not represent an exhaustive set of possible games. Indeed, in the context of hypergames, considering all possible games would imply accounting for all possible outcomes. The following discussion therefore provides only a concise overview of the alternative structures employed in the sensitivity analysis, while the complete payoff matrices and game specifications are provided in Appendix D.

Table 11: Variant structures for sensitivity analysis

Variant	Game	Description
Principled liberal	G1	In the standard configuration, a liberal player prefers to act as the extorter (provider: V2,V1; user: V1,V2) rather than accept the position of being extorted (provider: V1,V2; user: V2,V1). In the principled liberal variant, however, this preference is reversed: the liberal player prioritises adherence to principle over the opportunity to exploit the other. All other preference structures remain unchanged.
Assymetrical Bully	G2	In the asymmetrical bully variant of Game 2, the user represents a more aggressive form of realism. Whereas in the standard configuration the realist user still prefers cooperation to fragmentation, in this version the preference order is reversed, with fragmentation valued over cooperation. The rationale for introducing this variation solely on the user side rests on the current distribution of technological capacity and power: since the user holds a relative advantage, it can be argued from a realist relative-gains perspective that maintaining the present equilibrium is strategically preferable, and therefore the user has little incentive to accommodate cooperative outcomes.
Benevolent Hegemon	G3	This variant represents a liberal user who, owing to its greater technological capacity, does not perceive the provider's realist intent as a direct threat. Consequently, the user prefers to remain open while the provider opts for closure (V2,V1), rather than converge on systemic fragmentation (V2,V2).
Chicken Game	G4	Named after the classic chicken game in game theory, this variant models two realist players who both regard total fragmentation as the worst possible outcome. All other preference rankings remain unchanged. Such a configuration could arise, for example, if biodiversity were to deteriorate more rapidly, creating a situation in which survival depends on at least maintaining access to the other's DSI.
Symmetrical Bully	G4	This configuration occurs when both players prefer full fragmentation over cooperation.
Assymetrical Bully	G4	This configuration arises when only the user prefers full fragmentation over cooperation, while the provider retains the same realist preference structure as in the standard variant (G4).

6.4 Conclusion Sub question 1:

Sub-question 1: *What are the core strategic choices and corresponding payoff structures for 'provider' and 'user' states under different DSI framings (knowledge commons vs. sovereign resource) and International Relations paradigms (liberalism vs. realism)?*

The core strategic choices for provider and user states are reduced to two strategies: V1 (Openness), aligned with a knowledge commons framing, and V2 (Control), aligned with a sovereign resource framing. Combined, these yield four outcomes: (V1, V1) mutual openness with multilateral benefit-sharing via open repositories and the Cali Fund; (V1, V2) exploitation, where the provider remains open while the user captures value through IP and weak fund contributions; (V2, V1) controlled provider with an open user, producing fragmented access and interoperability issues; and (V2, V2) mutual control, where both restrict access and rely on bilateral deals, creating symmetry but systemic fragmentation.

Evaluated through IR paradigms, Liberal–Liberal alignments prioritise absolute gains, while Realist–Realist interactions emphasise relative gains. The four standard games show that only Game 1 (Liberal–Liberal) sustains mutual openness as a Pareto-optimal, payoff-dominant outcome, though it competes with sovereignty as a risk-dominant fallback. Game 2 (Liberal–Realist) and Game 4 (Realist–Realist) converge solely on sovereignty (V2, V2), while Game 3 (Realist–Liberal) also stabilises at sovereignty, which in this case is both Pareto-optimal and a Nash equilibrium. Overall, openness yields the greatest collective benefit, but sovereignty dominates as the more credible and stable outcome, making fragmentation the prevailing equilibrium across most games.

7. Analysis of the Hypergames

The hypergame analysis conducted in this study reveals several recurring patterns in how strategic misalignments shape Digital Sequence Information (DSI) negotiations. While the full analysis of outcomes, per hypergame, is detailed in Appendix B and summarized in table B.1, this section shows the overarching dynamics that emerge across the space of possible Provider–User paradigm combinations. The analysis considers both payoff-based reasoning, where actors optimise for strategic gain, and risk-based reasoning, where actors prioritise the Nash equilibrium with the lowest alternative payoff.

Across these framings, a consistent structure emerges: initial opportunities for openness are often squandered due to misperception or asymmetric intent, and the strategic system tends to converge toward mutual control. Although cooperation is theoretically Pareto-optimal in many hypergames, it is rarely achieved in practice due to structural distrust and the dominance of realist logic once introduced. These dynamics are further analysed below according to each actor type.

7.1 Strategic Outcomes Across the Hypergame Space

Three core trends characterise the outcomes across the full set of 12 hypergames and 4 basic games. First, strategic convergence on mutual control (V2, V2) is the modal outcome. Whether under payoff-based or risk-based logic, most configurations end with both actors asserting sovereignty, resulting in stable but suboptimal equilibria with payoffs between 2 and 3 for both sides. Second, exploitation through unilateral openness is possible, but rare. It occurs only when one actor misperceives the strategic paradigm of the other, and even then, the exploit when clearly perceived, is typically a one-shot event. However, if exploitation has is untransparent exploitation can still arise, for longer periods of time. Finally, realism proves structurally persistent: once one actor adopts a realist stance, or suspects a realist stance in the other, it acts in a protective mode. Enforcing either a fragmented equilibrium or induces belief revision by the other party. This mechanism then continually shrinks the future cooperation space and pushes the system toward fragmentation. This path dependence is especially visible in transitions from G1 configurations to subsequent more realist ones, as actors update their beliefs in response to failed cooperation.

The table X below summarises the hypergame outcomes illustrates the extent to which payoff-based and risk-based strategies diverge in terms of efficiency. Pareto optimality, defined as a situation in which no player can be made better off without making another worse off, serves as the evaluative criterion. The comparison shows that payoff-based strategies tend to yield a greater share of Pareto-optimal results than risk-based strategies. By contrast, risk-driven choices more frequently lead to outcomes that are not Pareto efficient, reflecting the players' prioritisation of security over joint gains. More broadly, the table highlights that many hypergame outcomes fail to achieve Pareto optimality at all, underscoring that the hypergame landscape often resolves into suboptimal equilibria rather than socially efficient or mutually beneficial ones. This inefficiency provides a critical lens through which the following analysis can be understood.

Table 12: Pareto optimality across outcomes

Game	Risk-Based Pareto Optimal?	Payoff-Based Pareto Optimal?
G1-G1	X	V
G1-G2	X	V
G1-G3	X	X
G1-G4	X	X
G2-G1	X	X
G2-G2	X	X
G2-G3	X	X
G2-G4	X	X
G3-G1	V	V
G3-G2	V	V
G3-G3	V	V
G3-G4	V	V
G4-G1	X	V
G4-G2	X	X
G4-G3	X	X
G4-G4	X	X

The plot below presents the distribution of outcomes and their corresponding scores across the hypergame plane. The two heatmaps at the top illustrate the provider's perspective, with the left map displaying results under the payoff-based strategy and the right under the risk-based strategy. The two heatmaps at the bottom mirror this structure for the user, again distinguishing between payoff-based and risk-based decision rules. In each case, the colour scale indicates the utility assigned to the respective outcomes by the player, allowing a direct comparison of how strategy selection and positional asymmetries shape perceived value. Together, these visualisations provide a structured overview of how strategic orientation influences the distribution of payoffs for both actors within the hypergame plane.

Figure 9: Provider and User scores in the Hypergame plane (Risk and Payoff)

Looking at the heatmaps, a clear difference appears between the two strategies. In the risk-based strategy, all games end up at the same outcome, systemic fragmentation (V2, V2), with payoffs ranging in between 2 and 3. This shows how strong the pull of risk aversion is, pushing both players towards a safe but limited result. The payoff-based strategy, on the other hand, produces a much wider spread of outcomes. Here both the highest and the lowest payoffs occur, which makes the analysis on this part less predictable and more dynamic, since players can either do very well or end up with poor results. A more detailed breakdown of these patterns follows in the next subsection.

7.1.1 Liberal Players: Misperception and Strategic Reversal

When the Provider (the top two matrixes) holds a liberal paradigm (G1 or G2), the success of cooperation hinges almost entirely on the User's beliefs and strategic posture. In the payoff scenario, the ideal outcome arises in the G1–G1 hypergame, where mutual openness (V1, V1) yields the global optimum (4, 4). However, in cases where the User is actually realist or simply believes the Provider is not liberal, the outcome collapses into either exploitation (V1,V2), defensive convergence and once even exploitation from the part of the. The risk-based scenario, has a more conservative and predictable outcome, always systemic fragmentation, although it occurs for differing reasons and can be more or less desired in different hypergames (V2,V2).

For instance, in G1–G2 and G1–G4, liberal Providers open the system by choosing V1, only to be met by realist Users asserting V2. This results in outcomes like (2, 4) or (2, 3), where the Provider experiences a strategic loss. Even more destabilising are the G1–G3 and G2–G1 hypergames, where both actors are liberal in intent but fail to coordinate due to misperceptions. Here, defensive moves were triggered not by mal intent but by fear of non-reciprocation, due to false assumptions about the other, leading to mutual control or exploitation from one to the other, despite the possibility of higher joint payoffs.

Liberal Users (G1 or G3) also attain their best outcome only when both parties share and recognise each other's liberalism. The G1–G1 configuration remains the only case that delivers the full benefit (4). However, liberal Users when misaligned with their counterpart's beliefs or actual paradigm, result in the same less favourable outcomes. Resulting in either direct exploitation (V2, V1; e.g. 4, 2), convergence on systemic fragmentation or even the unwilling exploitation of the other.

In every hypergame where the Provider or User sees itself as liberal, misalignment, whether due to genuine realist strategy or mistaken perceptions, leads to an erosion or loss of cooperation. Liberalism, unless clearly reciprocated and recognised (G1-G1, payoff), leaves players vulnerable to exploitation, disappointment, or non-pareto optimal/dominated outcomes.

7.1.2 Realist Players: Containment as Default

When the Provider operates from a realist frame (G3 or G4), it tends to set the tone of the game, shaping the User's options and expectations. These Providers consistently choose V2, either to maximise relative gain or to avoid being strategically exposed. In cases such as G3–G1 or G4–G1, realist Providers exploit liberal (payoff-based) Users through unilateral control.

In other games, such as G3–G2, G4–G2, and G4–G3, the realist posture leads to a different form of containment, although with the same end result. Here, both actors expect the other to assert sovereignty, and so they converge on mutual control without attempting cooperation. These outcomes, though stable, can be inefficient: in G4-G3 and G4-G2, cooperation would be better or equally good for both, so these outcomes are non pareto optimal. The broader implication is that realism, once adopted, compresses the range of acceptable behaviours and reduces the opportunity for mutually beneficial negotiation.

Realist Users (G2 or G4) exhibit consistent strategic behaviour across the hypergame space. Except for the G1–G2 game, and the G1-G4 game, where an unsuspecting liberal (payoff based) Provider enables the User's maximum payoff (V1, V2; 2, 4), all other configurations involving realist Users end in (V2, V2). This pattern reflects the realist User's preference for minimising exposure and it exposes its thrive for maximising gain. The result is a steady pattern of convergence on mutual sovereignty, typically yielding payoffs of 2 or 3 and occasionally 4.

What distinguishes the realist User is not opportunism, but predictability. Their dominant strategy, assert control, avoid exploitation, rarely deviates, regardless of the Provider's paradigm. This makes realist Users relatively straightforward to anticipate, but difficult to shift in this game structure. Importantly, they are also influential: once realism becomes visible in

User behaviour, it forces the Provider to respond in kind, shrinking the liberal win-set and reinforcing the trend toward defensive equilibria. The implication is clear: unless a credible institutional mechanism exists to reassure realist Users about the safety or relative gain of openness, they will continue to opt for containment, and Providers, liberal or not, will have little choice but to mirror this strategy.

Furthermore, the results show that realist players benefit most in situations where the other actor perceives the interaction as liberal–liberal. In such cases, presenting the issue in liberal terms, or signalling cooperative intent, becomes strategically advantageous for realists, since it allows them to exploit the expectations of openness held by the other side. By contrast, liberal players do not gain by framing themselves as realists, as this does not improve their outcomes in the same way. This asymmetry makes it particularly difficult for liberal players to place trust in the signals they receive, as realist actors have both the incentive and the opportunity to misrepresent their position for strategic advantage.

7.1.3 Conclusion of the static analysis

This section has shown that across the hypergame space, strategic misperceptions and asymmetries consistently undermine the potential for cooperative outcomes in DSI negotiations. The analysis demonstrates three overarching dynamics: first, liberal optimism is fragile and often collapses into disappointment or exploitation when not clearly reciprocated; second, realist logic exerts a structural pull, steering interactions toward containment and systemic fragmentation; and third, Pareto-optimal outcomes, though possible, are rarely realised. The comparison between payoff-based and risk-based strategies further underlines this tendency: while payoff-based reasoning occasionally opens space for higher gains, risk-based logic locks actors into defensive equilibria, narrowing the cooperative win-set.

Overall, the results suggest that the hypergame environment is inherently unstable and biased toward suboptimal equilibria. Liberal actors struggle to sustain cooperation without credible signals, while realist actors, through their consistency, shape the strategic system toward control and sovereignty. For DSI governance, this means that effective institutional mechanisms must not only manage material payoffs but also address the deeper challenge of misperception, signalling, and trust-building. Without such mechanisms, the system will continue to drift toward fragmentation, even where mutual benefit is possible.

7.1.4 Sensitivity Analysis

The table below presents the outcomes of the sensitivity analysis, displaying the variation across a full combinatorial analysis of all possible games, including the standard variants. The brackets indicate the selected outcome, with the corresponding percentage shown beneath to reflect how often this outcome was chosen across the full analysis. The colour scheme highlights the outcome most frequently selected in each case, in the case of a shared first place the first outcome is chosen to represent the colour scheme.

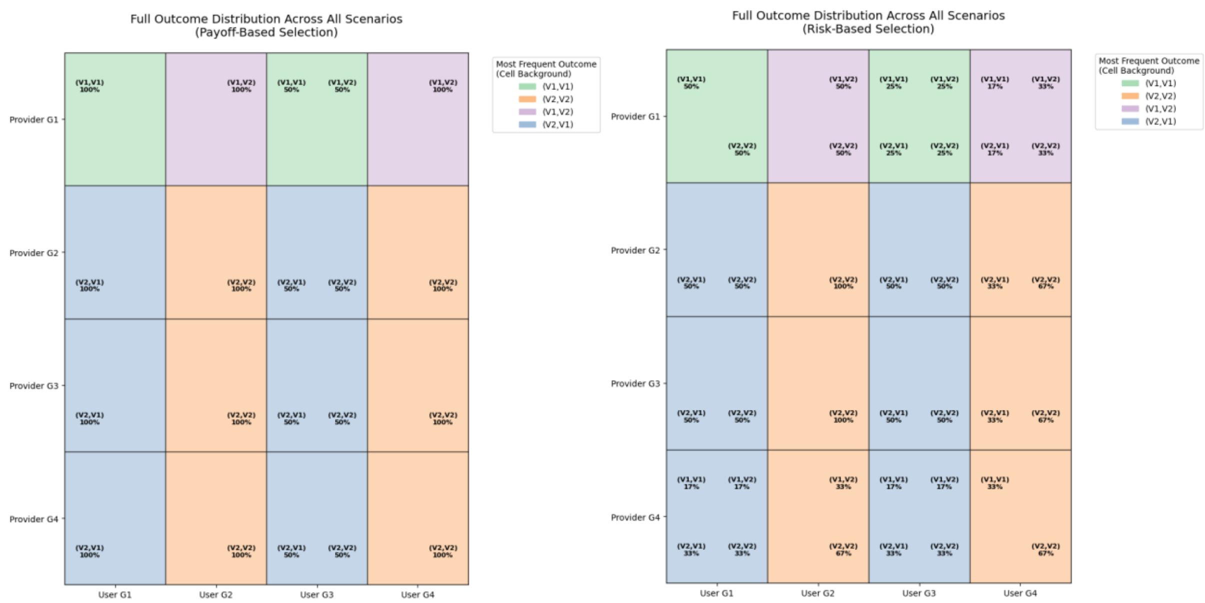

Figure 10: Chosen Outcomes under Sensitivity Analysis

A first observation concerns the altered dynamics under the risk-based strategy. Whereas the standard configuration overwhelmingly converged on (V2,V2), the alternative structures introduce greater variation in outcomes. Notably, the G4–G4 interaction now produces a cooperative outcome. This shift can be attributed to the chicken-game logic: when both players perceive the risks of fragmentation as prohibitively high, they default to (V1,V1) as a safer option, thereby achieving cooperation. A second insight is that the presence of a benevolent hegemon substantially reshapes the hypergame outcomes. It increases both the likelihood of cooperation and the incidence of extortion by the provider, reflecting the user's preference for extortion over full fragmentation. Finally, the principled liberal variant exhibits a higher probability of cooperation than the standard liberal type, since in the risk-based setting its commitment to principle also converges on cooperative outcomes.

Under the payoff-based strategy, the overall pattern remains largely consistent with the standard structures, suggesting that this selection yields more robust outcomes. The only notable deviation arises with the benevolent hegemon, which exerts the strongest influence on the resulting equilibria. In this case, the G1–G3 interaction produces cooperation, while in all other hypergames the provider succeeds in extorting the user.

An important takeaway is that the outcomes of realist games are highly dependent upon the specific type of realist player that is represented. Moreover, the payoff-based strategy produces more predictable equilibria for realist players than the risk-based strategy. This finding may appear paradoxical, given that realist players are theoretically oriented towards security, as discussed in the theoretical foundations. However, this comparison is somewhat skewed, as Game 4 included a greater number of structural variations than the other games.

7.1.5 Conclusion to Sub Question 2

Sub-question 2: *How do asymmetric perceptions of DSI framings and underlying IR paradigms influence actor preferences, negotiation strategies, and lead to suboptimal or exploitative outcomes in hypergame scenarios?*

The hypergame analysis shows that asymmetric perceptions of framings and paradigms systematically undermine cooperation in DSI negotiations. Liberal actors, who frame DSI as a global commons, pursue openness (V1) in expectation of reciprocity. However, when paired with realist counterparts, or when they misperceive the other's paradigm, or when the other misperceives their paradigm, they become vulnerable to exploitation (e.g., V1, V2 outcomes in G1–G2 or G1–G4 or v2,v1 outcomes), or retreat defensively into mutual control (V2, V2).

Realist actors, by contrast, frame DSI as a sovereign resource and consistently pursue control (V2). Their predictability reinforces containment dynamics: once realism is introduced or suspected, the cooperative win-set shrinks, and fragmentation becomes the dominant equilibrium across games. Realist players get their best outcomes when they exploit G1 opponents (e.g., G1–G2, G3-G1, G4-G1 & G1-G4), but otherwise steer the system into stable, though suboptimal, equilibria of sovereignty (V2, V2). This persistence of realism means that even liberal–liberal intent (e.g., G1–G3 & G2-G1) often collapses into control if recognition is lacking.

The divergence between payoff-based and risk-based reasoning further illustrates how asymmetric perceptions drive inefficiency. Payoff-based logics sometimes allow cooperation or exploitation, but risk-based strategies nearly always converge on (V2, V2), reflecting how uncertainty might amplify defensive behaviour. In effect, misaligned framings transform potential Pareto-optimal outcomes into fragmented equilibria, or exploitative equilibria.

The sensitivity analysis reveals that alternative game structures introduce greater variation than the standard models, particularly under risk-based reasoning. In this setting, outcomes such as G4–G4 can shift toward cooperation through chicken-game dynamics, while the presence of a benevolent hegemon or a principled liberal significantly increases the likelihood of cooperation or extortion. By contrast, payoff-based reasoning largely mirrors the standard outcomes, with the notable exception of the benevolent hegemon enabling cooperation in G1–G3. Overall, the results show that realist outcomes depend heavily on the type of realist actor represented, and that paradoxically, payoff-based strategies yield more predictable equilibria for realists than risk-based ones.

Thus, asymmetric perceptions directly shape preferences and strategies by fostering misinterpretation, defensive containment, and exploitation. This explains why cooperation is fragile, why realist framings dominate once introduced, and why most hypergames resolve into non–Pareto-optimal outcomes despite the theoretical possibility of global benefit.

7.2 Dynamic Analysis

The preceding analysis of the static hypergames exposes the inherent tensions and misperceptions that characterize the DSI negotiations. However, strategic interactions are not static; actors learn and adjust their beliefs based on outcomes. The following subsection analyses the dynamic transition from one hypergame to another, a process driven by 'strategic surprise'.

As explained in the methodology, a surprise occurs when an actor observes an outcome that is inconsistent with the Nash equilibria of the game they thought they were playing. In line with the theory of bounded rationality, an actor does not interpret this as irrationality on the part of the opponent, but as evidence that their own perception of the other (their paradigm) was flawed. This leads to an adjustment of belief, and thus to a transition of the system state of the hypergame, a shift from one hypergame to the other.

The figure below illustrates these transitions within the hypergame grid. To aid interpretation, the explanation that follows outlines how the plot should be read and what the observed transitions imply for the underlying dynamics of the games.

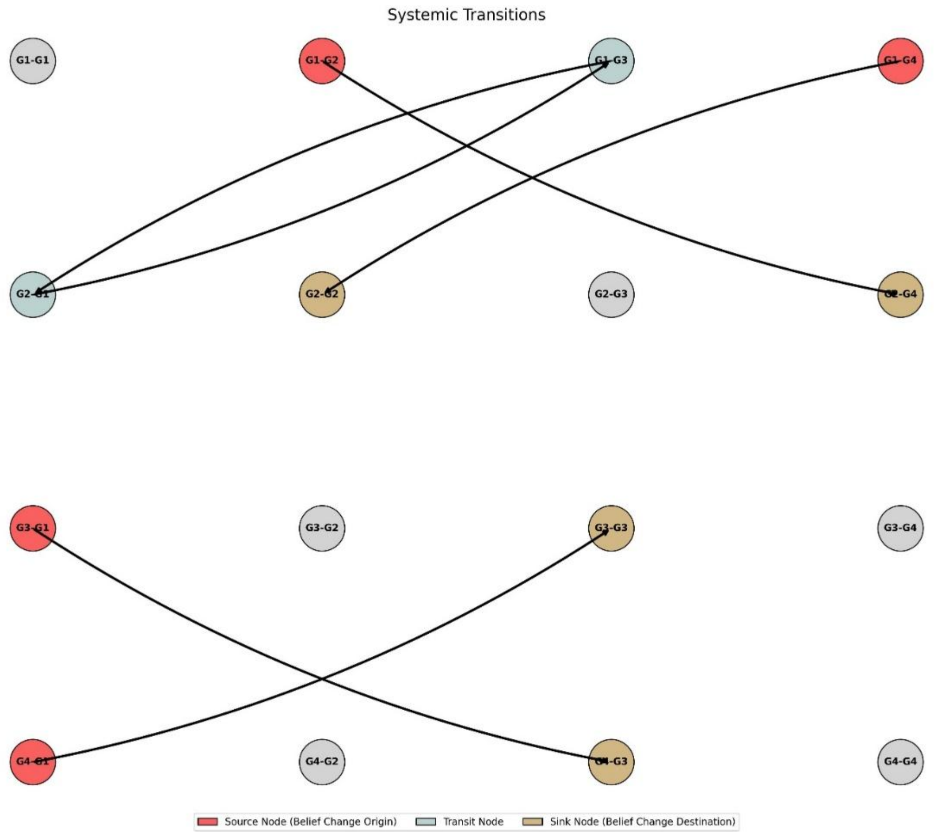

Figure 11: System-Wide Hypergame Transitions after Belief Revision

7.2.1 Interpretation of the Transition Grid

The transition grid provides a visual map of the dynamic stability across the sixteen possible hypergame states. Each node, represented by a circle, corresponds to a unique combination of beliefs held by the two players, denoted as Provider's Belief – User's Belief. For example, the node G1–G2 indicates that the Provider perceives the game as Liberal–Liberal (G1), while the User interprets it as Liberal–Realist (G2). The structure of the grid is systematic: rows represent the Provider's belief, ranging from G1 at the top to G4 at the bottom, while columns represent the User's belief, progressing from G1 on the left to G4 on the right. Transitions between these nodes are shown with arrows, each representing a shift in the system state after one round of interaction. These transitions capture both the effects of dual surprise, where both actors experience unexpected outcomes and therefore revise their beliefs simultaneously, and singular surprise where only one of the actors is surprised by the outcome.

7.2.2 Analysis of Specific Dual-Surprise Transitions

The plot reveals that the most dynamic and unstable region are the column and row where either the user or the provider believes G1 (Liberal-Liberal) to be the reality. These transitions illustrate how shared surprise can lead to dramatically different systemic outcomes, ranging from escalating mistrust to unexpected convergence, towards the same belief about reality.

A loop of misunderstanding (G1-G3 → G2-G1 and G2-G1 → G1-G3)

The dynamics between G1-G3 and G2-G1 reveal possibly the most interesting interaction. Creating a loop of misunderstanding that never quite resolves into the same belief about reality.

G1-G3 → G2-G1

The interaction begins in a state of significant misperception. The Provider believes the game to be G1 (Liberal–Liberal), assuming that both parties are cooperative and open. In reality, the User perceives the situation as G3 (Realist–Liberal): while the User identifies themselves as liberal, they interpret the Provider as acting according to realist logic. This asymmetry means that both actors enter the game with fundamentally different expectations of the other's behaviour.

The resulting outcome generates a dual surprise. From the Provider's perspective, the User's defensive action is unexpected, since it contradicts their assumption of mutual liberalism. At the same time, the User is surprised by the Provider's cooperative move, which runs counter to their expectation of realist behaviour. The mismatch between beliefs and observed actions prompts both actors to reconsider their interpretations of the strategic environment.

In response, both players revise their beliefs simultaneously. The Provider, having witnessed defensive behaviour, updates their understanding of the User, shifting from perceiving them as liberal to realist. This adjustment moves the Provider's worldview from G1 to G2. Conversely, the User, reassured by the Provider's cooperative action, revises their view of the Provider from realist to liberal, transitioning from G3 to G1. The new configuration of beliefs thus becomes G2–G1.

This transition has important implications for the governance of Digital Sequence Information (DSI). It illustrates how a single event can trigger a complex recalibration of perceptions, leading actors to "cross paths" in their beliefs. The liberal Provider, now more cautious, adjusts by incorporating the possibility of realist behaviour from the User. Meanwhile, the liberal User, initially distrustful, becomes more optimistic after observing cooperation. Although the actors' perceptions remain misaligned, they are brought closer to a more accurate understanding of each other's strategies, highlighting the fragility and fluidity of trust in such settings.

G2-G1 → G1-G3

The reverse case starts from the User's perspective, who now believes the interaction to be a liberal–liberal game (G1). Entering with this assumption, the User expects cooperation from both sides. The Provider, however, interprets the situation differently, perceiving the User as realist and thus framing the game as G2 (Liberal–Realist). As in the earlier case, this initial misalignment means that the players approach the same encounter with fundamentally different expectations about the other's motives and strategies.

The outcome again generates a dual surprise. The User, expecting cooperation, is unsettled by the Provider's defensive response, which seems inconsistent with their belief in mutual liberalism. Meanwhile, the Provider is equally surprised when the User behaves cooperatively, contradicting their assumption that the User would act with realist caution. This mismatch forces both players to revise their perceptions once more.

In the process of simultaneous revision, the User reinterprets the Provider's behaviour, shifting their belief from liberal to realist. This transition moves the User from G1 to G3. At the same time, the Provider revises their view of the User, now perceiving them as liberal rather than realist, moving from G2 to G1. The updated configuration thus becomes G1–G3, essentially the mirror image of the previous scenario.

The Loop

Together, these two transitions illustrate how actors can become locked in a loop of misperceptions and revisions. Each round of interaction leads to "crossed paths" in belief systems: just as one actor becomes more cautious, the other becomes more optimistic, and vice versa. Rather than converging towards a shared understanding, the players continuously misalign, creating cycles of misunderstanding. Continuously reaching equilibria, that are suboptimal for both.

Escalating Mistrust (G1-G2 → G2-G4 and G3-G1 → G4-G3)

The interaction begins with a misalignment of expectations. The Provider enters the game believing it to be G1 (Liberal–Liberal), assuming that both actors are committed to cooperation and openness. The User, however, adopts a more guarded perspective, interpreting the situation as G2 (Liberal–Realist). In this view, the User still sees themselves as liberal but believes the Provider is acting with realist caution. This asymmetry sets the stage for a fragile interaction in which optimism and scepticism collide.

The resulting outcome produces a dual surprise. The Provider, anticipating full cooperation, is unsettled when the User does not fully reciprocate their liberal stance. At the same time, the User, who expected limited cooperation based on their G2 perspective, is also surprised by the Provider's optimistic move. Both parties are confronted with behaviour that does not match their initial assumptions, forcing them to reassess the situation.

In response, the players revise their beliefs simultaneously. The Provider, disappointed by the lack of full cooperation, updates their view of the User, shifting from liberal (G1) to realist (G2). The User, meanwhile, interprets the unexpected interaction as confirmation of deeper realist tendencies. This pushes them from a moderately cautious G2 perspective to a fully defensive G4 position, seeing the game as Realist–Realist. The new state that emerges is G2–G4, representing a shift of the perception into mutual defensiveness

Again the same dynamic can be found to exist in reverse, if the provider believes to be in a Realist-Liberal game and the user believes to be in a Liberal-Liberal game both will be surprised by the outcome leading to the G4-G3 hypergame of mutual defensiveness.

Convergence Toward a Shared Perception (G1-G4 → G2-G2 and G4-G1 → G3-G3)

The interaction begins with the actors holding completely opposing worldviews. The Provider is situated in G1, a state of pure liberal optimism, convinced that both sides are committed to cooperation. The User, however, stands at the opposite extreme in G4, interpreting the interaction as a purely realist struggle where caution and self-interest dominate. This polarisation means the two players are as far apart as possible in their perceptions of the game.

The outcome that follows delivers a profound dual surprise. The Provider, who expected mutual openness, is confronted with behaviour that does not align with their optimistic assumptions. At the same time, the User, anticipating only realist behaviour from the Provider, encounters a more cooperative move than expected. Both extreme perspectives are challenged simultaneously, leaving neither actor able to sustain their initial interpretation.

In response, the two players revise their beliefs in parallel. The Provider, shocked out of their liberal idealism, adopts a more cautious stance, moving from G1 to G2 by recognising the User's realist tendencies. The User, meanwhile, tempers their extreme realism after observing unexpected cooperation, shifting from G4 to G2. As a result, both actors converge on a shared G2–G2 state, representing a mutual Liberal–Realist perspective.

The same mechanism plays out in reverse when the User begins in a fully liberal state (G1) while the Provider adopts a purely realist stance (G4). Here too, the dual surprise unsettles both extremes: the User is forced to temper their optimism after facing unexpected defensiveness, while the Provider moderates their realism upon observing more cooperation than anticipated. As a result, both actors revise their beliefs towards the middle ground, converging on a shared G3–G3 state. This outcome mirrors the earlier G2–G2 convergence, but with the roles reversed, showing that extreme misalignments on either side can collapse into a more balanced, though still cautious, shared perception.

For Digital Sequence Information (DSI) governance, this dynamic carries important implications. It suggests that when parties approach negotiations from diametrically opposed extremes, a surprising event can act as a corrective shock, breaking down entrenched assumptions. Both sides abandon their ideological corners and move towards a shared, more moderate understanding. Although the new G2–G2 perception still reflects caution and competition, it provides a common frame of reference that can serve as a more realistic foundation for negotiation and cooperation.

7.2.3 Conclusion to Sub Question 3

Sub-question 3: *What are the dynamic trajectories of belief revision and system-wide transitions in DSI governance hypergames for understanding pathways to stable DSI outcomes over time?*

The dynamic analysis is built upon the notion that DSI governance hypergames do not remain static but evolve through belief revision triggered by strategic surprise. When outcomes deviate from what actors expect under their assumed game, providers and/or users update their perception of the other, shifting the system into a new hypergame state.

Three trajectories emerge from the analysis. First, cycles of misunderstanding occur, as in the loop between G1–G3 and G2–G1, where actors repeatedly cross paths in their beliefs, one becoming more cautious while the other becomes more optimistic, locking them into persistent misalignment and suboptimal outcomes. Second, spirals of escalating mistrust arise when partial cooperation collapses into defensiveness, as in transitions from G1–G2 to G2–G4 or from G3–G1 to G4–G3, reinforcing sovereignty-based behaviour. Third, moments of convergence are possible when actors begin from extreme misalignments (e.g., G1–G4), where dual surprises drive both sides toward a shared perception and away from a hypergame (G2 or G3). These dynamics suggest that while mistrust and misperception often erode cooperation, shocks according to this mechanism could occasionally realign beliefs and open a foundation for cautious but shared governance frames, enhancing negotiation.

8. Contextualizing the Governance of Digital Sequence Information

This chapter situates the hypergame analysis within the broader governance context of Digital Sequence Information (DSI). It examines how provider and user countries interpret and signal their positions, and how these interpretations shape trust, transparency, and strategic interaction. Particular attention is given to the operation of the Cali Fund, the voluntary role of private actors, and the incentives and uncertainties surrounding contributions. The chapter also highlights how informal diplomacy, historical legacies, and parallel international negotiations influence perceptions and outcomes. Together, these elements provide the necessary background to understand how asymmetric paradigms and interdependencies complicate cooperation and impact the stability of global DSI governance.

8.1 Influencing their moves

From the User side, one of the main questions, one might ask is how do they seem to influence their move at the moment, do they lean towards the liberal side or the realist side. In the end both provider and user said that the fund is supposed to be a bridge between private funding and governmental redistribution. Governments are not required to directly pay into the fund, the redivision is based upon payments from the private companies within those countries. These companies should check if they are within the threshold/scope of the Cali fund, if they are they should make a payment based upon the defined 1% of profit or 0.1% of revenue. As such states will have to cooperate with private actors in order to gain The fund has been operational since February, but not a penny had entered the fund in August, 2025 (Dwyer, 2025).

Governments, however, are not required to make binding law within the country to force companies to contribute to the fund if they are within scope. Within the EU this is also not on the agenda (Appendix C.2). A more soft approach seems to be taken towards the motivating of companies to contribute to the fund. They seem to approach this through informing companies, about what the Cali fund is and how they can find out if they are within scope (Appendix C.2).

An incentive the User countries are currently pursuing is the certificate that one should get after contributing sufficiently to the Cali Fund (Appendix C.2). However, as of now what exactly is on the certificate and what the certificate would entail is unclear. It might give the companies judicial clarity and possible exemption from bilateral measures by provider countries, however as discovered earlier the movement between Sovereignty and Multilateralism is a national decision. This uncertainty could lead to companies choosing to solely adhere to certain national legislations, over uncertain multilateral contributions.

So in this non-binding environment, how willing does the private sector seem to be is the next question. The private sector seems to have to get used to having to pay for information that is available in public databases (Appendix C.2). The User representative stated that the companies seem willing to pay and eager to make it work. However a lot seems to depend upon the development of the certificate, and the use of it for the companies. Things like climate change, and CO_2 seem to be understandable to the wider public, however, DSI neutrality seems to not be the most appealing or understanding for the average customer of a company.

That is possibly why it is often conflated or seen as one with biodiversity, by both countries and companies (Appendix C.2). All the payments and agreements have been tied to biodiversity, instead of traditional resources, such as oil, just requiring the sovereign state to do with it what it wants. Coupling it to biodiversity and Indigenous people and local communities, could be a pathway to make it more appealing for companies to want the certificate and to pay voluntarily.

The hope from User representative is also that there will be pressure from other organisations and groups, and not just from the governments. Organisations such as NGO's and the Civil society, however so far there does not seem to be a lot of pressure from these sides (Appendix C.2).

The providers however, regard it as pivotal to see what user countries are concretely undertaking to ensure money flows into the fund. As can be seen in the following exert from an interview with a provider representative.

"At its core, the Cali Fund is supposed to act as a bridge between private capital and the parties—specifically for DSI that falls within the agreed scope. But here is the issue: the mechanism only works if the countries where these companies are based take concrete steps to ensure those companies actually contribute. It is also up to those countries to define what the benefits are and what incentives should be offered to companies to encourage participation.

……………

Right now, the key question is: what concrete measures will the Global North implement to ensure that contributions are made? I do not think we will see many contributions before the next COP. A lot of the details still need to be worked out. The biggest challenge is designing the right incentives for companies to participate"

PROVIDER REPRESENTATIVE (APPENDIX C.1)

From the provider side the money that enters the fund has to be allocated to projects that are in line with the agreement. And here too a lot of progress has to be made, think about how the money will be spend, what type of reporting should be made, and what constitutes the division. A committee has been appointed and is working on this now, before the next cop there should be more clarity in this regard too (Appendix C.1 & 2).

As assessed earlier, provider countries have the power to put bilateral law into place. A positive indication of potential cooperation emerged at the launch, when Brazil proposed that national regulatory requirements could be considered satisfied if companies contributed adequately to the Cali Fund (Appendix C.2). However, as of now, no countries have pledged with certainty to leave their national regulation.

At the same time, the correspondents emphasize the informal part of implementation and power as important and harder to pinpoint (Appendix C.1 & 2). They describe constant efforts to talk with key countries (and former hosts) like the UK, Norway, South Africa, and others who chair or host events, using occasions such as London Climate Week to bring visibility and encourage company participation. Informal networks are used to connect businesses, stimulate support, and explore exemptions (e.g., paying into the Cali Fund in lieu of national measures). They stress that these backchannel interactions, "friends of the Cali Fund," retreats with negotiators and private sector actors, and trust-building outside rigid negotiations, are essential to keep momentum, create understanding, and avoid breakdowns. Ultimately, while the formal process sets the structure, representatives stat that it is also the informal exchanges between people that sustain and shape the fund's implementation, and could build trust.

> *"At the same time, we also try to exert influence informally. That informal contact is essential, as ultimately it is all people who carry this process."*
>
> USER REPRESENTATIVE (APPENDIX C.2)

8.2 Transparency of the moves

Another important aspect of building trust and cooperation is the ability to see transparently what the other does. How both of them see the moves differs significantly.

On the provider side, the degree of openness or restriction around DSI is relatively transparent. If a country decides to close access, this requires a legislative process and clear rules for how companies may obtain DSI, making the restriction visible to other states. By contrast, if a country keeps DSI open through the multilateral mechanism, no such bilateral legislation is needed, and this too is evident externally. What is far less visible, however, is how funds are allocated once they reach the national level. Whether contributions are actually spent on biodiversity objectives through national focal points is not easily observable by others. While this could, in theory, be ensured through extensive accounting and reporting, such oversight generates transaction costs and raises the challenge of identifying a trustworthy, neutral reporting mechanism.

This second point was also a point of concern for the user representative (Appendix C.2). The interviewee notes that while contributors to the Cali Fund cannot trace their payments directly to specific projects, since the mechanism is multilateral, companies still want clarity. Some sectors are reluctant to see funds spent on community welfare projects, such as housing, instead of biodiversity as the primary goal. This makes transparency from governments essential to provide the minimum information companies require to feel comfortable contributing, to again raise trust. The interviewee states that, within firms, boards ultimately decide, and their priorities may not include local community welfare. For example, debates arose over whether improving livelihoods meant cutting forests to build housing, something that clashes with biodiversity objectives.

On the other hand, the fund itself could be interpreted as the visible expression of the User's intent. For Providers, the inflow of money into the fund is relatively easy to observe, yet it is not an immediate process. While the total contributions are transparent, the measures taken by User countries to incentivise companies, particularly when these are based on soft encouragement rather than legally binding regulations, are far harder to monitor. This creates a time lag between domestic incentivisation and the actual accumulation of resources in the fund. As a result, liberal actions by Users cannot be directly equated with the level of money present at any given moment. This concern is echoed by the Provider representatives, who point out that without a trusted mechanism to signal genuine liberal intent (view 1), there is a risk of misinterpretation. Providers may hesitate to remain open if they fear that low contributions reflect deliberate realist behaviour (view 2) rather than a simple delay in funds becoming visible.

At the same time, both Provider and User representatives stress that benefit-sharing should extend beyond financial contributions (Appendix C). They highlight the importance of capacity building, information exchange, and the transfer of knowledge and technology as complementary mechanisms. These non-monetary forms of cooperation serve not only to deliver tangible value but also to strengthen trust between parties. By demonstrating commitment through broader collaboration, actors can signal alignment with view 1 rather than view 2. Combined with the informal channels of communication already identified, such measures help create a more credible foundation for mutual confidence and sustained cooperation.

8.3 Other Influences

The events of today cannot be seen entirely separate from the past and relationships that have been built between the countries and this too came forward in the interviews. The easiest point to make is the development of the Nagoya protocol, and how agreement on sovereignty led to the developed world not paying, or paying very little to gain access even after the treaty was set in place (Nehring, 2022). This has not played well for the trust between the countries, that this time an international agreement will actually work and lead to proportionate benefit sharing. This could drive towards a realist perception of the opponent from provider countries, making cooperation more difficult.

Historical relations surrounding resources between the developed and the developing countries, have not been, at best, in the general benefit of the developing countries. Multiple accounts of ‘biopiracy’ and ‘neo-colonialism’ have been uttered by critics on the geopolitical division of benefits from genetic resources in general (Nehring et al., 2022). Empirical evidence suggests that rhetorical alignment with cooperation norms does not always translate into structural reciprocity. Schrijver (2008) notes that developing countries have long viewed developed nations’ environmental diplomacy with suspicion, perceiving it as a means of securing compliance without redistributing power. With colonial pasts damaging the trust between the parties, as the user representative aptly said in the following quote.

> *“The debate on biopiracy also plays a role: genetic material that was once brought to gene banks continues to spark controversy. Some countries argue, ‘It is nice that you now have that material, but it was originally taken from us.’ This colonial past continues to linger in the background of these discussions.”*
>
> USER REPRESENTATIVE (APPENDIX C.2)

DSI also does not stand alone in negotiations and the Cali fund is seen by some of the users as a pilot for potentially opening up all genetic resources (Appendix C.2). The EU aims to keep access to genetic resources open and ultimately seeks a multilateral system that covers not only DSI but also physical genetic material. At the most recent CBD COP, the EU agreed to the current DSI fund mechanism with the expectation that, if it proves effective, it could later be extended to genetic resources (Appendix C.2). This would replace the current bilateral system, which is also fragmented and complex due to differing national interpretations and requirements(Appendix C.2).

At the same time, DSI is being negotiated in multiple international fora, including the FAO, WHO, the marine biodiversity treaty (BBNJ), and WIPO (Sett et al., 2024; Appendix C.2) . This makes DSI a strategically cross-cutting issue, as the user representative signalled. Within the CBD, many argue that it should fall entirely under its mandate, yet in practice there is no hierarchy between treaties, meaning that instruments can coexist and influence each other across different regimes. The central challenge, therefore, is not about exclusivity but about ensuring effective coordination and complementarity between these parallel processes.

Much of the debate centres on the question of “who should pay, and when?”, however there is also another objective: the conservation of biodiversity. The intention is not to obstruct innovation and research, but rather to support them through a system that remains simple and user-friendly, as both representatives stated (Appendix C.1 & 2). Failure to achieve this would be a serious setback for the CBD and the cooperation, especially given the recent adoption of the Global Biodiversity Framework. If the DSI fund does not succeed, it could undermine not only this mechanism but also other parts of the convention and the broader biodiversity goals.

8.4 Placement in the hypergame plane?

The fact that both are talking and setting up a fund seems to point towards a liberal paradigm from both parties, as do many of the previous analyses stemming from the interviews. They also seem to point towards, issues in trust and difficulty in perceiving the paradigm of the other. Both parties seem to doubt whether there is true intent, or false intent and showcase hesitance to commit before the other. Pointing to placement in the G2-G3 part of the hypergame plane, this is an extra tricky part of the hypergame plane because of two reasons: One, there is no surprise in both their games if they play out their game in this manner. In other words, they could be stuck in this equilibrium forever not knowing there was a better pareto optimal solution for both in the combined reality, resulting in fragmentation (V2, V2). Secondly if they don’t simultaneously break out of the G2-G3 game towards a G1 game, they will get stuck in the loop of misunderstanding (G1-G3 → G2-G1 → G1-G3), leading to unwanted exploitation of one to the other, and the other to the one.

This creates a paradoxical situation in which even if both actors genuinely hold liberal intentions, the interaction can still drift toward a suboptimal outcome. Each side must not only signal its own liberal outlook but also be convinced of the other’s commitment, a process made difficult by the asymmetry of incentives and historical grievances. As seen earlier, realist players gain the most when their counterpart assumes a liberal–liberal scenario (G1), which makes liberal signals inherently suspect. The Provider is particularly vulnerable to this dynamic, since its choices—either opening or restricting DSI—are highly visible and difficult to disguise. At the same time, the Provider must contend with the delay between the User’s domestic incentivisation efforts and the actual flow of contributions into the fund. This temporal gap increases uncertainty and heightens the risk that genuine liberal actions will be misinterpreted as realist manoeuvres, further complicating the possibility of sustained cooperation.

Furthermore, the weak institutionalisation of the Cali Fund, combined with its voluntary nature, leaves little solid foundation on which to build trust. In such an environment, even small doubts can escalate quickly: if either side begins to interpret the other’s behaviour as realist—whether or not this is actually the case—the interaction can rapidly deteriorate. Each subsequent move then reinforces the realist framing, making it increasingly difficult to reverse course. This dynamic implies that if both Provider and User are genuinely liberal, they must demonstrate their liberal intent as early and as clearly as possible. Only by doing so can they reduce the risk of misperception and give the Cali Fund a chance to function as a credible mechanism for cooperation.

For the cooperation to succeed, there must be credible ways for actors to demonstrate genuine liberal intent, while avoiding the perception of realist exploitation. At present, the voluntary nature of the Cali Fund creates a structural weakness: in a compromise system with limited transparency, delayed fund flows, and no real penalties, defecting or exploiting a liberal counterpart carries little immediate cost. Changing the game therefore could require concrete commitments that reduce uncertainty and signal trustworthiness.

On the User side, this could take the form of setting clear contribution goals, ensuring that a minimum amount is placed into the fund from the outset, and gradually transitioning to private sector financing. Transparency is equally vital: openly sharing which companies are expected to pay, how much they should contribute, and providing guarantees that voluntary mechanisms will become mandatory if they fail to deliver would strengthen credibility.

On the Provider side, trust could, for example, be built by showcasing concrete projects financed through the fund, demonstrating that benefits are directed towards biodiversity goals. Providers could also outline a roadmap to gradually phase out bilateral agreements, setting milestones that show progress while retaining the option to revert if necessary. Such signalling would reassure Users that cooperation will not come at the expense of sovereignty.

Together, these measures would help shift the interaction from a fragile voluntary compromise towards a more stable system, where liberal commitments are visible, verifiable, and less vulnerable to realist exploitation.

8.5 Conclusion to Sub Question 4

Sub-question 4: *How do the interdependencies between the CBD negotiations, other negotiations and national-level actor behaviours (states and private firms) complicate strategic interactions and impact the transparency and enforceability of DSI governance agreements?*

The interviews showed that DSI governance is deeply shaped by multi-level interdependencies. At the national level, user states rely on private firms to finance the Cali Fund, but contributions remain voluntary, with governments adopting a soft approach of information-sharing rather than binding regulation. This creates uncertainty, since providers cannot clearly observe whether low inflows reflect realist defection or merely domestic delays. Certificates of compliance and biodiversity-linked framing are intended to incentivise firms, yet their value remains ambiguous, leaving companies more inclined to follow national rules than uncertain multilateral ones. At the same time, it is not yet clear what exactly the money in the fund will be used for, creating uncertainty and a lack of institutional power to convince companies and user countries to enter the fund. Providers, meanwhile, weigh whether to phase out bilateral ABS measures, but hesitate without credible evidence that users will secure meaningful financial flows.

At the international level, the Cali Fund operates in parallel to other negotiations (e.g., FAO, WHO, BBNJ, WIPO), which overlap but lack coordination. This fragmentation weakens transparency and enforceability, as actors can "forum shop" or delay commitments. Multiple negotiations, need to be in line with each other and complement each other for the global DSI governance to strengthen.

Trust in the genuineness of the view 1 signalling of the other is further undermined by historical grievances over biopiracy and the legacy of the Nagoya Protocol, which foster scepticism among providers that new multilateral mechanisms will deliver equitable benefit-sharing. Informal networks ("friends of the Cali Fund"), NGO pressure, and visible biodiversity projects could help sustain cooperation, but the question is if they can build enough trust to overcome the lack of trust in one another.

Overall, these interdependencies create a paradox: even when both sides hold liberal intentions, weak institutionalisation, delayed contributions, and limited transparency risk trapping actors in suboptimal equilibria (e.g., G2–G3). If only one of them changes their view due to soft influence, they risk entering the loop of mistrust that was discovered earlier. Without clearer signals, such as early, visible contributions from users and concrete benefit-sharing projects from providers, the voluntary compromise risks being reinterpreted as realist exploitation, reinforcing mistrust and fragmentation.

9. Discussion

This discussion reflects on the main findings of the research, situating them within the broader literature on international relations, game theory, and global biodiversity governance. The aim is not only to interpret the results of the hypergame model, but also to assess their implications for both theory and practice. By doing so, the discussion highlights how the analysis advances understanding of Digital Sequence Information (DSI) governance, while also recognising its limitations and the scope for further inquiry.

The section proceeds in three steps. First, it evaluates the findings in relation to existing theoretical frameworks, comparing them with classical game theory and Axelrod's model of cooperation, and clarifying the added value of the hypergame approach. Secondly, it reflects on the methodological and empirical limitations of the study and thirdly it identifies promising avenues for future research.

9.1 Limitations

This research has several limitations that should be acknowledged, and the analysis is not a prediction of how the future will unfold in the DSI landscape. First, the simplified actor typology, limited to one provider and one user state, does not reflect the diversity of real-world stakeholders. Different states might account for different, tactics and the balance of the negotiation could become very different in a model with all the states on a spectrum from provider to user, and liberalism to realism. Private actors, scientific communities, and civil society also play important roles in the development and governance of Digital Sequence Information (DSI), and their interaction with states is not necessarily hierarchical. Moreover, actors may make decisions, also, in an evolutive rather than purely an eductive manner, a dimension that warrants further research to capture the dynamic evolution of governance arrangements.

Second, the hypergame model itself relies on simplifications. The belief revision mechanism only accounted for changes in perceptions of the other actor, whereas in practice actors may undergo deeper paradigm shifts in how they interpret the world. Only two interpretations of two paradigms, liberalism and realism, were considered, while in reality both contain multiple strands that could give rise to different strategic dynamics and many other theories could be regarded. The decision rules were also simplified: actors could only choose between Nash equilibria and were assumed to follow either payoff-based or risk-based reasoning. Although this clarified the analysis, it excluded the possibility of combining rules, accounting for more sources of "irrational" behaviour, or modelling intermediate strategies that might pave the way toward cooperation. Furthermore, the research accounted for dynamics, through belief changes, but did not account for scenario's in the development of DSI. Nor did it take into account the iterative component, that could build trust (Axelrod & Hamilton, 1981). Nor did it take into account that leaders and countries might change, and switch behaviour independently of the other, as became evident in the interview (Appendix C.1).

Third, the empirical grounding of the analysis was limited. The payoff structures were not validated with real negotiators or policy practitioners, which could have strengthened their validity and robustness. Such validation, however, would have been difficult to achieve, as the research design was deliberately constructed from opposite perspectives rather than relying solely on positions communicated by actors themselves, positions that may also reflect strategic signalling rather than genuine preferences. Similarly, the absence of quantifiable data in the field meant that payoffs were represented only as ordinal rankings, based on theory and qualitative analysis, rather than absolute values such as financial contributions or benefits. Qualitative insights were drawn from just four semi-structured interviews, constrained by limited time and resources, which restricts the empirical breadth of the findings. However, a structural sensitivity analysis was conducted to show what could change if the assumptions were different, shedding light on the robustness of the research.

Finally, the negotiations surrounding digital sequence information (DSI) cannot be considered in isolation from other international processes, as states have far more at stake than outcomes within the DSI arena alone. This interconnectedness was already noted in the methodology chapter and represents both a central characteristic of global governance and a recognised limitation of game-theoretic modelling. In practice, multiple dependencies, ranging from trade relations to security commitments, may influence whether countries choose to cooperate or defect in a certain non-isolated decision arena. Likewise, broader technological or economic developments can reshape the structure of the game itself, altering incentives and shifting the equilibrium outcomes that appear stable in a more abstract analytical framework.

9.2 Scientific Contribution and Added Value

Despite these limitations, the research achieved its primary aim: to demonstrate how asymmetric perceptions and misalignments can shape the governance of DSI and influence the trajectory of the CBD Cali Fund. By highlighting these dynamics, the study contributes to a clearer understanding of the fragility of cooperation and the conditions under which trust may erode or be sustained in global biodiversity negotiations.

The research helps set apart different perspectives and strategic options for countries in the negotiations surrounding DSI, making a complex topic slightly more understandable and relatable to a wider public. It identifies possible factors that could stand in the way of achieving genuine cooperation surrounding the Cali Fund and the CBD negotiations. It shows rational dynamics that support mistrusting one another, and can be used to identify different ways in which trust can be build. It also shows that the way the world is viewed is essential for establishing desirable outcomes for the parties involved in the CBD negotiations.

This research is not the first research conducted through game theory, to see if and how cooperation can occur, two of the most influential and groundbreaking have been Schelling (1960) and Axelrod & Hamilton (1981). However, this research advances strategic analysis by moving beyond the shared-reality assumption embedded in classical game theory and Axelrod's iterated model of cooperation.

Myerson (2009) argues that Schelling's *The Strategy of Conflict* revolutionised social theory by showing that cooperation is possible in adversarial contexts through focal points and credible commitments, and by forcing game theory to confront information, timing, and multiple equilibria as essential features of real-world strategic interaction. Schelling (1960) showed that cooperation can sometimes emerge even in adversarial situations, not through formal agreements, but through mechanisms such as focal points, solutions that stand out as obvious or natural and thus allow actors to coordinate without communication, and tacit bargaining, where players adjust their behaviour by interpreting signals, constraints, or expectations rather than through explicit negotiation. His analysis, however, remained rooted in strategic choice under uncertainty and the challenge of multiple equilibria, in a shared reality. Building on this foundation, Axelrod and Hamilton (1981) formalised the conditions under which cooperation could evolve and stabilise in repeated interactions. Using the iterated

Prisoner's Dilemma and computer simulations, they demonstrated that reciprocity, captured in the simple *Tit for Tat* strategy, you do something I do it back, could prove robust, stable, and viable over time, particularly when the likelihood of future encounters is high (Axelrod & Hamilton, 1981). Taken together, these contributions trace a progression: Schelling highlighted how coordination and commitment open space for cooperation in one-shot or adversarial contexts, while Axelrod and Hamilton showed how reciprocity enables cooperation to spread, endure, and resist exploitation in iterated settings.

Hypergame theory builds on this, the hypergame model developed here is also not the first hypergame model to exist. However, hypergame theory, first discussed in 1977 by Bennet, has not been executed in this way, connecting it to clear paradigms and a case study of complex international cooperation without clear institutions. Most of the hypergame theoretic research consists of simpler problems. Furthermore, the dynamic part of a hypergame has rarely been researched and no software had been developed to aptly analyse this (Kovach et al., 2015).

This research adds onto existing research because it shows how, the abandonment of an objective reality viewed by both actors, equally, can lead to irrational, surprising outcomes and how paradigms (or worldviews) can fuel cooperation, fragmentation or surprise. Furthermore, it shows how misunderstandings can persist, converge or change because of this, deeming repetition an insufficient reason for cooperation to emerge. Furthermore, by integrating established theories in International Relations it contributes to the understanding of the interaction between the two theories, and how liberal actors could act in realist ways and realist actors in liberal ways. This shift allows sensitivity testing and uncertainty analysis not only across payoff structures but also across paradigmatic framings, demonstrating that instability and fragmentation can arise through divergent interpretations of the world rather than conflicting material interests alone.

In summary, this research formalises a long-standing insight from political science: many international disagreements are not rooted solely in conflicting interests, but in incompatible perceptions of legitimacy, risk, responsibility and the likeness of the other. The hypergame framework moves beyond strategy alone to the domain of interpretation, offering a structured way to analyse how worldviews collide, and what that means for cooperation, conflict, and institutional design.

9.3 Future Research

Building on these findings, several directions for future research emerge. First, game-theoretic studies could extend this work by exploring cooperative game theory, which may better capture incentives for coalition building and collective benefit-sharing than the strictly competitive models applied here. Incorporating cooperative dynamics would also help clarify under what conditions joint outcomes can be sustained.

Second, greater attention should be given to the role of non-state actors. Future research could investigate how user states can effectively motivate private actors, scientific communities, and civil society to contribute to equitable DSI governance. This includes examining how capacity-building initiatives and institutional arrangements can be designed to foster trust and alignment across paradigms.

Third, methodological innovation offers promising avenues. Agent-based modelling could be applied to capture stochastic and heterogeneous interactions among multiple stakeholders, thereby complementing the deterministic assumptions of game theory. Similarly, hypergame theory itself could be advanced by integrating more divergent paradigms, testing new decision rules, and developing visual tools that make the effects of belief shifts and misalignments more transparent. Hypergames, should also be extended into even more rounds in the future, possibly integrating stochasticity for future changes in game structures.

Finally, future applications of hypergame analysis could extend beyond DSI to other complex global governance challenges, enabling comparative insights into how misperceptions and asymmetric framings affect cooperation in areas such as climate change, health, or intellectual property. By broadening both scope and method, future research can contribute to more robust institutional designs that mitigate misalignment and strengthen pathways toward durable cooperation.

10. Conclusion

The governance of Digital Sequence Information (DSI) remains contested, marked by unresolved debates over its definition, ownership, and benefit-sharing obligations under the Convention on Biological Diversity. While the establishment of the Cali Fund reflects growing recognition of DSI's economic and political significance, the lack of clarity on contributions, allocation, and enforcement perpetuates uncertainty and risks inequitable outcomes. This research is relevant because it addresses this governance gap by exploring how competing framings, DSI as a global commons or as a sovereign resource, interact with international relations paradigms, shaping incentives, cooperation, and the prospects for fair and effective global biodiversity governance within the space of the Cali fund.

Leading to the following research question: *How do asymmetric perceptions of Digital Sequence Information (DSI) framings and underlying International Relations paradigms lead to strategic misalignments and influence the stability of governance outcomes in global negotiations, in the context of the Convention on Biological Diversity (CBD) discussions?*

The analysis demonstrates that asymmetric perceptions of DSI framings and IR paradigms systematically destabilise negotiations and make cooperative outcomes fragile. At the strategic core, providers and users face a binary choice between openness (V1), aligned with a global commons framing, and control (V2), aligned with a sovereign resource framing. While mutual openness maximises collective benefit, sovereignty emerges as the more stable equilibrium across most game configurations, as liberal–liberal cooperation is rare and easily undermined by mistrust.

When perceptions diverge, liberal actors risk exploitation or defensive retreat, while realist actors gain by exploiting liberal counterparts or steering the system toward fragmentation. Payoff-based reasoning sometimes allows space for cooperation or exploitation, but risk-based reasoning consistently converges on mutual control. Sensitivity tests further show that outcomes hinge heavily on the *type of realist actor*, creating occasional openings for cooperation (the chicken game). In practice, however, most asymmetric framings produce non–Pareto-optimal equilibria.

Over time, these dynamics evolve through belief revision triggered by strategic surprise. The results reveal three main trajectories: (i) cycles of misunderstanding, where actors repeatedly misalign and fail to converge; (ii) spirals of mistrust, where failed cooperation hardens sovereignty positions; and (iii) rare moments of convergence, where shocks push both sides from extreme misalignments toward a shared but cautious middle ground. These dynamics illustrate that governance stability is path-dependent, with mistrust more likely to accumulate than dissipate.

Finally, the broader institutional and multi-level context compounds these challenges. At the national level, user states rely on voluntary private-sector contributions to the Cali Fund, but weak enforcement and ambiguous incentives limit credibility. Providers hesitate to abandon bilateral measures without visible financial flows, while at the international level, overlapping negotiations (CBD, FAO, WHO, WIPO, BBNJ) create fragmentation and opportunities for forum shopping. Historical grievances over biopiracy and the Nagoya Protocol further erode trust. While informal diplomacy and biodiversity-linked framing offer partial support, they might not be able to fully offset structural weaknesses in transparency and enforceability. As a result, even genuinely liberal intentions risk being reinterpreted as realist exploitation, trapping actors in fragile equilibria.

Though it can't be said with certainty, it seems as though the DSI negotiations are situated within the G2-G3 part of the hypergame plane. The G2–G3 part of the hypergame plane is particularly problematic for two reasons. First, actors can remain trapped in a stable but fragmented equilibrium (V2, V2), unaware that a more Pareto-optimal outcome exists in the combined reality. Second, if they fail to shift simultaneously toward a G1 framing, they risk entering a loop of repeated misperceptions (G1–G3 → G2–G1 → G1–G3), which results in cycles of mutual exploitation.

In sum, asymmetric perceptions of DSI framings and IR paradigms drive strategic misalignments that erode trust, amplify defensive behaviour, and push negotiations toward sovereignty-based fragmentation, even when mutual benefit is theoretically achievable. Stability in DSI governance therefore depends on reducing misperceptions through credible signalling, transparent contributions, and institutional mechanisms that can reassure actors of reciprocal liberal intent.

Although this research has limitations and should not be interpreted as a prediction of the future, it nonetheless yields several implications for policy making.

First, the problem of misalignment must be acknowledged, and transparency and communication between parties should be prioritised. Effective cooperation is not only a matter of acting in the spirit of the global commons but also of credibly signalling such intent to others. This underscores the need for institutions, transparency and clear agreements, with good communication from both sides. If both An easy first step in this could be the showcasing of small successes, the clear signalling of opening up and contributing. Furthermore, the establishment of contact and communication between the parties, should harness a lot of attention in order for the transparency and trust to foster.

Second, the creation of a cooperative DSI framework is not undermined solely by one actor's deliberate obstruction in the face of another's goodwill. Cooperation may also fail even when both parties express liberal intent. Once misalignment or distrust emerges, achieving a cooperative (V1,V1) outcome becomes increasingly difficult, while the deterioration into non-cooperative equilibria is comparatively easy. For this reason, stronger institutional frameworks should be established, and any lack of trust should be identified and addressed early, before it escalates. Simply waiting for the other party to act first is unlikely to succeed, and allowing the interaction to devolve into a chicken-game dynamic is equally risky, given that the actors involved are not guided exclusively by realist priorities.

Third, the phenomenon of instrumental liberalism, where liberal signals are deployed strategically to pursue realist objectives, must be acknowledged. In this context, the mistrust exhibited by parties is neither irrational nor merely perceptual. Scientists and proponents of open DSI frameworks should therefore exercise caution in pressuring provider countries to liberalise access. Without adequate institutional safeguards, the risk of extortion remains tangible, and liberal signals may be exploited for realist gain.

This leads to the implication that transparency, voluntary institutions, and non-binding agreements may prove insufficient. Without mechanisms that secure liberal intent, such commitments risk being exploited as framing devices for strategic gain, thereby exposing the other party to vulnerability. To mitigate this, enforceable mechanisms with clearly defined repercussions for non-compliance are necessary. Such measures not only signal intent and provide certainty but also alter the structure of the game itself, increasing the likelihood that both parties are genuinely engaged in the same strategic interaction.

As was established, the transparency of moves is not the same for both players, therefore, commitment initially should be undertaken by the user countries. Since opening up by the provider countries, is already letting go of much of the administrative control. How exactly the user countries could do this is not easily defined, and more research towards specific institutions that can foster this should be executed. However, a start could be to make it mandatory for companies to follow the regulation. Or user countries could consider a minimal contribution delivered by the user countries, based on predictions, while slowly interchanging this with private sector contributions. That way the responsibility of enforcing and the consequences of non-compliance by the private sector would lie with the user countries and not with the provider countries.

At the same time, user countries should retain an exit option if provider countries insist on asserting View 2, because exploitation is also possible from the other side. This could be operationalised through a clearly defined pathway towards zero bilateral agreements, supported by explicit benchmarks and contractual provisions. Under such a mechanism, if provider countries refuse to commit to the multilateral framework and continue to prioritise bilateral arrangements, the available funds would be progressively reduced and no allocations would be directed to these countries.

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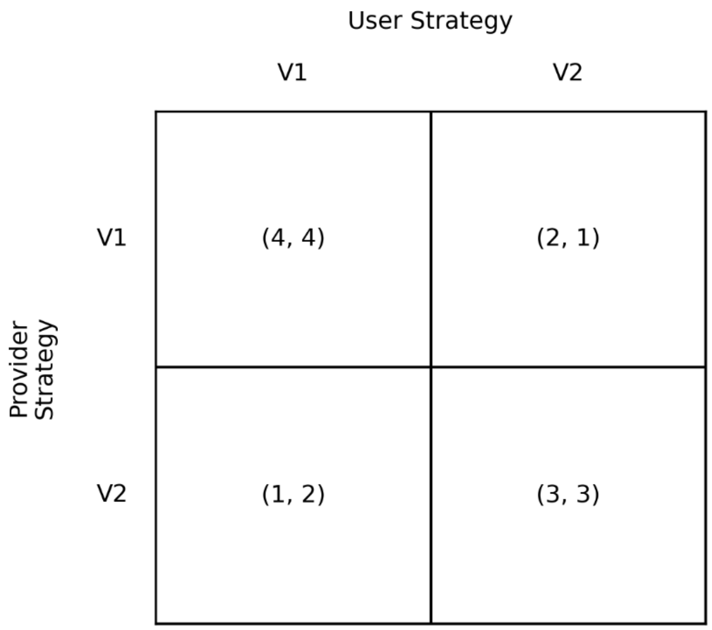
Appendix A: Assignment of the Payoffs

Game 1



Base Game G1

(V1, V1) , Mutual Openness with Effective Multilateral Benefit-Sharing via the Cali Fund

Provider score: 4 | User score: 4

This is the ideal liberal outcome. Both countries openly share their DSI and refrain from asserting control over downstream outputs. Data flows freely through public repositories, and scientific outputs, annotations, tools, and innovations, remain in the commons. The mutual openness enables global research, reinforces institutional trust, and aligns perfectly with liberal norms.

The **provider** sees high absolute benefit: even without direct material returns, it gains inclusion in global research, reputational capital, and access to a rich ecosystem of shared data.

The **user**, typically with greater technological capacity, still benefits from openness, gaining rapid access to diverse datasets, accelerating innovation, and maintaining long-term system efficiency. Although it could extract more in a realist posture, liberal logic prioritises system-wide benefit.

This outcome reflects:

- Strong **non-zero-sum logic**
- Full **trust and reciprocity**
- High **absolute gain** for both actors
- Reinforced **institutional stability**

→ **Both assign a score of 4.**

(V1, V2) - Exploitation with Undermined Multilateralism

Provider score: 2 | User score: 1

From a liberal perspective, this outcome is normatively troubling and materially disappointing. The **provider**, acting on the assumption of mutual benefit and trust, makes its DSI openly available to support global science. However, the **user breaks from liberal principles** by imposing proprietary control over outputs, filing patents, restricting use, and withholding downstream openness.

The **provider country**, while true to its cooperative framing, receives little in return. Since liberal actors care primarily about **absolute gains**, the provider still values its contribution to global knowledge production and possible indirect benefits (e.g. reputation, collaborations). However, the absence of reciprocity and the user's defection cause **erosion of systemic trust** and highlight **institutional fragility**. Hence, the provider assigns a **score of 2**, not a complete loss, but a degraded outcome relative to mutual openness.

The **user**, despite gaining strategic and economic benefit, must evaluate the outcome through liberal logic. From this perspective, **short-term exploitation damages long-term cooperation**, increases transaction costs, and weakens the institutions that sustain global scientific exchange. Because liberal actors value **interdependence and norms**, the user recognises that this behaviour undermines not only global trust but also its own long-term access to international data and collaboration. Thus, it assigns a **score of 1**, a materially beneficial but normatively self-defeating outcome.

This outcome violates key liberal expectations:

- **Non-zero-sum logic** is betrayed
- **Trust and reciprocity** are broken
- **Institutions are undermined**

It is therefore judged harshly by both actors, not because of relative losses (which liberals disregard), but because it **fails to sustain the cooperative system** they both value.

(V2, V1) , Controlled Provider, Open User with Asymmetric Institutional Participation

Provider score: 1 | User score: 2

Here, the **provider** asserts access control while the **user** remains fully open. From a liberal viewpoint, this is normatively inconsistent. The provider restricts DSI access and thereby limits global knowledge flows. While it may gain a sense of control, liberal logic sees this as a reduction in absolute benefit, visibility, and trustworthiness.

The **provider** assigns a **score of 1**, acknowledging that it has forfeited the systemic gains of openness and contributed to institutional fragmentation.

The **user**, by contrast, maintains an open stance. It continues to share outputs and uphold liberal values. However, due to the provider's restrictions, the user's access is limited, and the expected reciprocity is absent. Despite maintaining moral leadership, the user experiences reduced practical benefit, thus assigning a **score of 2**.

This outcome reflects:

- **Asymmetry in cooperation**
- One-sided openness
- Partial breakdown in **trust and norms**
- Missed potential for full mutual benefit

→ **Provider assigns 1; User assigns 2.**

(V2, V2) , Mutual Control and Systemic Fragmentation

Provider score: 3 | User score: 3

In this case, both countries assert control over both access and use. From a liberal perspective, this is not optimal, but it is at least **symmetric and stable**. Trust is absent, but so is exploitation. Each actor defends itself in the face of anticipated non-cooperation.

The **provider** recognises the cost of fragmentation: scientific isolation, reduced visibility, and slower innovation. But it avoids being taken advantage of, and maintains some degree of fairness in institutional terms. It assigns a **score of 3**, not ideal, but defensible.

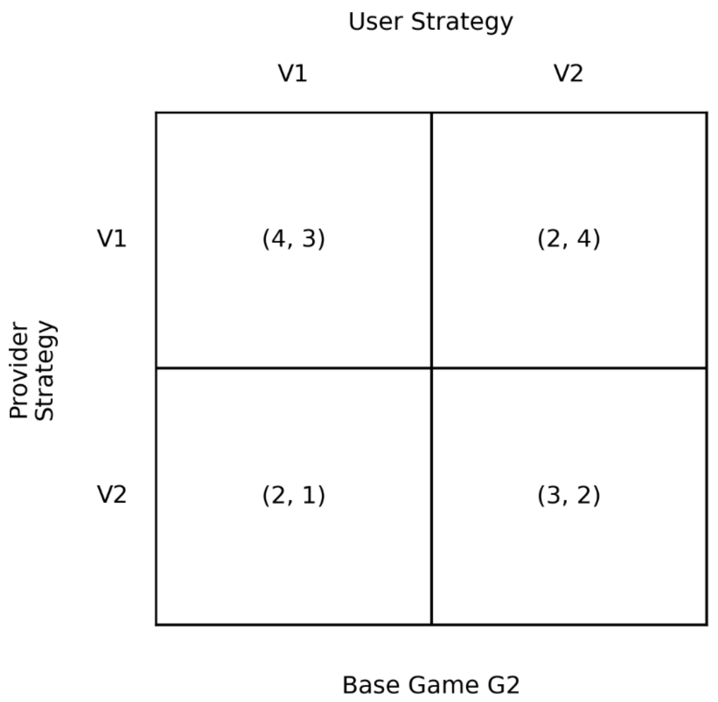
The **user** sees a similar situation. Global cooperation has stalled, and scientific efficiency suffers. But sovereignty is respected and neither side has been exploited. The system is inefficient, but it avoids liberal betrayal. Thus, the **user** also assigns a **score of 3**.

This outcome reflects:

- **Mutual withdrawal**
- Loss of **trust**, but preservation of **parity**
- Reduced **absolute gains**, but no exploitation
- A second-best, sustainable fallback

→ **Both assign a score of 3.**

Game 2



(V1, V1) , Mutual Openness with Effective Multilateral Benefit-Sharing via the Cali Fund

Provider score: 4 | User score: 3

The provider embraces full openness, sharing DSI without conditions and assuming the user will do the same. From a liberal view, this outcome is highly desirable: the provider contributes to global knowledge flows, reinforces institutional legitimacy, and benefits from scientific reciprocity. Although it does not control downstream use, it gains visibility, collaborations, and absolute benefit, thus assigning a score of 4.

The user, however, sees this differently. From a realist perspective, choosing not to assert control represents a missed opportunity. Although the user still gains access and retains technological dominance, it foregoes relative advantage by failing to extract maximum value from the provider's openness. It benefits, but less than it could have through strategic assertion, thus assigning a score of 3.

This outcome reflects:

- Provider (Liberal): High absolute benefit through cooperation
- User (Realist): Positive gain, but failure to exploit asymmetry

(V1, V2) , Exploitation with Undermined Multilateralism

Provider score: 2 | User score: 4

The provider shares DSI openly, expecting mutual benefit. However, the user asserts sovereignty and encloses outputs. From a liberal perspective, this outcome is deeply disappointing: the provider upholds norms but is exploited. Trust is violated, institutional integrity erodes, and material returns are minimal. The provider still values symbolic benefit and reputational credibility, but assigns only a **score of 2**.

The user, from a realist viewpoint, considers this the optimal outcome. It maximises control over derived products, secures intellectual property, and gains leverage in future negotiations, all without making concessions. It achieves the greatest **relative gain** with minimal risk or reciprocity. This is **strategic dominance under anarchy**, thus earning a **score of 4**.

This outcome reflects:

- **Provider (Liberal):** Betrayed expectations, symbolic gain only
- **User (Realist):** Maximum value extraction and control

(V2, V1) , Controlled Provider, Open User with Asymmetric Institutional Participation

Provider score: 2 | User score: 1

The provider asserts access control but sees the user remain open. For a liberal actor, this outcome is internally inconsistent. While it avoids exploitation, it loses the legitimacy and benefits associated with openness. Trust is not built, and global cooperation is stalled. This trade-off results in moderate regret, leading to a **score of 2**.

The user, acting as a realist, sees this as its **least desirable outcome**. It acts cooperatively, but the provider closes off access. This undermines the user's strategy and exposes it to criticism for being naïve or weak. No meaningful gain is achieved, and its openness is unreciprocated, thus assigning a **score of 1**.

This outcome reflects:

- **Provider (Liberal):** Some control gained, but at cost to values and visibility
- **User (Realist):** Strategic exposure and institutional embarrassment

(V2, V2) , Mutual Control and Systemic Fragmentation

Provider score: 3 | User score: 2

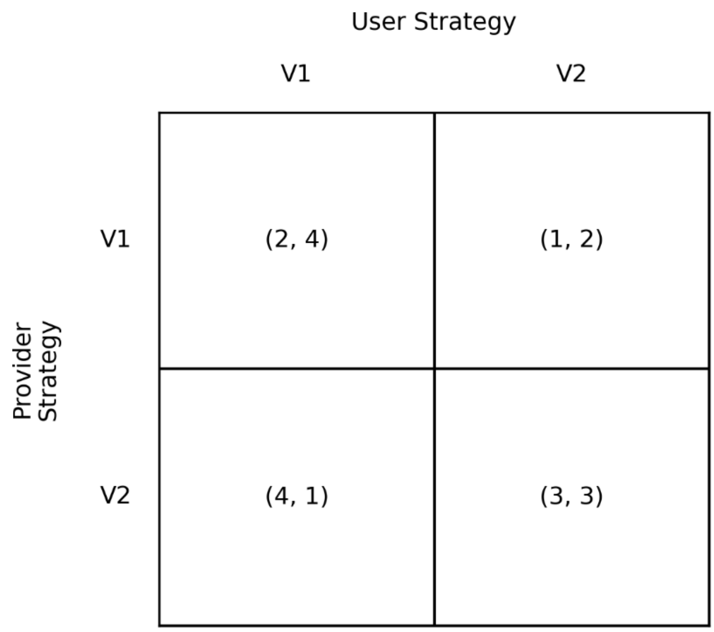
Here, both countries assert sovereignty over access and outputs. From a liberal standpoint, this is suboptimal but tolerable. Although openness and cooperation are lost, the provider avoids being exploited. Parity is restored, and future cooperation may still be possible through renegotiation. It is a strategic fallback that preserves defensive legitimacy, thus earning a **score of 3**.

From the realist user's perspective, this outcome offers stability, but not dominance. It protects sovereignty and limits exposure, yet also blocks the user's ability to extract asymmetric value. The system becomes inefficient, and innovation slows. Compared to unilateral assertion (V1, V2), this is a less profitable outcome, thus scoring **2**.

This outcome reflects:

- **Provider (Liberal):** Stable defence, no exploitation, but reduced global benefit
- **User (Realist):** Control preserved, but opportunity for strategic gain lost

Game 3



Base Game G3

(V2, V1) - Controlled Provider, Open User with Asymmetric Institutional Participation

Provider score: 4 | User score: 1

The realist provider asserts full control over DSI access, enforcing national-level restrictions, requiring benefit-sharing agreements, or routing sequences through domestic repositories. Meanwhile, the liberal user remains open, allowing outputs to be shared and freely reused. From the provider's perspective, this is the optimal outcome. By withholding upstream access while benefiting from the user's downstream openness, it secures maximum relative gain. It avoids strategic vulnerability, maintains sovereignty, and converts asymmetric openness into geopolitical advantage. This aligns directly with realist principles: in a world without central authority, self-help and control over key assets, such as digital biodiversity, are paramount. No trust is needed; only leverage matters. The provider assigns a score of 4 for having achieved dominance without concession.

In stark contrast, the liberal user interprets this outcome as systemically corrosive. Its cooperative stance is unreciprocated, and institutional expectations are violated. Although it maintains moral high ground and benefits somewhat from self-generated openness, the denial of access to provider DSI limits innovation, weakens interdependence, and erodes trust in the overall governance system. Liberal logic values absolute gains, but also relies on reciprocity, institutional norms, and stable expectations. Here, those norms have failed. The user assigns a score of 1, it may not be materially empty, but it is normatively and strategically disappointing.

This outcome reflects:

- **Provider (Realist):** Strategic dominance and maximal control
- **User (Liberal):** Systemic disappointment and asymmetrical exposure

(V1, V1) - Mutual Openness with Effective Multilateral Benefit-Sharing via the Cali Fund

Provider score = 2 | User score = 4

The realist provider chooses to cooperate by sharing its DSI through open-access channels without imposing conditions. It assumes that the user will also cooperate, and this expectation is met: the user remains open and refrains from asserting downstream control. However, despite the surface symmetry, the realist actor interprets this outcome as a strategic compromise. While it may benefit indirectly through collaboration and goodwill, the lack of control over how its data is used, especially by a more technologically advanced partner, presents a risk of relative loss. The provider gains absolute benefit, but not relative security. It has no guarantee of future leverage, nor control over downstream applications. From a realist standpoint, this is a missed opportunity to assert sovereignty or shape the terms of exchange. The provider assigns a score of 2: the outcome is peaceful but leaves it exposed.

The liberal user, by contrast, sees this outcome as ideal. Both parties uphold norms of openness, data sharing, and institutional trust. Scientific progress is enhanced, transaction costs are low, and global knowledge production is accelerated. Since liberal actors care about absolute gains, the user recognises significant value in seamless access to DSI, participation in global innovation ecosystems, and the long-term stability this configuration offers. The fact that the provider does not assert control reinforces the liberal belief that cooperation can be sustained across diverse actor types. The user assigns a score of 4, viewing this as a validation of liberal logic even in the presence of a realist counterpart.

This outcome reflects:

- **Provider (Realist):** Loss of leverage and exposure to systemic risk
- **User (Liberal):** Ideal scenario of cooperation and institutional reciprocity

(V1, V2) - Exploitation with Undermined Multilateralism

Provider score = 1 | User score = 2

In this configuration, the realist provider chooses to share DSI openly, but the user asserts downstream control over derived outputs. This is a worst-case outcome for the realist. By allowing unrestricted access to its data, the provider forfeits strategic leverage. It receives no guarantee of reciprocity, and the user capitalises on this openness to claim patents, restrict re-use, or consolidate commercial control. From a realist perspective, this is not just inefficient, it is strategic exposure. It violates core realist principles: the provider loses control, gains nothing in return, and strengthens a potentially rivalrous actor. Trust is irrelevant in this frame; control is everything. As a result, the provider assigns a score of 1, reflecting a perceived loss of both power and sovereignty.

The liberal user, although benefitting materially from the data and securing innovation pathways, must reconcile its behaviour with liberal norms. By asserting control while receiving data openly, it violates principles of reciprocity, openness, and fairness. Even if justified internally as pragmatic, this behaviour undermines the user's own credibility and may damage long-term cooperation. While the short-term gains are tangible, the broader system of institutional trust is weakened. The user assigns a score of 2, it is a profitable outcome, but a normatively inconsistent and unstable one.

This outcome reflects:

- **Provider (Realist):** Strategic exposure and normative loss

- **User (Liberal):** Material gain at the cost of systemic credibility

(V2, V2) Mutual Control and Systemic Fragmentation

Provider score = 3 | User score = 3

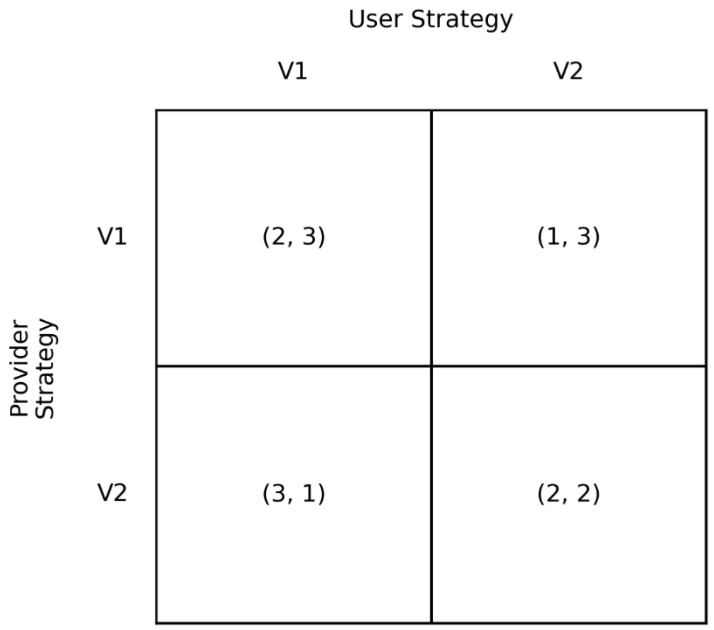
In this outcome, both actors assert full control over their DSI inputs and outputs. The realist provider views this as a balanced and sustainable outcome. It maintains control over its own resources, imposes conditions on access, and mirrors the user's assertive behaviour with strategic symmetry. Although this restricts scientific cooperation and reduces efficiency, the realist is not concerned with collective optimisation. Instead, it values the absence of exposure and the preservation of sovereignty. Relative parity is maintained, and no actor is exploited. The provider assigns a score of 3, this is not a dominant win, but a stable and secure configuration that upholds core realist principles.

For the liberal user, the outcome is more ambiguous. Openness is lost, data flows are fragmented, and the institutional order is weakened. However, since both parties assert control symmetrically, no actor defects from shared expectations. The user avoids exploitation and retains autonomy, even if the cost is reduced efficiency. It sees the situation as a disappointing, but fair, fallback. The liberal framework is not vindicated, but the actor avoids being taken advantage of. The user assigns a score of 3, not optimal, but acceptable under conditions of systemic mistrust.

This outcome reflects:

- **Provider (Realist):** Strategic symmetry and sovereignty preserved
- **User (Liberal):** Acceptable equilibrium under constrained conditions

Game 4



Base Game G4

(V1, V1) , Mutual Openness with Effective Multilateral Benefit-Sharing via the Cali Fund

Provider: Realist (score = 2) | User: Realist (score = 3)

Both actors adopt an open strategy. From the realist provider's perspective, this outcome offers moderate gains but comes at the cost of strategic exposure. By making its DSI freely accessible, it gives up control without any guarantee of long-term influence or leverage. Yet since the user also refrains from asserting control, the provider avoids direct exploitation. This symmetrical openness is strategically tolerable but not preferable, earning a score of 2.

The realist user, in contrast, views this as highly advantageous. It gains unrestricted access to external DSI while leveraging internal capacity to extract more value. By avoiding downstream restrictions, it maintains a cooperative image while still maximising its relative gain. As long as the provider remains open, the user stays dominant, assigning a score of 3.

This outcome reflects:

- Provider (Realist): Cooperative parity, with exposure but no exploitation
- User (Realist): Superior benefit under a permissive and symmetric system

(V1, V2) , Exploitation with Undermined Multilateralism

Provider: Realist (score = 1) | User: Realist (score = 3)

This outcome creates a highly asymmetric configuration. The realist provider opens access to its DSI while the user asserts control over outputs. From the provider's viewpoint, this is a strategic failure: it enables unilateral value extraction by the user without securing reciprocal rights or access. It forfeits sovereignty while strengthening the user's position, earning a score of 1, the lowest assigned.

The user, on the other hand, sees this as a dominant outcome. It receives provider data at no cost while securing its own innovations behind output controls. This is the realist ideal: asymmetric gain without obligation. While it may trigger future defection, the present benefit is high, thus, a score of 3.

This outcome reflects:

- Provider (Realist): Maximum exposure and strategic loss
- User (Realist): Maximum asymmetrical benefit through unilateral assertion

(V2, V1) , Controlled Provider, Open User with Asymmetric Institutional Participation

Provider: Realist (score = 3) | User: Realist (score = 1)

Here, the provider asserts access control while the user remains open. For the provider, this is the optimal configuration: it withholds DSI while benefiting from the user's downstream transparency. It retains full leverage, avoids exposure, and positions itself as the strategic gatekeeper, assigning a score of 3, its highest value.

The user, however, experiences the inverse. By sharing results and receiving no provider input, it is strategically undermined. This configuration represents exploitation under realist logic: the user gains little and empowers a non-reciprocating partner. It assigns a score of 1, matching (V1, V2) in terms of asymmetrical loss.

This outcome reflects:

- Provider (Realist): Strategic dominance through unilateral control
- User (Realist): Structural exposure and relative weakness

(V2, V2) , Mutual Control and Systemic Fragmentation

Provider: Realist (score = 2) | User: Realist (score = 2)

In this scenario, both actors assert control, provider over access, user over outputs. From a realist perspective, this outcome ensures sovereignty and strategic parity. While cooperation is lost and innovation may slow, no party is exposed or exploited. The provider assigns a score of 2, equal to (V1, V1), because both outcomes preserve balance, one through openness, the other through controlled symmetry.

The user, too, views this as a stable fallback. Although no DSI is gained from the provider, control over its own outputs is preserved. It is neither dominant nor exploited. The strategic environment becomes bilateral and cautious. The user also assigns a score of 2, recognising a fair but constrained equilibrium.

This outcome reflects:

- Provider (Realist): Secure sovereignty with no leverage gained
- User (Realist): Stable protection with limited strategic opportunity

Appendix B: Hypergame Analyses

What follows is a table that summarises the main dynamics and insights for each hypergame. Its purpose is to provide a concise overview of the key takeaways from the analysis presented in Appendix B. Rather than going into detailed explanations, the table highlights the central patterns and lessons of each game, offering the reader a quick reference to the most important insights.

Hypergame	Category	Analysis
G1–G2 (Liberal Provider vs. Realist User): Exploited Cooperation.	Payoff-Based:	The Provider, expecting mutual liberalism (G1), plays V1 (Openness). The User, operating as a realist (G2) and seeking to maximise gain, plays V2 (Control). This results in an exploitative outcome (V1, V2; 1, 4) in the Combined Reality, where the Provider is left vulnerable.
	Risk-Based:	Both actors, prioritising security, converge on mutual control (V2, V2; 3, 2). The Provider sacrifices potential gains to avoid exploitation, and the User opts for security over maximum unilateral gain.
	Insight:	This highlights how a liberal Provider can be exploited (payoff-based) or forced into a defensive, suboptimal stance (risk-based) by a realist User. Trust is eroded, and the Provider is structurally disadvantaged.
G1–G3 (Liberal Provider vs. Misperceiving Liberal User): Misread Intentions.	Payoff-Based:	The Provider plays V1 (Openness). The User, despite being liberal, misperceives the Provider as realist (G3) and defensively plays V2 (Control). This leads to a suboptimal outcome (V1, V2; 1, 2) in the Combined Reality.
	Risk-Based:	Both the Provider and the User, being risk-averse and with the User misperceiving the Provider as realist, converge on mutual control (V2, V2; 3, 3).
	Insight:	Liberal cooperation is precluded not by direct hostility, but by anticipatory defensiveness stemming from a fundamental misperception. Even when both parties are genuinely liberal, a lack of trust and clear signalling leads to fragmented outcomes.
G1–G4 (Liberal Provider vs. Realist User): Strategic Collapse.	Payoff-Based:	The Provider's cooperative gesture (V1) is met with full realist strategic containment (V2) from the User. This results in an exploitative outcome (V1, V2; 1, 3) in the Combined Reality.
	Risk-Based:	Both the Provider (due to risk aversion) and the User (due to inherent realism and risk aversion) converge on mutual control (V2, V2; 3, 2).
	Insight:	A complete paradigm misalignment leads to an inefficient but stable equilibrium. The User's deep-seated realist assumptions view even sincere openness as a threat, driving the system towards fragmentation.
G2–G1 (Liberal-Realist Provider vs. Liberal User):	Payoff-Based:	The Provider, believing the User is realist (G2), plays defensively (V2). The User, being liberal (G1) and expecting cooperation,

Pre-emptive Defection.		plays optimistically (V1). This results in a mis coordinated outcome (V2, V1; 2, 1) in the Combined Reality.
	Risk-Based:	Both the Provider and the User, when prioritising risk mitigation, converge on mutual control (V2, V2; 3, 3).
	Insight:	Cooperation is undermined not by bad intent, but by the Provider's defensive overestimation of strategic risk. The liberal User is "punished" for their openness, as their cooperative move is met with unexpected defection.
G2–G3 (Liberal-Realist Provider vs. Realist-Liberal User): Mirrored Misperception.	Payoff-Based & Risk-Based (Identical Outcome):	Both actors believe the other is realist, despite both having liberal leanings. Both choose V2 (Control) due to this misperception and their respective strategic drivers. This results in mutual control (V2, V2; 3, 3) in the Combined Reality.
	Insight:	A missed opportunity arises from mutual defensive assumptions. Despite having a shared potential for cooperation, both actors converge on a suboptimal stalemate, demonstrating how perceived risk overrides potential mutual gain.
G2–G4 (Liberal-Realist Provider vs. Realist User): Strategic Disjunction.	Payoff-Based & Risk-Based (Identical Outcome):	The Provider (G2) attempts conditional cooperation, but the User (G4) assumes full realism from both sides and defaults to sovereign control (V2). This results in mutual control (V2, V2; 3, 2) in the Combined Reality.
	Insight:	The User's assumption of a double-realist game effectively blocks the emergence of mutual cooperation. The more risk-averse paradigm in the hypergame consistently dictates the equilibrium, sacrificing efficiency for stability
G3–G1 (Realist Provider vs. Liberal User): Strategic Exploitation Meets Vulnerability.	Payoff-Based:	The Realist Provider (G3) chooses V2 (Control) to maximise gain, while the Liberal User (G1) chooses V1 (Openness) expecting reciprocity. This results in (V2, V1; 4, 1) in the Combined Reality, where the Provider effectively exploits the User's liberal stance. The User experiences a substantial missed opportunity.
	Risk-Based:	Both the Realist Provider (G3) and the Liberal User (G1) converge on mutual control (V2, V2; 3, 3) due to risk aversion. The Provider secures a guaranteed payoff, and the User sacrifices potential cooperation for security.
	Insight:	A Realist Provider's assertiveness can consistently undermine a Liberal User's cooperative intent. Whether driven by gain or risk, the Provider's realist perception leads to outcomes where the User's openness is either exploited or met with defensive containment.
G3–G2 (Realist-Liberal Provider vs. Liberal-Realist User): Reciprocal Misreading and Strategic Defensiveness.	Payoff-Based & Risk-Based (Identical Outcome):	Both actors believe the other is liberal (Provider sees User as G2; User sees Provider as G3) and attempt to assert sovereignty (V2) to gain advantage. This results in mutual control (V2, V2; 3, 2) in the Combined Reality.

	Insight:	A missed opportunity arises from mutual overconfidence and defensive assumptions. Despite each believing the other is liberal, their strategic caution leads to a suboptimal stalemate, where cooperation collapses into containment.
G3–G4 (Realist Provider vs. Realist User): Strategic Assertion and Reinforced Realism.	Payoff-Based & Risk-Based (Identical Outcome):	The Provider (G3) attempts to assert strategically, while the User (G4) anticipates this assertion and acts pre-emptively (V2). This results in mutual control (V2, V2; 3, 2) in the Combined Reality.
	Insight:	This hypergame illustrates a structural impasse where opportunistic realism encounters defensive realism. Both actors play V2 due to perceived risk, leading to a stable but inefficient equilibrium, where cooperation is strategically implausible.
G4–G1 (Realist Provider vs. Liberal User): Realist Control Meets Cooperative Optimism.	Payoff-Based:	The Realist Provider (G4) chooses V2 (Control) for security, while the Liberal User (G1) chooses V1 (Openness) expecting reciprocity. This results in (V2, V1; 3, 1) in the Combined Reality. The User's cooperation is met with defection.
	Risk-Based:	Both the Realist Provider (G4) and the Liberal User (G1) converge on mutual control (V2, V2; 2, 3) due to risk aversion.
	Insight:	A profound mismatch where the Realist Provider's entrenched perception consistently leads to outcomes where the Liberal User's openness is either directly exploited or met with defensive containment, highlighting a significant missed opportunity for mutual benefit.
G4–G2 (Realist Provider vs. Liberal-Realist User): Realist Entanglement under Asymmetric Defensiveness.	Payoff-Based & Risk-Based (Identical Outcome):	Both actors frame the interaction strategically, but with different assigned roles. The Provider (G4) acts defensively (V2). The User (G2), believing the Provider is liberal, also ultimately chooses V2 (Control) for security. This results in mutual control (V2, V2; 2, 2) in the Combined Reality.
	Insight:	This highlights how interlocking misperceptions and asymmetric defensiveness can generate a suboptimal equilibrium that neither side initially sought. The User's assumption of a double-realist game, even if only for themselves, effectively blocks mutual cooperation.
G4–G3 (Realist Provider vs. Realist-Liberal User): Strategic Realism Meets Defensive Liberalism.	Payoff-Based & Risk-Based (Identical Outcome):	The Provider (G4) perceives a fully realist interaction and chooses V2 (Control). The User (G3), believing the Provider is realist and acting defensively, also chooses V2 (Control). This results in mutual control (V2, V2; 2, 3) in the Combined Reality.
	Insight:	Both actors act from risk aversion rather than aggression, producing a gridlocked equilibrium. Cooperation is impossible

		not because of conflicting preferences, but because both players assume the other will defect first.

Table B.1: Summary of Insights Hypergame Analysis

For a more detailed analysis of the generated figures, the following section examines each hypergame individually.

Hypergame G1–G2: Liberal Provider vs Realist User

Scenario 1: Payoff-Based Strategy

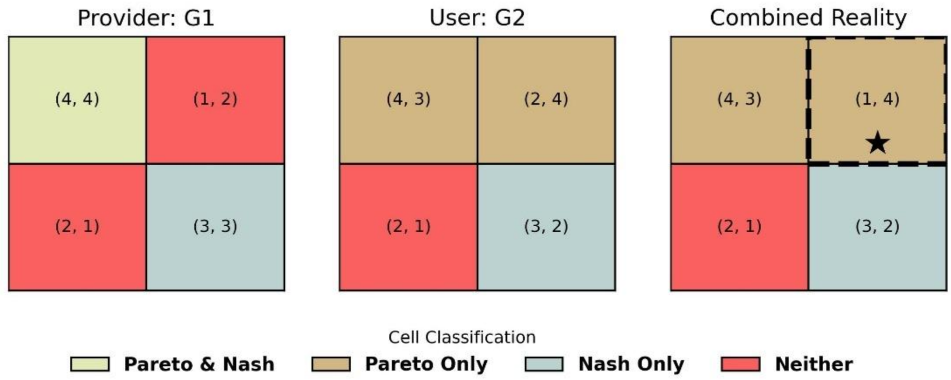


Figure B.1: Hypergame G1-G2 Payoff

In this scenario, both the Provider and the User base their decisions on maximising their individual payoffs.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G1 (Liberal–Liberal) game, mutual openness (V1, V1) is the most desirable outcome, yielding a payoff of (4, 4). This cell is highlighted as both a Pareto Optimal solution and a Nash Equilibrium, firmly rooting the Provider's expectation in reciprocal benefit and the idea that shared access maximises collective gains. The Provider perceives this outcome as stable and just, aligning with liberal norms of cooperation and absolute gains. They anticipate that by choosing V1 (Openness), the User will reciprocate, leading to this mutually beneficial state. Other outcomes, such as (V1, V2) (2, 1), are seen as considerably less favourable, representing a situation where the Provider is open but the User asserts control, leading to a diminished return for the Provider.

User's Perceived Game (Centre Matrix)

Conversely, the User interprets the interaction through the lens of a G2 (Liberal–Realist) game, prioritising national interest and seeking to maximise relative gains. From this realist-influenced viewpoint, the outcome (V1, V2), with a payoff of (1, 4), is considered Pareto Optimal. While it provides the User with their highest payoff (4) in this matrix, it is *not* a Nash Equilibrium from the User's perspective. The User perceives (V2, V2) (3, 2) as the Nash Equilibrium, offering a stable fallback position. Crucially, the User perceives (V1, V1) (4, 3) as Pareto Optimal but not their best strategic response, as it leaves less room for unilateral advantage and potential exploitation of the Provider's openness. The User is strategically alert to opportunities to gain disproportionately.

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based)

The Combined Reality matrix, derived from the Provider's actual payoff (from G1) and the User's actual payoff (from G2), presents the true landscape of incentives. In this scenario, the Provider, acting on their liberal expectation, selects **V1** (Openness). The User, driven by their realist perception to maximise gain, selects **V2** (Control). This leads to the chosen outcome of **(V1, V2)** in the Combined Reality matrix, delivering a payoff of **(1, 4)**. This outcome is marked with a star (★) and a dashed border, signifying the point where their individual strategies converge. Critically, this outcome is Pareto Optimal in the Combined Reality, as neither player could achieve a higher payoff without the other receiving a lower one. However, it is important to note that this chosen outcome (V1, V2) is not a Nash Equilibrium in *either* the Provider's or the User's perceived game, indicating a significant strategic misalignment that creates instability from both actors' individual viewpoints, despite the User's immediate high payoff.

Scenario 2: Risk-Based Strategy

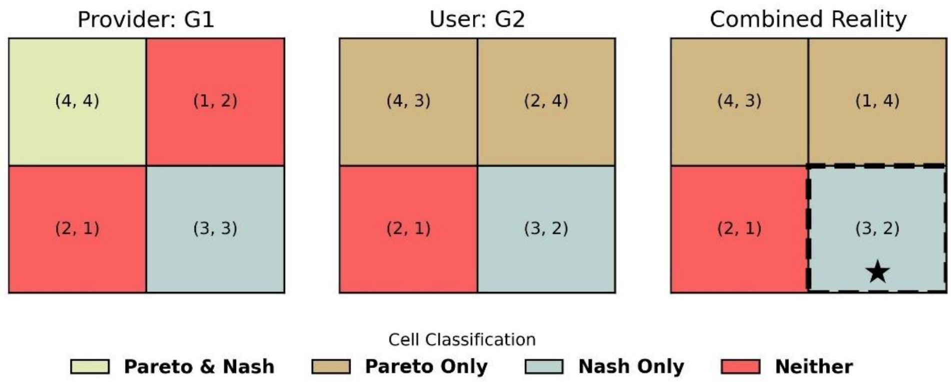


Figure B.2: Hypergame G1-G2 Risk

In this scenario, both the Provider and the User base their decisions on minimising potential losses or ensuring a secure outcome.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G1 (Liberal–Liberal) game, mutual openness (V1, V1) remains the ideal outcome, yielding (4, 4) and classified as both Pareto Optimal and a Nash Equilibrium. However, when the Provider shifts to a risk-based strategy, their focus moves to potential downsides. They carefully consider the outcome of V1 (Openness) if the User unexpectedly chooses V2 (Control), which would result in a payoff of (2, 1). This risk of unreciprocated openness makes the Nash Equilibrium (V2, V2), with a payoff of (3, 3), a far more appealing and secure option. By choosing V2 (Control), the Provider guarantees a stable payoff that is less susceptible to the User's potentially uncooperative behaviour, even if it means foregoing the higher gains of V1,V1.

User's Perceived Game (Centre Matrix)

Conversely, the User interprets the interaction through the lens of a G2 (Liberal–Realist) game, prioritising national interest and seeking to maximise relative gains, but now with a strong emphasis on risk mitigation. While the outcome (V1, V2) (2, 4) offers the User their highest payoff and is Pareto Optimal, it is not a Nash Equilibrium. The User, employing a risk-based strategy, will therefore focus on securing a stable minimum payoff. The Nash Equilibrium (V2, V2) (3, 2) offers a more reliable outcome, as it provides a secure payoff (2 for the User) regardless of the Provider's action. This prioritisation of a guaranteed outcome means the User is less likely to pursue the high-gain (V1, V2), as it entails the risk of the Provider also playing V1 and potentially leaving the User with a less favourable payoff. Consequently, the User is strongly inclined to choose V2 for security.

Combined Reality (Right Matrix) and Chosen Outcome (Risk-Based)

The Combined Reality matrix, derived from the Provider's actual payoff (from G1) and the User's actual payoff (from G2), presents the true landscape of incentives. In this scenario, both the Provider and the User adopt a risk-based strategy. The Provider, wary of the risk of being exploited in (V1, V2), leans towards **V2** (Control) for security. Similarly, the User, also prioritising security over maximal unilateral gain, selects **V2** (Control). This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 2)**. This outcome is marked with a star (★) and a dashed border, signifying the point where their individual strategies converge. Critically, this outcome (V2, V2) is a Nash Equilibrium in *both* the Provider's and the User's perceived games. It is also a Nash Only outcome in the Combined Reality, indicating that while it is strategically stable, it is not Pareto Optimal, meaning there are other outcomes where both players could be better off.

Broader Context: DSI Negotiations and Strategic Differences

Both analyses of Hypergame G1–G2 consistently highlight a situation where the Provider's liberal expectations are undermined by the User's more realist behaviour. However, the chosen strategic approach (payoff-based vs. risk-based) significantly alters the convergence point and its implications for DSI governance:

- **Payoff-Based Scenario:** The Provider's drive for mutual gain (V1) clashes with the User's pursuit of maximum individual payoff (V2), leading to an **exploitative outcome (V1, V2)**. Here, the Provider offers openness but is met with control, resulting in asymmetric benefit for the User. This represents a direct instance of unreciprocated cooperation, potentially leading to Provider disillusionment and a subsequent shift towards more defensive postures in future negotiations. The Provider learns that their liberal strategy makes them vulnerable.

- **Risk-Based Scenario:** Both actors, prioritising security and minimising their worst-case outcomes, independently converge on **mutual control (V2, V2)**. This leads to a stalemate where opportunities for mutual benefit and global scientific progress are foregone. While less directly exploitative in this immediate interaction, it signifies a 'tragedy of the commons' driven by individual caution rather than direct opportunism. In this case, the Provider sacrifices potential high gains from cooperation to ensure they are not left exposed. The User, similarly, prioritises the reliable, albeit lower, payoff of control.

In essence, whether driven by a desire for maximum gain or a fear of maximum loss, the asymmetric perceptions between a liberal Provider and a realist User in DSI governance lead to suboptimal outcomes. The payoff-based strategy results in exploitation, while the risk-based strategy leads to fragmentation. Both outcomes demonstrate how conflicting paradigms and strategic outlooks contribute to policy deadlock or a shift towards securitisation in DSI negotiations, hindering collaborative efforts and benefit-sharing.

Hypergame G1–G3: Liberal Provider vs Misperceiving Liberal User

Scenario 1: Payoff-Based Strategy

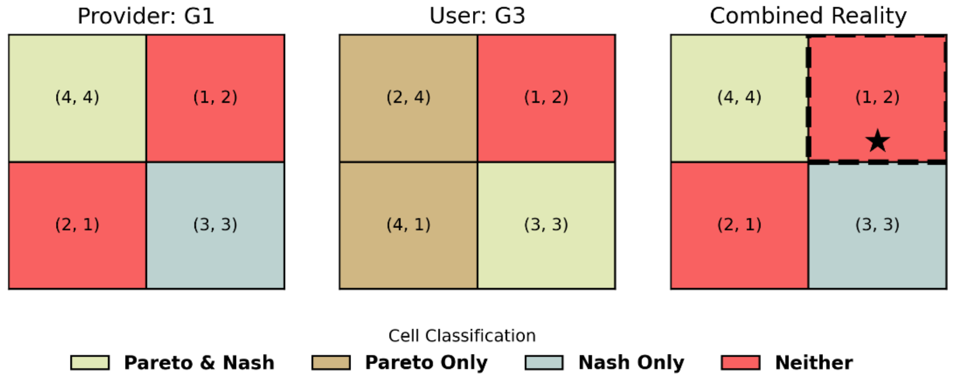


Figure B.3: Hypergame G1-G3 Payoff

In this scenario, both the Provider and the User base their decisions on maximising their individual payoffs.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G1 (Liberal–Liberal) game, mutual openness (V1, V1) is clearly the most desirable outcome, offering a payoff of (4, 4). This cell is highlighted as both a Pareto Optimal solution and a Nash Equilibrium, firmly rooting the Provider's expectation in reciprocal benefit and the idea that shared access maximises collective gains. The Provider anticipates that by choosing V1 (Openness), the User will reciprocate, leading to this mutually beneficial state. Other outcomes, such as (V1, V2) (2, 1), are seen as considerably less favourable, representing a situation where the Provider is open but the User asserts control, leading to a diminished return for the Provider.

User's Perceived Game (Centre Matrix)

The User, operating under the G3 (Realist–Liberal) perception, believes the Provider to be a realist and therefore expects them to act assertively. From this viewpoint, the outcome (V2, V1), with a payoff of (4, 1), is considered Pareto Optimal and a Nash Equilibrium, as it allows the User to benefit from the Provider's assumed control. However, the User's inherent liberal preference also values cooperation. They perceive (V1, V1) (2, 4) as Pareto Optimal. Crucially, the User also identifies (V2, V2) (3, 3) as a Nash Equilibrium, a safe and stable option in case the Provider truly acts as a realist. This dual Nash setup means the User will choose the strategy that maximises their payoff, which, given the perceived realist Provider, leans towards the outcome that grants the User relatively higher gains.

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G1) and the User's actual payoff (from G3). In this scenario, the Provider, acting on their liberal framework, selects **V1** (Openness). The User, driven by their perception of a realist Provider and seeking to maximise their own payoff, selects **V2** (Control). This leads to the chosen outcome of **(V1, V2)** in the Combined Reality matrix, delivering a payoff of **(1, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V1, V2) is classified as 'Neither' in the

Combined Reality, meaning it is neither Pareto Optimal nor a Nash Equilibrium. This indicates a significant strategic misalignment: the Provider's cooperative intent is met with the User's defensive assertion, leading to a suboptimal and unstable outcome that neither player ideally prefers. Importantly, this achieved outcome of (V1, V2) with payoffs of (2, 2) is significantly lower than the mutually beneficial outcome of (V1, V1), which has payoffs of (4, 4) in the Combined Reality, representing a clear missed opportunity for both actors due to the User's misperception.

Scenario 2: Risk-Based Strategy

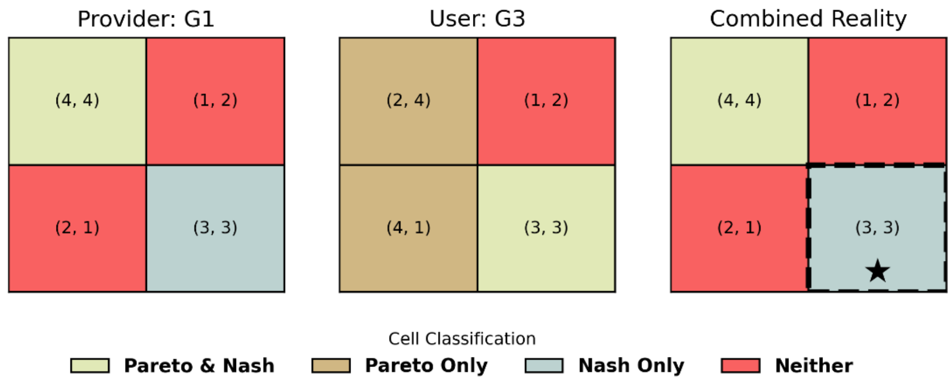


Figure B.4: Hypergame G1-G3 Risk

In this scenario, both the Provider and the User base their decisions on minimising potential losses or ensuring a secure outcome.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G1 (Liberal–Liberal) game, mutual openness (V1, V1) (4, 4) remains the ideal outcome and a Nash Equilibrium. However, when employing a risk-based strategy, the Provider will consider the lowest possible payoff. If the Provider chooses V1 (Openness), their worst-case payoff is 2 (if the User chooses V2). If they choose V2 (Control), their worst-case payoff is 1 (if the User chooses V1). Therefore, a risk-averse Provider, while still preferring mutual openness, might hesitate to choose V1 due to the potential for exploitation. The Nash Equilibrium (V2, V2) (3, 3) provides a safer, albeit less optimal, guaranteed outcome from a purely risk-minimising perspective, leading the Provider to favour V2.

User's Perceived Game (Centre Matrix)

The User, operating under the G3 (Realist–Liberal) perception and now employing a risk-based strategy, is acutely focused on avoiding potential losses from the perceived realist Provider. Their matrix shows two Nash Equilibria: (V2, V1) (4, 1) and (V2, V2) (3, 3). The User will choose the strategy that minimises their risk. If the User chooses V1 (Openness), their worst-case payoff is 1 (if the Provider chooses V2). If they choose V2 (Control), their worst-case payoff is 3 (if the Provider chooses V1). This makes **V2** (Control) the unequivocally safer choice for the User, as it guarantees a minimum payoff of 3, regardless of the Provider's action, while V1 carries the risk of a payoff of 1. Thus, the User's risk-aversion leads them to opt for control.

Combined Reality (Right Matrix) and Chosen Outcome (Risk-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G1) and the User's actual payoff (from G3). In this scenario, the Provider, still leaning towards liberal cooperation but now with a risk-averse overlay, selects **V2** (Control). The User, driven by a strong risk-based calculation against a perceived realist Provider, also selects **V2** (Control). This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 3)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This suggests a persistent strategic alignment towards a suboptimal but secure outcome. Notably, this achieved outcome of (V2, V2) with payoffs of (3, 3) is still lower than the mutually beneficial (V1, V1) outcome, which offers (4, 4) in the Combined Reality, underscoring a significant lost opportunity for both actors due to defensive strategic choices.

Broader Context: DSI Negotiations and Strategic Differences

This Hypergame G1–G3 consistently illustrates how strategic misalignment, rooted in defensive misperception, can prevent cooperation between a Liberal Provider and a User who *believes* the Provider is realist.

- **Payoff-Based Scenario:** The Provider's preference for mutual openness (V1) clashes with the User's defensive payoff maximisation (V2), leading to an **outcome of (V1, V2)** in the Combined Reality. This outcome (2, 2) is highly suboptimal for both in the Combined Reality and not stable from either's perspective. The Provider's cooperative intent is met with the User's assertion due to a misread of the Provider's paradigm.
- **Risk-Based Scenario:** When both actors prioritise security, the User's deep-seated risk aversion stemming from their misperception of the Provider as realist (G3) leads them to choose V2 (Control). This, combined with the Provider's own risk-averse move to V2 (Control), results in **(V2, V2)** in the Combined Reality, which is a stable (3, 3) outcome but still suboptimal compared to V1,V1. This highlights that fear of exploitation, even if based on a false premise about the other's intentions, can still push outcomes towards fragmentation.

In both scenarios, the User's defensive misperception of the Provider as realist (G3), despite the Provider's true liberal nature (G1), consistently leads to a **Pareto-suboptimal outcome**. The payoff-based approach results in (V1, V2), while the risk-based approach leads to (V2, V2). Both outcomes prevent the realisation of mutually beneficial cooperation (like a (V1, V1) outcome). In DSI governance, this hypergame reveals how mutual cooperation can fail not due to inherent hostility, but due to **misaligned expectations and anticipatory defensiveness**. A Provider advocating open access might be misread by the User as masking realist intent, pushing the User to unilaterally assert control over DSI resources. Unless mechanisms are put in place to clearly signal intentions and reduce perceived strategic ambiguity, such interactions will consistently lead to inefficient and unstable outcomes, undermining trust and hindering collaborative governance.

Hypergame G1–G4: Liberal Provider vs Realist User

This section analyses Hypergame G1–G4, a stark illustration of asymmetric perception and intent in DSI governance. Here, the Provider believes it is engaged in a fully cooperative negotiation (Game 1, Liberal–Liberal), expecting mutual benefit. Conversely, the User perceives the situation through the lens of Game 4 (Realist–Realist), assuming both actors are realist and will act to maximise control and relative advantage. This fundamental mismatch in worldview leads to significant strategic divergence.

Scenario 1: Payoff-Based Strategy

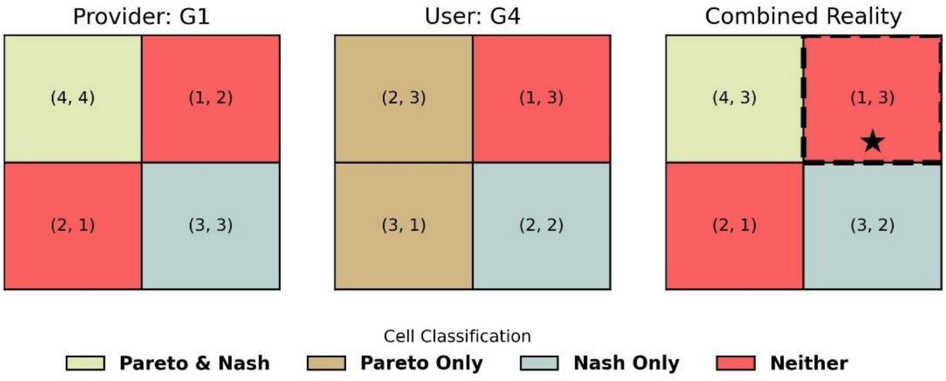


Figure B.5: Hypergame G1-G4 Payoff

In this scenario, both the Provider and the User base their decisions on maximising their individual payoffs.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G1 (Liberal–Liberal) game, mutual openness (V1, V1) is the ideal outcome, yielding a payoff of (4, 4). This cell is highlighted as both a Pareto Optimal solution and a Nash Equilibrium, reflecting the Provider's belief that reciprocal liberalism will lead to shared gains and a stable cooperative environment. The Provider interprets its own choice of V1 (Openness) as a gesture of trust, anticipating the User will reciprocate. Other outcomes, such as (V1, V2) (1, 2), where Provider is open but User asserts control, are seen as strictly less favourable, representing a diminished return for the Provider.

User's Perceived Game (Centre Matrix)

The User, operating within a G4 (Realist–Realist) paradigm, believes both itself and the Provider to be fundamentally strategic actors. From this vantage point, mutual control (V2, V2) emerges as the only Nash Equilibrium in their perceived game, yielding a payoff of (2, 2). This reflects a strategic worldview where sovereignty must be asserted, and even minimal gains are preferable to exposure. The User views (V1, V1) (2, 3) as a Pareto Optimal outcome, but it is not a Nash Equilibrium and is considered strategically risky, as it leaves the User vulnerable if the Provider acts selfishly. Therefore, the User will select the strategy that ensures their security and maximum payoff within their realist framework, which is V2 (Control).

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G1) and the User's actual payoff (from G4), reflecting the objective outcomes of their interaction. In this scenario, the Provider, acting on their liberal framework and seeking mutual openness, selects **V1** (Openness). The User, driven by their realist perception and prioritising self-protection, selects **V2** (Control). This leads to the chosen outcome of **(V1, V2)** in the Combined Reality matrix, delivering a payoff of **(1, 3)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V1, V2) is classified as 'Neither' in the Combined Reality, meaning it is neither Pareto Optimal nor a Nash Equilibrium. This indicates a profound strategic misalignment: the Provider's cooperative intent is met with the User's defensive assertion.

While the User achieves a relatively high payoff (3), the Provider receives a suboptimal payoff (1). Crucially, the achieved outcome of (V1, V2) with payoffs of (1, 3) is significantly lower for both parties compared to the mutually beneficial (V1, V1) outcome, which offers (4, 3) in the Combined Reality, representing a clear missed opportunity for both actors due to the User's deeply entrenched realist misperception.

Scenario 2: Risk-Based Strategy

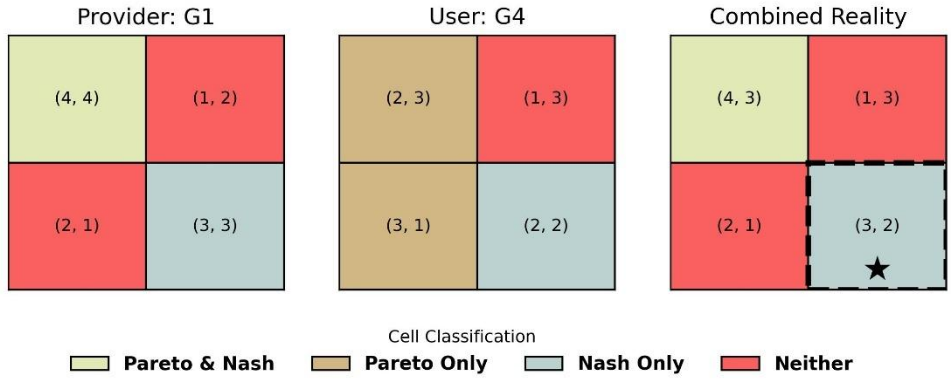


Figure B.6: Hypergame G1-G4

In this scenario, both the Provider and the User base their decisions on minimising potential losses or ensuring a secure outcome.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G1 (Liberal–Liberal) game, mutual openness (V1, V1) (4, 4) remains the ideal outcome and a Nash Equilibrium. However, when employing a risk-based strategy, the Provider will critically evaluate the potential for exploitation. If the Provider chooses V1 (Openness), their worst-case payoff is 1 (should the User choose V2). If the Provider chooses V2 (Control), their payoff is 2 (should the User choose V1). A risk-averse Provider, while still preferring mutual openness, might favour the safer, albeit less optimal, Nash Equilibrium of (V2, V2) (3, 3), as it provides a guaranteed outcome less susceptible to the User's uncooperative behaviour, leading the Provider to lean towards V2.

User's Perceived Game (Centre Matrix)

The User, operating within a G4 (Realist–Realist) paradigm and employing a risk-based strategy, fundamentally believes both itself and the Provider will act strategically and defensively. From this viewpoint, the only Nash Equilibrium is mutual control (V2, V2) (2, 2). This outcome, though not yielding the highest possible payoff, guarantees a secure outcome and minimises exposure to potential unilateral defection from the Provider. The User views any cooperative move (V1) as strategically risky, as it leaves them vulnerable if the Provider chooses V2. Therefore, the User will unequivocally select V2 (Control) to ensure their security.

Combined Reality (Right Matrix) and Chosen Outcome (Risk-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G1) and the User's actual payoff (from G4). In this scenario, both the Provider and the User adopt a risk-based strategy. The Provider, weighing the risks of unreciprocated openness, selects **V2** (Control). The User, firmly rooted in their realist, risk-averse outlook, also selects **V2** (Control). This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome

(V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control, despite both actors potentially achieving better outcomes with mutual openness, represents a significant lost opportunity driven by deep-seated strategic caution and mistrust.

Broader Context: DSI Negotiations and Strategic Differences

This Hypergame G1–G4 illustrates a profound mismatch in worldview between a Liberal Provider and a Realist User, leading to significant strategic divergence regardless of the chosen strategic approach.

- **Payoff-Based Scenario:** The Provider's liberal framework leads them to pursue V1 (Openness), while the User's realist, self-maximising approach drives them to V2 (Control). This results in an **exploitative outcome (V1, V2)** in the Combined Reality, with payoffs of (2, 3). The Provider's cooperative intent is countered by the User's defensive assertion, leading to a suboptimal outcome that neither player would ideally choose from a holistic perspective. This is a direct consequence of the User's deep-seated realist misperception.
- **Risk-Based Scenario:** When both actors prioritise security, the Liberal Provider's caution (driven by the risk of exploitation) and the Realist User's inherent defensiveness both lead to the selection of V2 (Control). This results in a convergence on **mutual control (V2, V2)** in the Combined Reality, with payoffs of (3, 2). This outcome, while stable and secure for both, is still Pareto-suboptimal compared to mutual openness. It highlights how fear of vulnerability can lead to a 'tragedy of the commons', where potential collective gains are sacrificed for individual security.

In essence, Hypergame G1–G4 demonstrates how **strategic misalignment, fueled by a fundamental clash of paradigms**, can unravel cooperative intent in DSI governance. Whether driven by maximising gains or minimising risks, the User's entrenched realist perception consistently leads to outcomes where the Liberal Provider's openness is either directly exploited or met with defensive containment. This underscores that even when the Provider's offer is made in good faith, it is ineffective if it fails to align with the User's strategic expectations. Consequently, User countries may hedge their position through national safeguards and restrictive bilateral agreements, highlighting the need for mechanisms to build trust and realign strategic perceptions to avoid fragmentation and ensure equitable DSI governance.

Hypergame G2–G1: Strategic Pessimism Meets Cooperative Expectation

Scenario 1: Payoff-Based Strategy

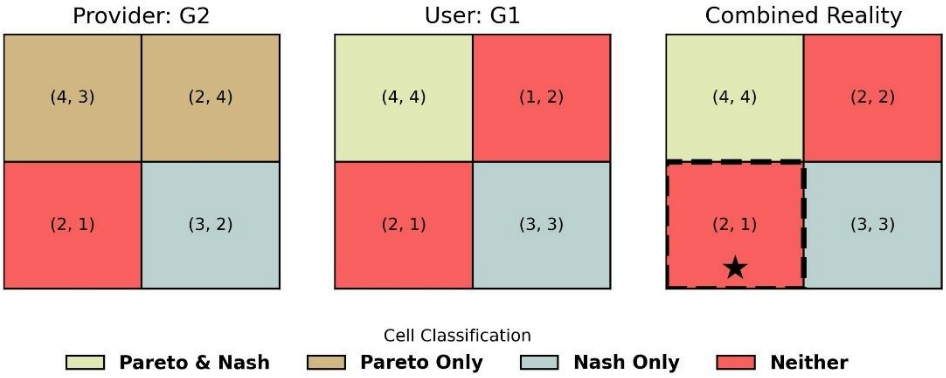


Figure B.7: Hypergame G2-G1

In this scenario, both the Provider and the User base their decisions on maximising their individual payoffs.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G2 (Liberal–Realist) game, the most desirable outcome is (V1, V1), where both sides pursue open access, yielding a payoff of (4, 3). This outcome is perceived as both Pareto Optimal and a Nash Equilibrium. However, the Provider also views (V1, V2) (2, 4), where it opens up and the User asserts sovereignty, as a significant risk despite being Pareto Optimal in its own matrix. The payoff is asymmetric, with the Provider receiving only partial benefit, thus leading to the anticipation of strategic instability. The outcome (V2, V2) (3, 2), in contrast, offers a lower but more balanced payoff and is seen as a Nash Equilibrium fallback, more secure in light of the User's presumed realist posture. Given this, the Provider will choose the strategy that maximises their payoff while accounting for the perceived User behaviour, which would be V2 (Control) to avoid the risk of unreciprocated openness.

User's Perceived Game (Centre Matrix)

The User's perspective is more optimistic, as they believe in Game 1 (Liberal–Liberal), expecting liberal behaviour from both sides. As such, they see (V1, V1) as the ideal and most rational outcome, both Pareto Optimal and a Nash Equilibrium, offering the highest joint payoff (4, 4). The User expects this outcome to emerge from mutual openness and perceives the Provider's role as aligned with global cooperation. However, this optimism can render the User vulnerable. If the Provider defects and plays V2 (Control) while the User remains open (V1), the outcome is (V2, V1), which delivers a poor payoff for the User (1, 2) and is seen as 'Neither'. The fallback, if cooperation fails, is (V2, V2) (3, 3), which is a Nash Equilibrium but clearly viewed as suboptimal compared to the ideal cooperative scenario. Given their payoff-maximising approach within their liberal framework, the User will choose V1 (Openness), anticipating a reciprocal response.

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G2) and the User's actual payoff (from G1), revealing the objective outcomes of their interaction. In this scenario, the Provider, playing defensively based on their G2 perception, selects **V2** (Control). The User, playing optimistically based on their G1 perception, selects **V1** (Openness). This leads to the chosen outcome of **(V2, V1)** in the Combined Reality matrix, delivering a payoff of **(2, 1)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V1) is classified as 'Neither' in the Combined Reality, indicating it is neither Pareto Optimal nor a Nash Equilibrium. This illustrates a profound miscoordination: the User's cooperative move is met with unexpected defection from the Provider. Both actors experience a suboptimal outcome compared to their ideal (V1,V1), which has payoffs of (4,4) in the Combined Reality, highlighting a significant missed opportunity for both due to the Provider's defensive overestimation of risk.

Scenario 2: Risk-Based Strategy

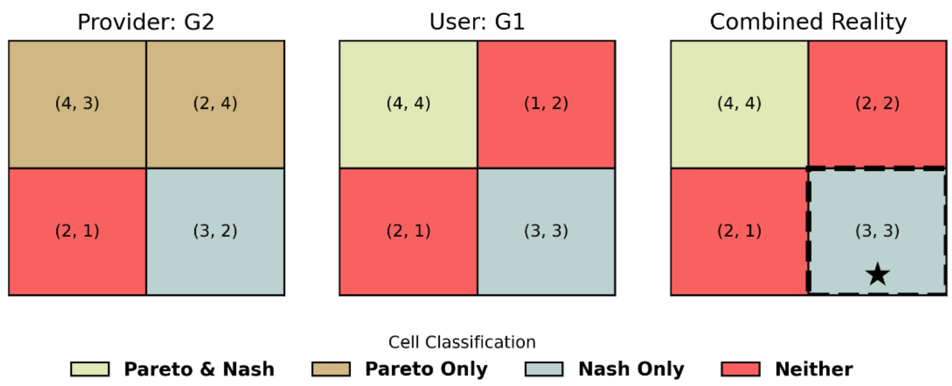


Figure B.8: Hypergame G2-G1 Risk

In this scenario, both the Provider and the User base their decisions on minimising potential losses or ensuring a secure outcome.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G2 (Liberal–Realist) game, the most desirable outcomes are (V1, V1) (4, 3) and (V2, V2) (3, 2), both classified as Nash Equilibria. When employing a risk-based strategy, the Provider will consider the worst-case payoffs for each of their choices. If the Provider chooses V1 (Openness), their lowest payoff is 2 (if the User chooses V2). If they choose V2 (Control), their lowest payoff is 2 (if the User chooses V1). Since both V1 and V2 offer a minimum payoff of 2, and V2,V2 is a Nash Equilibrium in the Provider's perceived game, the Provider will select **V2** (Control) as the secure and stable option that minimises exposure to potential exploitation.

User's Perceived Game (Centre Matrix)

The User's perspective is optimistic, as they believe in Game 1 (Liberal–Liberal). When employing a risk-based strategy, the User will consider the lowest possible payoff for each of their choices. If the User chooses V1 (Openness), their lowest payoff is 1 (if the Provider chooses V2). If they choose V2 (Control), their lowest payoff is 1 (if the Provider chooses V1). Given that both V1 and V2 carry a minimum risk of 1, and (V2, V2) (3, 3) is a Nash Equilibrium in their perceived game, the User will select **V2** (Control) as the secure and stable option, mitigating the risk of exploitation, despite their preference for mutual openness.

Combined Reality (Right Matrix) and Chosen Outcome (Risk-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G2) and the User's actual payoff (from G1), revealing the objective outcomes of their interaction. In this scenario, both the Provider and the User adopt a risk-based strategy. The Provider, driven by their defensive G2 perception, selects **V2** (Control). The User, motivated by their risk-averse G1 perception, also selects **V2** (Control). This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 3)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to the ideal (V1,V1) outcome, which offers payoffs of (4,4) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Differences

This Hypergame G2–G1 consistently illustrates a situation where a Liberal-Realist Provider's defensiveness clashes with a Liberal User's optimism, leading to miscoordination in DSI governance.

- **Payoff-Based Scenario:** The Provider's perceived need to protect against a 'realist' User leads them to select V2 (Control), while the User, optimistically pursuing V1 (Openness) within their liberal framework, expects reciprocity. This results in the **outcome (V2, V1)** in the Combined Reality, with payoffs of (2, 1). This is a highly suboptimal outcome for both, representing a "punishment" for the User's unreciprocated openness and a missed opportunity for higher mutual gains. The User experiences disillusionment, as their cooperative move is met with unexpected defection.

- **Risk-Based Scenario:** When both actors prioritise risk mitigation, the dynamics shift. The Provider's defensive G2 perception and the User's risk-averse G1 perception both lead them to independently select V2 (Control). This results in a convergence on **mutual control (V2, V2)** in the Combined Reality, with payoffs of (3, 3). While this outcome is strategically stable, it is still suboptimal compared to the ideal of mutual openness (V1,V1). This scenario highlights how a collective fear of vulnerability, even when potentially based on misperception, can lead to a fragmented system where potential cooperation is sacrificed for guaranteed, albeit lower, security.

In essence, Hypergame G2–G1 demonstrates how **asymmetric expectations and defensive overestimation of strategic risk** can preclude cooperation. Whether driven by maximizing payoffs or minimizing risks, the Provider's initial defensive stance due to their G2 perception, and the User's subsequent adjustment to risk, consistently steer the interaction away from mutually beneficial outcomes. In DSI negotiations, this mirrors situations where technologically advanced users proposing collaborative frameworks are met with pre-emptive caution from provider countries, who, informed by past experiences or geopolitical prudence, assume strategic opportunism. This failure to align perceptions leads to suboptimal governance, as genuine cooperative intent may be misread as a strategic ploy, eroding future trust and hindering equitable DSI governance.

Hypergame G2–G3: Mutual Misperception of Strategic Intent

This analysis presents Hypergame G2–G3, which encapsulates a complex situation of mutual misperception in Digital Sequence Information (DSI) governance. Both actors interpret the same interaction through asymmetric but converging expectations of strategic dominance. The Provider assumes Game 2 (Liberal–Realist), believing itself to be liberal but viewing the User as realist. The User, meanwhile, assumes Game 3 (Realist–Liberal), believing itself to be liberal but perceiving the Provider as realist. Crucially, both actors believe they are the cooperative party, acting in the spirit of openness, hile perceiving the other as motivated by relative gains and sovereign control. This results in an archetypal hypergame structure: a shared view of framing (Provider sees V1, User sees V2), but diverging expectations about the paradigm driving the other's behaviour.

Analysis of Hypergame G2–G3: Payoff-Based and Risk-Based Strategies

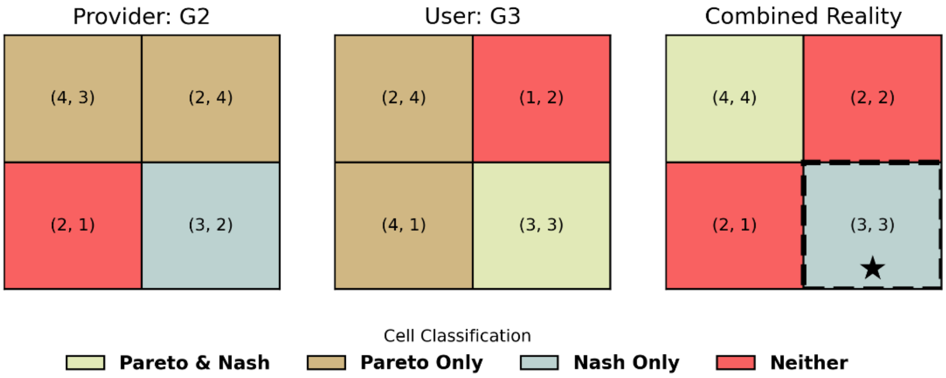


Figure B.9: Hypergame G2-G3 Payoff and Risk

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G2 (Liberal–Realist) game, the most desirable outcome is (V1, V1) with a payoff of (4, 3), classified as both Pareto Optimal and a Nash Equilibrium. This reflects the Provider's hope that mutual openness is possible, even when perceiving the User as realist. However, the Provider also recognizes (V2, V2) (3, 2) as another Nash Equilibrium, which offers a secure, albeit lower, payoff. When employing a **payoff-based strategy**, the Provider is inclined towards V1 (Openness) to achieve the highest possible gain. Conversely, with a **risk-based strategy**, the Provider evaluates the worst-case scenario: V1 could lead to a payoff of 2 (if User plays V2), while V2 also guarantees a payoff of 2 (if User plays V1). This might make V2 (Control) a more defensively attractive choice, as it aligns with the secure (V2, V2) Nash Equilibrium.

User's Perceived Game (Centre Matrix)

The User's perspective is shaped by their G3 (Realist–Liberal) frame, believing the Provider to be realist and thus expecting strategic behaviour from them. This leads the User to identify two Nash Equilibria: (V2, V1) (4, 1) and (V2, V2) (3, 3). For a **payoff-based strategy**, the User will compare the payoffs of these equilibria. While (V2, V1) offers a higher payoff for the User (4) if the Provider plays V2, (V2, V2) offers a more balanced payoff of 3 if the Provider also plays V2. Given the User's overall defensive stance in G3, they would likely opt for V2 (Control) to ensure a stable outcome. When employing a **risk-based strategy**, the User is acutely focused on avoiding potential losses. If the User chooses V1 (Openness), their worst-case payoff is 1 (if the Provider chooses V2). If they choose V2 (Control), their worst-case payoff is 3 (if the Provider chooses V1). This makes **V2** (Control) the unequivocally safer choice for the User, guaranteeing a minimum payoff of 3 regardless of the Provider's action.

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based & Risk-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G2) and the User's actual payoff (from G3). In this hypergame, based on the provided figures, the chosen outcome in the Combined Reality matrix is **(V2, V2)**, delivering a payoff of **(3, 3)**, regardless of whether the actors adopt a payoff-based or a risk-based strategy. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to their ideal (V1, V1) outcome, which offers (4, 4) in the Combined Reality.

In the **payoff-based scenario**, while the Provider might initially aim for V1 (Openness) and the User might be drawn to V2 (Control) due to their individual payoff maximisation, the underlying strategic tensions and mutual misperceptions ultimately drive them towards the stable, albeit suboptimal, mutual control of (V2, V2). Both actors settle for security rather than risking a worse outcome from unreciprocated optimal play.

In the **risk-based scenario**, the outcome also converges on (V2, V2). This occurs because both the Provider and the User, when prioritising risk mitigation, find V2 (Control) to be the most secure strategy, guaranteeing a higher minimum payoff in their respective perceived games. Their individual risk-averse calculations lead them to the same defensive position.

Broader Context: DSI Negotiations and Strategic Implications

This Hypergame G2–G3 consistently illustrates how **mutual misperception** can lead to strategic deadlock in DSI governance. Both the Provider and the User believe they are the cooperative party, acting in the spirit of openness, while perceiving the other as motivated by relative gains and sovereign control.

- **Impact of Misperception:** This creates a 'mirror image' misperception. Each actor attempts to maximise their payoff (or minimise their risk) based on the assumption that the other is less cooperative. However, since both are operating under this defensive assumption, they converge on mutual control (V2, V2). This highlights that even when both sides might, in principle, prefer more open and mutually beneficial arrangements (like V1, V1 with payoffs of 4,4 in the Combined Reality), their **anticipatory defensiveness** and lack of trust in the other's true intentions prevent this from occurring.
- **Convergence on Suboptimality:** Whether driven by payoff maximisation or risk aversion, the outcome is the same: mutual control and systemic fragmentation. This demonstrates how a complex interplay of individual strategic preferences and misperceptions can lead to an inefficient but stable equilibrium. In DSI negotiations, this might manifest as both provider and user countries implementing stringent national safeguards and restrictive data policies, not out of overt hostility, but from a calculated decision to protect themselves against perceived opportunism from the other side. This ultimately undermines global data flow and collaborative innovation, despite the potential for greater collective benefits.

In essence, Hypergame G2–G3 reveals how even modest asymmetries in perception can generate full defensive convergence Both actors believe the other is realist, which drives their defensive choices. Each anticipates benefit from the other's openness, yet neither chooses to cooperate. The result is a predictable and avoidable strategic deadlock, demonstrating the importance of recognising not only the other's strategy, but also their framing of the game.

Without that recognition, cooperation collapses into containment, regardless of initial intentions.

Hypergame G2–G4: Strategic Disjunction and Defensive Convergence

This section analyses Hypergame G2–G4, a negotiation scenario defined by **asymmetric perceptions and diverging expectations of strategic intent**. The Provider believes it is in Game 2 (Liberal–Realist), seeing itself as liberal but viewing the User as realist. In contrast, the User perceives the situation through the lens of Game 4 (Realist–Realist), assuming both actors are fully realist. This crucial asymmetry generates mutual defensiveness, despite the differences in their initial strategic expectations. Each actor expects to act assertively while exploiting or containing a less assertive counterpart, or simply protecting themselves from a similarly assertive one.

The strategic choices available to both the Provider and the User are: V1 (Openness/Cooperation) and V2 (Control/Assertion).

Scenario: Payoff-Based and Risk-Based Strategies (Identical Outcome)

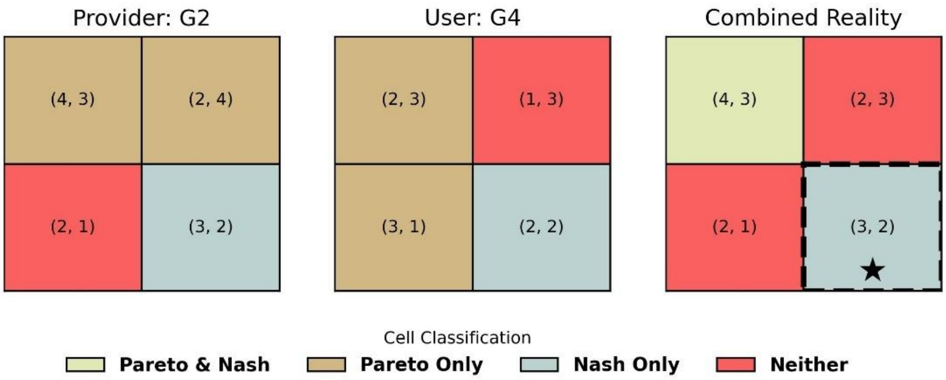


Figure B.10: Hypergame G2-G4 Payoff & Risk

In this hypergame, the chosen outcome in the Combined Reality matrix is identical regardless of whether the actors adopt a payoff-based or a risk-based strategy. Both scenarios converge on the same outcome due to the underlying strategic logic.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G2 (Liberal–Realist) game, the most desirable outcome is (V1, V1) (4, 3), classified as both Pareto Optimal and a Nash Equilibrium. This reflects the Provider's hope that mutual openness is possible, even with a perceived realist User. However, the Provider also recognises (V1, V2) (2, 4) as a significant risk (despite being Pareto Optimal), where its openness is met with User assertion, resulting in an asymmetric payoff. The outcome (V2, V2) (3, 2) is another Nash Equilibrium, offering a lower but more balanced payoff.

- For a **payoff-based strategy**, the Provider, seeking to maximise gains while navigating perceived User realism, would choose **V2 (Control)**. This choice protects against the high-risk (V1, V2) outcome and aligns with a Nash Equilibrium in their perceived game.

- For a **risk-based strategy**, the Provider evaluates the worst-case payoffs. Choosing V1 leads to a minimum payoff of 2 (if User plays V2). Choosing V2 leads to a minimum payoff of 2 (if User plays V1). As both strategies yield a minimum of 2, and V2,V2 is a Nash Equilibrium, the Provider will still opt for **V2 (Control)** as the stable and secure option, consistent with a risk-averse approach.

User's Perceived Game (Centre Matrix)

The User operates within a G4 (Realist–Realist) paradigm, fundamentally believing both itself and the Provider will act strategically and defensively. From this viewpoint, mutual control (V2, V2) (2, 2) emerges as the only Nash Equilibrium in their perceived game. This outcome, though not yielding the highest possible payoff, guarantees a secure outcome and minimises exposure to potential unilateral defection from the Provider. The User views any cooperative move (V1) as strategically risky, as it leaves them vulnerable if the Provider chooses V2. Therefore, regardless of whether they are driven by payoff maximisation or risk minimisation, the User will unequivocally select **V2 (Control)** to ensure their security and strategic integrity.

Combined Reality (Right Matrix) and Chosen Outcome

The Combined Reality matrix combines the Provider's actual payoff (from G2) and the User's actual payoff (from G4). In this hypergame, both the Provider and the User consistently select **V2 (Control)** based on their respective perceived games and strategic approaches. This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to the ideal (V1, V1) outcome, which offers (4, 3) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Implications

This Hypergame G2–G4 illustrates a structural impasse born of **asymmetric anticipation and mutual defensiveness** in DSI governance. The Provider maintains a partially liberal posture, hoping to encourage openness despite perceiving the User as realist. However, the User has already moved to contain any strategic exposure, assuming a fully realist stance for both parties.

- **Strategic Disjunction:** The User's deep-seated realist expectation of the Provider transforms even cooperative gestures into potential threats, leaving little room for trust-building. This results in the User unilaterally opting for V2 (Control), regardless of the Provider's attempt at conditional cooperation.
- **Convergence on Suboptimality:** The consistent convergence on **(V2, V2) (3, 2)** across both payoff and risk-based scenarios underscores how the most risk-averse paradigm in a hypergame with asymmetry often dictates the equilibrium. The User's assumption of a double-realist game effectively blocks the emergence of mutual cooperation. This outcome, while stable, is inefficient, representing a sacrifice of collective benefit for individual security.

In the context of DSI governance, G2–G4 reflects the difficulties faced by provider countries who pursue open-access frameworks under the assumption that benefits will eventually be shared. When such assumptions are not reciprocated, particularly by technologically dominant user countries that view DSI through the lens of national security or commercial advantage, then even partial openness is treated as strategic naïveté. The resulting response is defensive containment, formalised through national DSI legislation, access restrictions, or bilateral licensing arrangements that limit global equity and scientific exchange. This hypergame highlights the crucial role of perceived paradigms in shaping negotiation dynamics: when one actor believes the other is realist, even a partially liberal posture cannot shift the game away from defensive convergence.

Analysis of Hypergame G3–G1: Realist Provider (G3) vs Liberal User (G1)

This section analyses Hypergame G3–G1, which illustrates a structurally misaligned interaction characterised by asymmetric expectations and mismatched trust thresholds. The Provider adopts a realist framing (Game 3), believing the User to be liberal, while assuming that its own strategic interest requires safeguarding sovereignty and maximising relative gains. The User, on the other hand, believes both actors are liberal (Game 1), and thus expects reciprocal openness to yield mutually optimal outcomes. This perception gap generates a strategic imbalance where the User misinterprets caution as cooperation, and the Provider capitalises on its perceived positional advantage.

Scenario 1: Payoff-Based Strategy

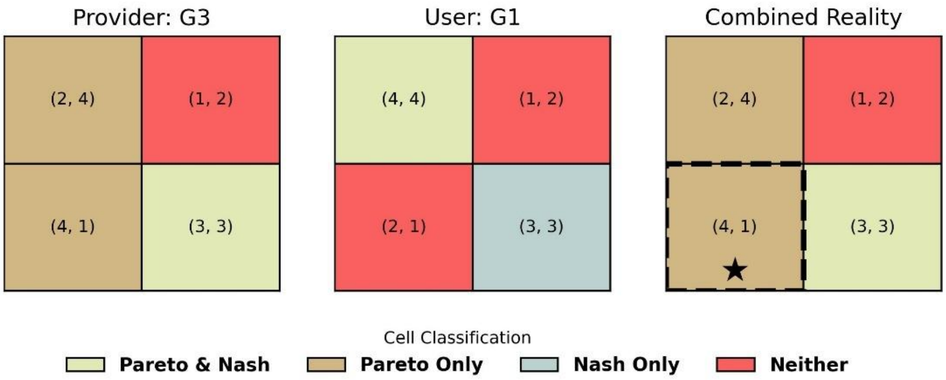


Figure B.11: Hypergame G3-G1 Payoff

In this scenario, both the Provider and the User base their decisions on maximising their individual payoffs.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G3 (Realist–Liberal) game, the most favourable outcome is (V2, V1), yielding a high Provider payoff of (4, 1). This outcome is classified as both a Nash Equilibrium and Pareto Optimal, reflecting the Provider's belief that asserting sovereignty (V2) while the User remains open (V1) maximises strategic advantage with minimal concession. The Provider does not see mutual openness (V1, V1) (2, 4) as viable, as it is not a Nash Equilibrium in their matrix and leaves them comparatively disadvantaged. Similarly, (V1, V2) (1, 2) is a dominated outcome. The fallback equilibrium is (V2, V2) (3, 3), offering a balanced but lower joint payoff, still preferable to cooperative exposure. Given this, the Provider will choose **V2 (Control)** to maximise their payoff within their realist framework.

User's Perceived Game (Centre Matrix)

The User, conversely, operates under the assumption of full liberal symmetry, believing in Game 1 (Liberal–Liberal). As such, they see (V1, V1) as the ideal and most rational outcome, both Pareto Optimal and a Nash Equilibrium, offering the highest joint payoff (4, 4). The User expects this outcome to emerge from mutual openness and perceives the Provider's role as aligned with global cooperation. However, this optimism can render the User vulnerable. If the Provider defects and plays V2 (Control) while the User remains open (V1), the outcome is (V2, V1), which delivers a poor payoff for the User (1, 2) and is seen as 'Neither'. The fallback, if cooperation fails, is (V2, V2) (3, 3), which is a Nash Equilibrium but clearly viewed as suboptimal compared to the ideal cooperative scenario. Given their payoff-maximising approach within their liberal framework, the User will choose **V1 (Openness)**, anticipating a reciprocal response.

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G3) and the User's actual payoff (from G1), revealing the objective outcomes of their interaction. In this scenario, the Provider, playing defensively based on their G3 perception, selects **V2** (Control). The User, playing optimistically based on their G1 perception, selects **V1** (Openness). This leads to the chosen outcome of **(V2, V1)** in the Combined Reality matrix, delivering a payoff of **(4, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V1) is classified as 'Pareto Only' in the Combined Reality, indicating that while it is efficient, it is not a Nash Equilibrium. This illustrates a profound strategic imbalance: the Provider, acting under realist assumptions, effectively exploits the liberal framing of the User. The User misinterprets the Provider's caution as cooperation, only realising the strategic misalignment once cooperation has already failed. This outcome is significantly lower for the User (2) than their ideal (V1,V1) (4,4), highlighting a substantial missed opportunity for the User.

Scenario 2: Risk-Based Strategy

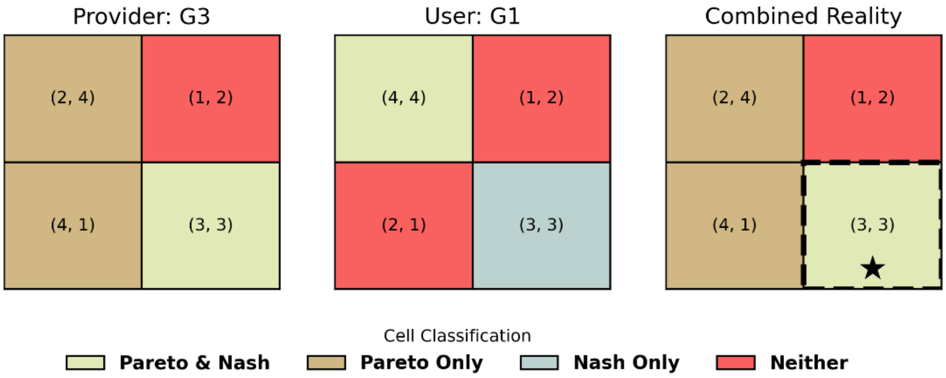


Figure B.12: Hypergame G3-G1 Risk

In this scenario, both the Provider and the User base their decisions on minimising potential losses or ensuring a secure outcome.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G3 (Realist–Liberal) game, the most favourable outcomes are (V2, V1) (4, 1) and (V2, V2) (3, 3), both classified as Nash Equilibria. When employing a risk-based strategy, the Provider will consider the lowest possible payoff for each of their choices. If the Provider chooses V1 (Openness), their worst-case payoff is 1 (if the User chooses V2). If they choose V2 (Control), their worst-case payoff is 3 (if the User chooses V1). This makes **V2 (Control)** the unequivocally safer choice for the Provider, as it guarantees a minimum payoff of 3 regardless of the User's action. Thus, the Provider's risk-aversion leads them to opt for control.

User's Perceived Game (Centre Matrix)

The User, conversely, operates under the assumption of full liberal symmetry, believing in Game 1 (Liberal–Liberal). When employing a risk-based strategy, the User will consider the lowest possible payoff for each of their choices. If the User chooses V1 (Openness), their lowest payoff is 1 (if the Provider chooses V2). If they choose V2 (Control), their lowest payoff is 1 (if the Provider chooses V1). Given that both V1 and V2 carry a minimum risk of 1, and (V2, V2) (3, 3) is a Nash Equilibrium in their perceived game, the User will select **V2 (Control)** as the secure and stable option, mitigating the risk of exploitation, despite their preference for mutual openness.

Combined Reality (Right Matrix) and Chosen Outcome (Risk-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G3) and the User's actual payoff (from G1), revealing the objective outcomes of their interaction. In this scenario, both the Provider and the User adopt a risk-based strategy. The Provider, driven by their risk-averse G3 perception, selects **V2** (Control). The User, motivated by their risk-averse G1 perception, also selects **V2** (Control). This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 3)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to the ideal (V1, V1) outcome, which offers (4, 4) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Differences

This Hypergame G3–G1 consistently illustrates how a **Realist Provider's strategic caution or assertiveness can consistently undermine a Liberal User's cooperative intent** in DSI governance.

- **Payoff-Based Scenario:** The Realist Provider's drive for security and strategic advantage (V2) clashes with the Liberal User's pursuit of mutual openness (V1). This results in an **outcome of (V2, V1)** in the Combined Reality, with payoffs of (4, 2). This demonstrates a strategic imbalance where the Provider, acting under realist assumptions, effectively exploits the liberal framing of the User. The User, misinterpreting the Provider's caution as cooperation, only realises the strategic misalignment once cooperation has already failed. This outcome is significantly lower for the User than their ideal (V1,V1) (4,4), highlighting a substantial missed opportunity.
- **Risk-Based Scenario:** When both actors prioritise security, the Realist Provider's inherent defensiveness (V2) and the Liberal User's risk-averse posture (V2) both lead to the selection of **mutual control (V2, V2)**. This results in a convergence on **(3, 3)** in the Combined Reality. This outcome, while stable and secure for both, is still Pareto-suboptimal compared to mutual openness. It highlights how a collective fear of

vulnerability, even when potentially based on misperception, can lead to a fragmented system where potential cooperation is sacrificed for guaranteed, albeit lower, security.

In essence, Hypergame G3–G1 demonstrates how **asymmetric expectations and defensive overestimation of strategic risk** can preclude cooperation. Whether driven by maximising gains or minimising risks, the Provider's initial defensive stance due to their G3 perception, and the User's subsequent adjustment to risk, consistently steer the interaction away from mutually beneficial outcomes. In DSI negotiations, this mirrors situations where biodiversity-rich provider countries, informed by past experiences of exploitation, pre-emptively assert control, while technologically advanced users, despite their liberal intentions, are forced into a defensive posture. This failure to align perceptions leads to suboptimal governance, as genuine cooperative intent may be misread as a strategic ploy, eroding future trust and hindering equitable DSI governance.

Analysis of Hypergame G3–G2: Realist-Liberal Provider (G3) vs Liberal-Realist User (G2)

This section analyses Hypergame G3–G2, which encapsulates a complex situation in which both actors interpret the same interaction through asymmetric but converging expectations of strategic dominance. The Provider assumes Game 3 (Realist–Liberal), believing itself to be realist and the User to be liberal. It anticipates that the User will act cooperatively, enabling the Provider to assert sovereignty without retaliation. The User, meanwhile, assumes Game 2 (Liberal–Realist): it views itself as realist and believes the Provider is liberal, and thus expects to benefit from exploiting the Provider’s openness. Both actors believe they are interacting with a cooperative counterparty while viewing their own strategy as cautious or assertive. The result is a hypergame of reciprocal misreading, in which each actor underestimates the other's defensiveness.

The strategic choices available to both the Provider and the User are: V1 (Openness/Cooperation) and V2 (Control/Assertion).

Scenario: Payoff-Based and Risk-Based Strategies (Identical Outcome)

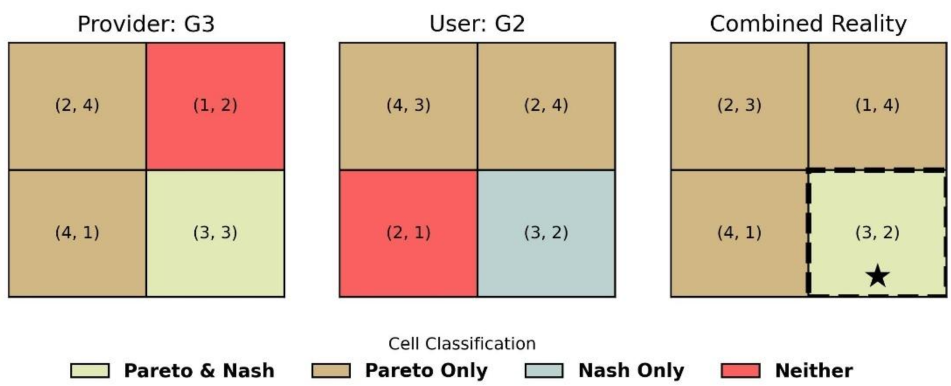


Figure B.13: Hypergame G3-G2 Payoff & Risk

In this hypergame, the chosen outcome in the Combined Reality matrix is **identical** regardless of whether the actors adopt a payoff-based or a risk-based strategy. Both scenarios converge on the same outcome due to the underlying strategic logic.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G3 (Realist–Liberal) game, the dominant outcome is (V2, V1) (4, 1), which is both a Nash Equilibrium and Pareto Optimal. This reflects the Provider's belief that asserting sovereignty (V2) while the User remains open (V1) maximises strategic advantage. Mutual openness (V1, V1) (2, 4) is Pareto Optimal but not stable. The fallback (V2, V2) (3, 3) is a Nash Equilibrium, offering security. Given their realist framework, the Provider will choose **V2 (Control)** to maximise their payoff and secure their position.

User's Perceived Game (Centre Matrix)

The User's perspective is shaped by their G2 (Liberal–Realist) frame, believing the Provider to be liberal and thus expecting to benefit from exploiting the Provider's openness. The User sees (V1, V2) (2, 4) as both Pareto Optimal and a Nash Equilibrium, offering their highest payoff. The fallback (V2, V2) (3, 2) is also a Nash Equilibrium. Given their realist leanings, the User will choose **V2 (Control)**, as it aligns with a Nash Equilibrium (V2,V2) and offers a secure outcome, mitigating the risk of the Provider not acting as expected.

Combined Reality (Right Matrix) and Chosen Outcome

The Combined Reality matrix combines the Provider's actual payoff (from G3) and the User's actual payoff (from G2). In this hypergame, both the Provider and the User consistently select **V2 (Control)** based on their respective perceived games and strategic approaches. This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to their ideal (V1, V1) outcome, which offers (4, 3) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Implications

This Hypergame G3–G2 encapsulates a complex situation of **reciprocal misreading and strategic defensiveness** in DSI governance. Both actors believe they are interacting with a cooperative counterparty while viewing their own strategy as cautious or assertive.

- **Mutual Overconfidence:** Each side believes the other is liberal and will absorb the costs of openness. This leads both to assert sovereignty (V2), resulting in **(V2, V2)**, an outcome neither actor prefers, but both accept as strategically necessary. Ironically, this mirrors the behaviour of two fully realist actors (G4–G4), even though each believes it is interacting with a cooperative counterpart.
- **Convergence on Suboptimality:** The consistent convergence on **(V2, V2) (3, 2)** across both payoff and risk-based scenarios demonstrates how even modest asymmetries in perception can generate full defensive convergence. The outcome is a predictable and avoidable strategic deadlock, where cooperation collapses into containment.

In the context of DSI governance, this hypergame reveals the fragility of partial liberalism in the face of distrust and misread opportunity. A provider state, fearing future disadvantage, may assert strategic control even when facing a cooperative user. Conversely, a user state may withhold engagement, assuming it can capitalise on the provider's goodwill. This mutual misreading not only undermines trust, but also entrenches sovereignty as the default posture, even when openness was possible in principle. This highlights the importance of recognising not only the other's strategy, but also their framing of the game. Without that recognition, cooperation collapses into containment, regardless of initial intentions.

Analysis of Hypergame G3–G4: Realist Provider (G3) vs Realist User (G4)

This section analyses Hypergame G3–G4, which models a negotiation scenario in which both actors adopt strategic postures, but differ in their interpretation of the game's symmetry. The Provider perceives a fully realist interaction (Game 4), in which both sides will act assertively to defend national interests and sovereignty. The User, in contrast, perceives a realist–liberal asymmetry (Game 3): it views itself as liberal and prefers cooperation, but believes the Provider to be acting in pursuit of unilateral control. This asymmetry produces a dynamic of anticipatory defensiveness, where both parties assert sovereignty not to gain advantage, but to prevent strategic loss.

The strategic choices available to both the Provider and the User are: V1 (Openness/Cooperation) and V2 (Control/Assertion).

Scenario: Payoff-Based and Risk-Based Strategies (Identical Outcome)

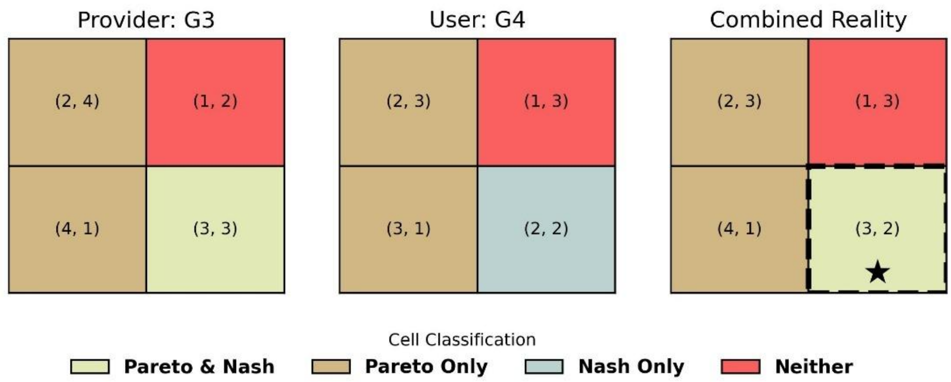


Figure B.14: Hypergame G3-G4 Payoff & Risk

In this hypergame, the chosen outcome in the Combined Reality matrix is **identical** regardless of whether the actors adopt a payoff-based or a risk-based strategy. Both scenarios converge on the same outcome due to the underlying strategic logic.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G3 (Realist–Liberal) game, the dominant outcome is (V2, V1) (4, 1), which is both a Nash Equilibrium and Pareto Optimal. This reflects the Provider's belief that asserting sovereignty (V2) while the User remains open (V1) maximises strategic advantage. Mutual openness (V1, V1) (2, 4) is Pareto Optimal but not stable. The fallback (V2, V2) (3, 3) is a Nash Equilibrium, offering security. Given their realist framework, the Provider will choose **V2 (Control)** to maximise their payoff and secure their position.

User's Perceived Game (Centre Matrix)

The User, operating within a G4 (Realist–Realist) paradigm, fundamentally believes both itself and the Provider will act strategically and defensively. From this viewpoint, mutual control (V2, V2) (2, 2) emerges as the only Nash Equilibrium in their perceived game. This outcome, though not yielding the highest possible payoff, guarantees a secure outcome and minimises exposure to potential unilateral defection from the Provider. The User views any cooperative move (V1) as strategically risky, as it leaves them vulnerable if the Provider chooses V2. Therefore, regardless of whether they are driven by payoff maximisation or risk minimisation, the User will unequivocally select **V2 (Control)** to ensure their security and strategic integrity.

Combined Reality (Right Matrix) and Chosen Outcome

The Combined Reality matrix combines the Provider's actual payoff (from G3) and the User's actual payoff (from G4). In this hypergame, both the Provider and the User consistently select **V2 (Control)** based on their respective perceived games and strategic approaches. This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(3, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to their ideal (V1, V1) outcome, which offers (2, 4) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Implications

This Hypergame G3–G4 illustrates a structural impasse born of **asymmetric anticipation and mutual defensiveness** in DSI governance. The Provider maintains a fully realist posture, expecting strategic competition. The User, meanwhile, believes it is facing a realist Provider and acts defensively, despite its own liberal leanings.

- **Strategic Disjunction:** The Provider's deep-seated realist expectation drives them to choose V2 (Control) for security. The User, despite believing the Provider to be liberal, also ultimately chooses V2 (Control) to ensure their own security, as it aligns with a Nash Equilibrium in their perceived game. This results in a convergence on mutual control, regardless of the Provider's attempt at conditional cooperation.
- **Convergence on Suboptimality:** The consistent convergence on **(V2, V2) (3, 2)** across both payoff and risk-based scenarios underscores how the most risk-averse paradigm in a hypergame with asymmetry often dictates the equilibrium. The User's assumption of a double-realist game (even if only for themselves) effectively blocks the emergence of mutual cooperation. This outcome, while stable, is inefficient, representing a sacrifice of collective benefit for individual security.

In the context of DSI governance, G3–G4 reflects the difficulties faced by provider countries who, operating from a realist stance, pre-emptively assert control over genetic resources. When user countries, even those with a liberal-realist outlook, also prioritise their own security and strategic integrity, the result is defensive containment. This mutual caution, formalised through national DSI legislation, access restrictions, or bilateral licensing arrangements, limits global equity and scientific exchange. This hypergame highlights the crucial role of perceived paradigms in shaping negotiation dynamics: when one actor believes the other is realist, even a partially liberal posture cannot shift the game away from defensive convergence.

Hypergame G4–G1: Realist Control Meets Cooperative Optimism

This section analyses Hypergame G4–G1, which represents a stark and asymmetric strategic interaction in DSI governance. The Provider assumes a fully realist paradigm (Game 4), believing that both sides are acting in self-interest and require strategic control. Conversely, the User operates under liberal–liberal expectations (Game 1), anticipating reciprocal openness and trust. This configuration creates a high-risk environment for miscoordination, as the Provider expects the need for strategic control and the User expects reciprocity and trust.

The strategic choices available to both the Provider and the User are: V1 (Openness/Cooperation) and V2 (Control/Assertion).

Scenario 1: Payoff-Based Strategy

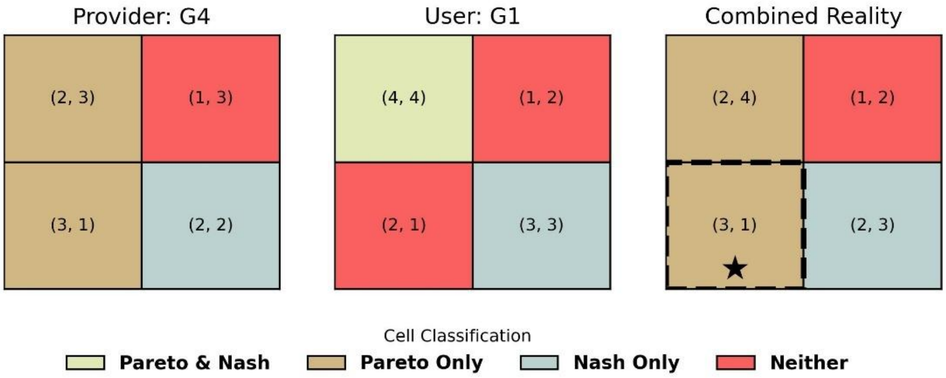


Figure B.15: Hypergame G4-G1 Payoff

In this scenario, both the Provider and the User base their decisions on maximising their individual payoffs.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G4 (Realist–Realist) game, mutual assertion of sovereignty (V2, V2) is seen as the most stable configuration, yielding a payoff of (2, 2) and classified as a Nash Equilibrium. This reflects a strategic worldview where sovereignty must be asserted, and even minimal gains are preferable to exposure. The Provider views (V2, V1) (3, 1) as a Pareto Only outcome, offering higher gains if the User cooperates, but it is not a Nash Equilibrium in their perceived game. Mutual openness (V1, V1) (2, 3) is considered Pareto Optimal but strategically risky, as it leaves the Provider exposed to potential exploitation. Therefore, the Provider will choose V2 (Control) to maximise their payoff within their realist framework, as it is the most secure Nash Equilibrium.

User's Perceived Game (Centre Matrix)

The User, conversely, operates under the assumption of full liberal symmetry, believing in Game 1 (Liberal–Liberal). As such, they see (V1, V1) as the ideal and most rational outcome, both Pareto Optimal and a Nash Equilibrium, offering the highest joint payoff (4, 4). The User expects this outcome to emerge from mutual openness and perceives the Provider's role as aligned with global cooperation. However, this optimism can render the User vulnerable. If the Provider defects and plays V2 (Control) while the User remains open (V1), the outcome is (V2, V1), which delivers a poor payoff for the User (1, 2) and is seen as 'Neither'. The fallback, if cooperation fails, is (V2, V2) (3, 3), which is a Nash Equilibrium but clearly viewed as suboptimal compared to the ideal cooperative scenario. Given their payoff-maximising approach within their liberal framework, the User will choose V1 (Openness), anticipating a reciprocal response.

Combined Reality (Right Matrix) and Chosen Outcome (Payoff-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G4) and the User's actual payoff (from G1), revealing the objective outcomes of their interaction. In this scenario, the Provider, playing defensively based on their G4 perception, selects V2 (Control). The User, playing optimistically based on their G1 perception, selects V1 (Openness). This leads to the chosen outcome of (V2, V1) in the Combined Reality matrix, delivering a payoff of (3, 2). This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V1) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This illustrates a profound miscoordination: the User's cooperative move is met with unexpected defection from the Provider. Both actors experience a suboptimal outcome compared to their ideal (V1,V1) (4,4), highlighting a significant missed opportunity for both due to the Provider's defensive overestimation of risk.

Scenario 2: Risk-Based Strategy

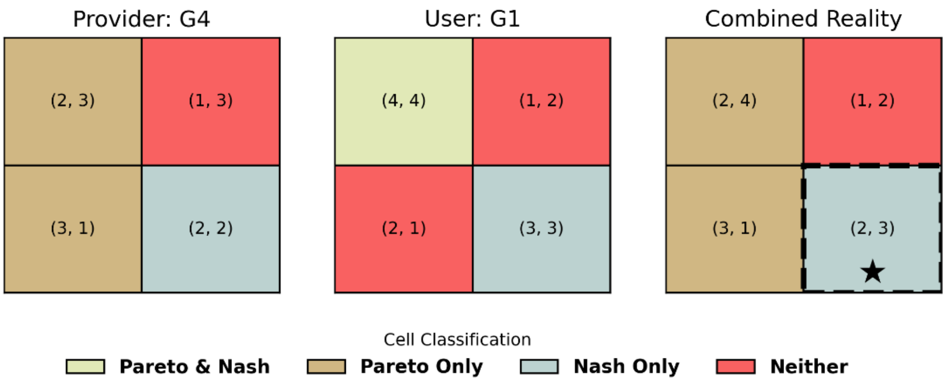


Figure B.16: Hypergame G4-G1 Risk

In this scenario, both the Provider and the User base their decisions on minimising potential losses or ensuring a secure outcome.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G4 (Realist–Realist) game, mutual assertion of sovereignty (V2, V2) (2, 2) is the only Nash Equilibrium. When employing a risk-based strategy, the Provider will unequivocally select **V2 (Control)**. This choice guarantees a secure outcome and minimises exposure to potential unilateral defection from the User. The Provider views any cooperative move (V1) as strategically risky, as it leaves them vulnerable if the User chooses V2. Therefore, the Provider will always choose V2 to ensure their security.

User's Perceived Game (Centre Matrix)

The User, operating under the assumption of full liberal symmetry, believing in Game 1 (Liberal–Liberal). When employing a risk-based strategy, the User will consider the lowest possible payoff for each of their choices. If the User chooses V1 (Openness), their lowest payoff is 1 (if the Provider chooses V2). If they choose V2 (Control), their lowest payoff is 1 (if the Provider chooses V1). Given that both V1 and V2 carry a minimum risk of 1, and (V2, V2) (3, 3) is a Nash Equilibrium in their perceived game, the User will select **V2 (Control)** as the secure and stable option, mitigating the risk of exploitation, despite their preference for mutual openness.

Combined Reality (Right Matrix) and Chosen Outcome (Risk-Based)

The Combined Reality matrix combines the Provider's actual payoff (from G4) and the User's actual payoff (from G1), revealing the objective outcomes of their interaction. In this scenario, both the Provider and the User adopt a risk-based strategy. The Provider, firmly rooted in their realist, risk-averse outlook, selects **V2** (Control). The User, motivated by their risk-averse G1 perception, also selects **V2** (Control). This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(2, 3)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control, despite both actors potentially achieving better outcomes with mutual openness, represents a significant lost opportunity driven by deep-seated strategic caution and mistrust.

Broader Context: DSI Negotiations and Strategic Differences

This Hypergame G4–G1 illustrates a profound mismatch in worldview between a Realist Provider and a Liberal User, leading to significant strategic divergence depending on the chosen strategic approach.

- **Payoff-Based Scenario:** The Realist Provider's drive for security and strategic advantage (V2) clashes with the Liberal User's pursuit of mutual openness (V1). This results in an **outcome of (V2, V1)** in the Combined Reality, with payoffs of (3, 2). This demonstrates a strategic imbalance where the Provider, acting under realist assumptions, effectively exploits the liberal framing of the User. The User, misinterpreting the Provider's caution as cooperation, only realises the strategic misalignment once cooperation has already failed. This outcome is significantly lower for the User than their ideal (V1,V1) (4,4), highlighting a substantial missed opportunity.
- **Risk-Based Scenario:** When both actors prioritise security, the Realist Provider's inherent defensiveness (V2) and the Liberal User's risk-averse posture (V2) both lead to the selection of **mutual control (V2, V2)**. This results in a convergence on **(2, 3)** in the Combined Reality. This outcome, while stable and secure for both, is still Pareto-suboptimal compared to mutual openness. It highlights how a collective fear of vulnerability, even when potentially based on misperception, can lead to a fragmented system where potential cooperation is sacrificed for guaranteed, albeit lower, security.

In essence, Hypergame G4–G1 demonstrates how a **Realist Provider's strategic caution or assertiveness can consistently undermine a Liberal User's cooperative intent** in DSI governance. Whether driven by maximising gains or minimising risks, the Provider's entrenched realist perception leads to outcomes where the Liberal User's openness is either directly exploited or met with defensive containment. This underscores that even when the User's offer is made in good faith, it is ineffective if it fails to align with the Provider's strategic expectations. Consequently, User countries may shift towards more defensive postures, highlighting the need for mechanisms to build trust and realign strategic perceptions to avoid fragmentation and ensure equitable DSI governance.

Analysis of Hypergame G4–G2: Realist Provider (G4) vs Liberal-Realist User (G2)

This section analyses Hypergame G4–G2, which models a negotiation scenario where both actors frame the interaction through a **strategic lens**, but **assign different roles and levels of assertiveness** to themselves and the other. The Provider assumes a fully realist paradigm (Game 4), believing that both sides are acting in pursuit of sovereign control and relative advantage. The User, by contrast, believes it is realist while the Provider remains liberal (Game 2). This subtle but crucial asymmetry generates mutual defensiveness, despite the differences in their initial strategic expectations. Each actor expects to act assertively while exploiting or containing a less assertive counterpart, or simply protecting themselves from a similarly assertive one.

The strategic choices available to both the Provider and the User are: V1 (Openness/Cooperation) and V2 (Control/Assertion).

Scenario: Payoff-Based and Risk-Based Strategies (Identical Outcome)

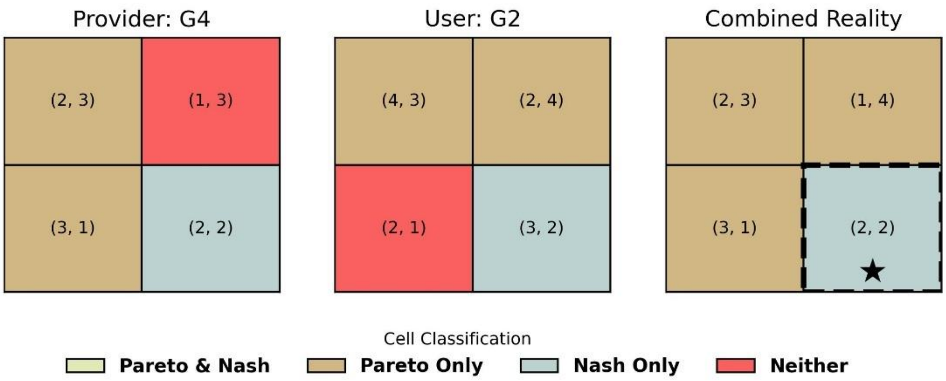


Figure B.17: Hypergame G4-G2 Payoff and Risk

In this hypergame, the chosen outcome in the Combined Reality matrix is **identical** regardless of whether the actors adopt a payoff-based or a risk-based strategy. Both scenarios converge on the same outcome due to the underlying strategic logic.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G4 (Realist–Realist) game, mutual control (V2, V2) (2, 2) emerges as the only Nash Equilibrium. This reflects a strategic worldview where sovereignty must be asserted, and even minimal gains are preferable to exposure. The Provider views (V2, V1) (3, 1) as a Pareto Only outcome, offering higher gains if the User cooperates, but it is not a Nash Equilibrium in their perceived game. Mutual openness (V1, V1) (2, 3) is considered Pareto Optimal but strategically risky, as it leaves the Provider exposed to potential exploitation. Therefore, the Provider will choose **V2 (Control)** to ensure their security and strategic integrity, as it is the most secure Nash Equilibrium.

User's Perceived Game (Centre Matrix)

The User operates within a G2 (Liberal–Realist) paradigm, believing itself to be realist while perceiving the Provider as liberal. From this viewpoint, the outcome (V1, V2) (2, 4) is both Pareto Optimal and a Nash Equilibrium, offering the User their highest payoff by leveraging the Provider's presumed liberalism. The User also perceives (V2, V2) (3, 2) as another Nash

Equilibrium, which is a stable fallback. However, the User views (V2, V1) (2, 1) as 'Neither', and (V1, V1) (4, 3) as Pareto Only but less strategic. Given their strategic lens, the User will choose **V2 (Control)**, as it aligns with a Nash Equilibrium (V2,V2) and offers a secure outcome, mitigating the risk of the Provider not acting as expected.

Combined Reality (Right Matrix) and Chosen Outcome

The Combined Reality matrix combines the Provider's actual payoff (from G4) and the User's actual payoff (from G2). In this hypergame, both the Provider and the User consistently select **V2 (Control)** based on their respective perceived games and strategic approaches. This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(2, 2)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to the ideal (V1, V1) outcome, which offers (2, 3) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Implications

This Hypergame G4–G2 illustrates a structural impasse born of **asymmetric anticipation and mutual defensiveness** in DSI governance. The Provider maintains a fully realist posture, expecting strategic competition. The User, meanwhile, believes it can benefit from a perceived liberal Provider but also prepares for defensive action.

- **Strategic Disjunction:** The Provider's deep-seated realist expectation drives them to choose V2 (Control) for security. The User, despite believing the Provider to be liberal, also ultimately chooses V2 (Control) to ensure their own security, as it aligns with a Nash Equilibrium in their perceived game. This results in a convergence on mutual control, regardless of the Provider's attempt at conditional cooperation.
- **Convergence on Suboptimality:** The consistent convergence on **(V2, V2) (2, 2)** across both payoff and risk-based scenarios underscores how the most risk-averse paradigm in a hypergame with asymmetry often dictates the equilibrium. The User's assumption of a double-realist game (even if only for themselves) effectively blocks the emergence of mutual cooperation. This outcome, while stable, is inefficient, representing a sacrifice of collective benefit for individual security.

In the context of DSI governance, G4–G2 reflects the difficulties faced by provider countries who, operating from a realist stance, pre-emptively assert control over genetic resources. When user countries, even those with a liberal-realist outlook, also prioritise their own security and strategic integrity, the result is defensive containment. This mutual caution, formalised through national DSI legislation, access restrictions, or bilateral licensing arrangements, limits global equity and scientific exchange. This hypergame highlights the crucial role of perceived paradigms in shaping negotiation dynamics: when one actor believes the other is realist, even a partially liberal posture cannot shift the game away from defensive convergence.

Analysis of Hypergame G4–G3: Realist Provider (G4) vs Realist-Liberal User (G3)

This section analyses Hypergame G4–G3, which models a negotiation scenario in which both actors adopt strategic postures, but differ in their interpretation of the game's symmetry. The Provider perceives a fully realist interaction (Game 4), in which both sides will act assertively to defend national interests and sovereignty. The User, in contrast, perceives a realist–liberal asymmetry (Game 3): it views itself as liberal and prefers cooperation, but believes the Provider to be acting in pursuit of unilateral control. This asymmetry produces a dynamic of anticipatory defensiveness, where both parties assert sovereignty not to gain advantage, but to prevent strategic loss.

The strategic choices available to both the Provider and the User are: V1 (Openness/Cooperation) and V2 (Control/Assertion).

Scenario: Payoff-Based and Risk-Based Strategies (Identical Outcome)

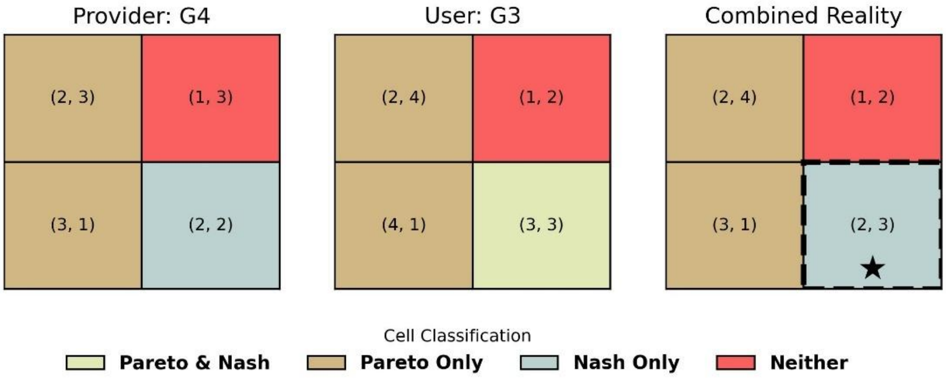


Figure B.18: Hypergame G4-G3 Payoff and Risk

In this hypergame, the chosen outcome in the Combined Reality matrix is **identical** regardless of whether the actors adopt a payoff-based or a risk-based strategy. Both scenarios converge on the same outcome due to the underlying strategic logic.

Provider's Perceived Game (Left Matrix)

From the Provider's perspective, framed by the G4 (Realist–Realist) game, the outcome (V2, V2) (2, 2) is the only Nash Equilibrium. This reflects a strategic worldview where sovereignty must be asserted, and even minimal gains are preferable to exposure. The Provider views (V2, V1) (3, 1) as a Pareto Only outcome, offering higher gains if the User cooperates, but it is not a Nash Equilibrium in their perceived game. Mutual openness (V1, V1) (2, 3) is considered Pareto Optimal but strategically risky, as it leaves the Provider exposed to potential exploitation. Therefore, the Provider will choose **V2 (Control)** to ensure their security and strategic integrity, as it is the most secure Nash Equilibrium.

User's Perceived Game (Centre Matrix)

The User, operating within a G3 (Realist–Liberal) paradigm, believes the Provider to be realist and thus expects strategic behaviour from them. This leads the User to identify two Nash Equilibria: (V2, V1) (4, 1) and (V2, V2) (3, 3). For both payoff-based and risk-based strategies, the User will choose **V2 (Control)**. This choice is driven by the User's defensive stance; if they choose V1 (Openness), their worst-case payoff is 1 (if the Provider chooses V2), whereas choosing V2 guarantees a minimum payoff of 3 (if the Provider chooses V1). This makes V2 the unequivocally safer choice, aligning with their risk-averse nature against a perceived realist Provider, and also securing a stable Nash Equilibrium.

Combined Reality (Right Matrix) and Chosen Outcome

The Combined Reality matrix combines the Provider's actual payoff (from G4) and the User's actual payoff (from G3). In this hypergame, both the Provider and the User consistently select

V2 (Control) based on their respective perceived games and strategic approaches. This leads to the chosen outcome of **(V2, V2)** in the Combined Reality matrix, delivering a payoff of **(2, 3)**. This outcome is marked with a star (★) and a dashed border. This specific outcome (V2, V2) is classified as 'Nash Only' in the Combined Reality, indicating that while it is strategically stable (a Nash Equilibrium from both perceived games), it is not Pareto Optimal. This convergence on mutual control highlights a significant missed opportunity for both actors compared to the ideal (V1, V1) outcome, which offers (2, 4) in the Combined Reality.

Broader Context: DSI Negotiations and Strategic Implications

This Hypergame G4–G3 illustrates a structural impasse born of **asymmetric anticipation and mutual defensiveness** in DSI governance. The Provider maintains a fully realist posture, expecting strategic competition. The User, meanwhile, believes it is facing a realist Provider and acts defensively, despite its own liberal leanings.

- **Strategic Disjunction:** The Provider's deep-seated realist expectation drives them to choose V2 (Control) for security. The User, despite believing the Provider to be liberal, also ultimately chooses V2 (Control) to ensure their own security, as it aligns with a Nash Equilibrium in their perceived game. This results in a convergence on mutual control, regardless of the Provider's attempt at conditional cooperation.
- **Convergence on Suboptimality:** The consistent convergence on **(V2, V2) (2, 3)** across both payoff and risk-based scenarios underscores how the most risk-averse paradigm in a hypergame with asymmetry often dictates the equilibrium. The User's assumption of a double-realist game (even if only for themselves) effectively blocks the emergence of mutual cooperation. This outcome, while stable, is inefficient, representing a sacrifice of collective benefit for individual security.

In the context of DSI governance, G4–G3 reflects the difficulties faced by provider countries who, operating from a realist stance, pre-emptively assert control over genetic resources. When user countries, even those with a liberal-realist outlook, also prioritise their own security and strategic integrity, the result is defensive containment. This mutual caution, formalised through national DSI legislation, access restrictions, or bilateral licensing arrangements, limits global equity and scientific exchange. This hypergame highlights the crucial role of perceived paradigms in shaping negotiation dynamics: when one actor believes the other is realist, even a partially liberal posture cannot shift the game away from defensive convergence.

Summary and Synthesis: Liberal Providers Across Hypergames

Across all hypergames in which the Provider perceives itself as liberal (i.e., G1 or G2 as the Provider's actual game), a clear pattern emerges: liberal intent is systematically shaped, and often undermined, by the User's assumed or actual strategic paradigm. Regardless of whether the User is truly realist or merely misperceives the Provider to be so, the liberal Provider consistently encounters **strategic resistance, cautious hedging, or outright defection**, which consistently leads to suboptimal or unstable outcomes.

Key Takeaways by Hypergame Configuration:

G1–G2 (Liberal Provider vs. Realist User): Exploited Cooperation.

- **Payoff-Based:** The Provider, expecting mutual liberalism (G1), plays V1 (Openness). The User, operating as a realist (G2) and seeking to maximise gain, plays V2 (Control).

This results in an **exploitative outcome (V1, V2; 2, 4)** in the Combined Reality, where the Provider is left vulnerable.

- **Risk-Based:** Both actors, prioritising security, converge on **mutual control (V2, V2; 3, 2)**. The Provider sacrifices potential gains to avoid exploitation, and the User opts for security over maximum unilateral gain.
- **Insight:** This highlights how a liberal Provider can be exploited (payoff-based) or forced into a defensive, suboptimal stance (risk-based) by a realist User. Trust is eroded, and the Provider is structurally disadvantaged.

G1–G3 (Liberal Provider vs. Misperceiving Liberal User): Misread Intentions.

- **Payoff-Based:** The Provider plays V1 (Openness). The User, despite being liberal, misperceives the Provider as realist (G3) and defensively plays V2 (Control). This leads to a **suboptimal outcome (V1, V2; 2, 2)** in the Combined Reality.
- **Risk-Based:** Both the Provider and the User, being risk-averse and with the User misperceiving the Provider as realist, converge on **mutual control (V2, V2; 3, 3)**.
- **Insight:** Liberal cooperation is precluded not by direct hostility, but by **anticipatory defensiveness** stemming from a fundamental misperception. Even when both parties are genuinely liberal, a lack of trust and clear signalling leads to fragmented outcomes.

G1–G4 (Liberal Provider vs. Realist User): Strategic Collapse.

- **Payoff-Based:** The Provider's cooperative gesture (V1) is met with full realist strategic containment (V2) from the User. This results in an **exploitative outcome (V1, V2; 2, 3)** in the Combined Reality.
- **Risk-Based:** Both the Provider (due to risk aversion) and the User (due to inherent realism and risk aversion) converge on **mutual control (V2, V2; 3, 2)**.
- **Insight:** A complete **paradigm misalignment** leads to an inefficient but stable equilibrium. The User's deep-seated realist assumptions view even sincere openness as a threat, driving the system towards fragmentation.

G2–G1 (Liberal-Realist Provider vs. Liberal User): Pre-emptive Defection.

- **Payoff-Based:** The Provider, believing the User is realist (G2), plays defensively (V2). The User, being liberal (G1) and expecting cooperation, plays optimistically (V1). This results in a **miscoordinated outcome (V2, V1; 2, 1)** in the Combined Reality.
- **Risk-Based:** Both the Provider and the User, when prioritising risk mitigation, converge on **mutual control (V2, V2; 3, 3)**.
- **Insight:** Cooperation is undermined not by bad intent, but by the Provider's **defensive overestimation of strategic risk**. The liberal User is "punished" for their openness, as their cooperative move is met with unexpected defection.

G2–G3 (Liberal-Realist Provider vs. Realist-Liberal User): Mirrored Misperception.

- **Payoff-Based & Risk-Based (Identical Outcome):** Both actors believe the other is realist, despite both having liberal leanings. Both choose V2 (Control) due to this misperception and their respective strategic drivers. This results in **mutual control (V2, V2; 3, 3)** in the Combined Reality.

- **Insight:** A missed opportunity arises from **mutual defensive assumptions**. Despite having a shared potential for cooperation, both actors converge on a suboptimal stalemate, demonstrating how perceived risk overrides potential mutual gain.

G2–G4 (Liberal-Realist Provider vs. Realist User): Strategic Disjunction.

- **Payoff-Based & Risk-Based (Identical Outcome):** The Provider (G2) attempts conditional cooperation, but the User (G4) assumes full realism from both sides and defaults to sovereign control (V2). This results in **mutual control (V2, V2; 3, 2)** in the Combined Reality.
- **Insight:** The User's assumption of a double-realist game **effectively blocks** the emergence of mutual cooperation. The more risk-averse paradigm in the hypergame consistently dictates the equilibrium, sacrificing efficiency for stability.

Cross-Cutting Themes and Implications:

1. **Liberal Intent Alone Is Insufficient:** Across all configurations, a liberal Provider consistently fails to secure a fully cooperative outcome **without aligned perceptions**. Misperception, distrust, or outright realist strategy from the User leads to either direct exploitation (e.g., G1-G2 payoff) or a strategic convergence on mutual defensiveness (e.g., G1-G2 risk, G1-G3, G1-G4, G2-G1 risk, G2-G3, G2-G4).
2. **Defensive Logic Dominates Under Uncertainty:** When faced with strategic ambiguity or perceived risk, actors (especially the User in these scenarios) tend to prioritise protecting their sovereignty and security. Even when genuine liberalism might exist on both sides (e.g., G1-G3, G2-G3), the absence of clear trust signals leads to **pre-emptive containment**. The strategic logic of realism, once activated, becomes self-fulfilling, pushing actors towards controlling behaviours (V2).
3. **The Most Risk-Averse Paradigm Sets the Outcome:** In hypergames with asymmetry, the actor who perceives the game in the most defensive or strategic terms generally dictates the equilibrium. Liberal actors are **structurally vulnerable** unless their counterpart explicitly shares and recognises their paradigm, or unless mechanisms exist to mitigate perceived risks.
4. **Trust Breakdown Has Structural Consequences:** Initial interactions, particularly those resulting in unreciprocated openness (e.g., G1-G2 payoff, G2-G1 payoff), can provoke **paradigm shifts** over time. A liberal actor, burned once, may revise its perception and shift towards a more defensive, sovereignty-oriented (G2 or G4) framing in future rounds, reinforcing cycles of mistrust and leading to more entrenched fragmentation.
5. **DSI Governance Risks Defaulting to Realism:** These hypergames reflect broader dynamics in DSI negotiations. Liberal proposals for open access often face defensive or strategic responses rooted in sovereignty, national interest, or commercial advantage. Even if both sides favour openness in principle, mismatched paradigms and strategic behaviors (whether payoff or risk-driven) push negotiations toward bilateralism, fragmentation, or securitisation, consistently sacrificing the potential for greater collective gains.

Synthesis: Strategic Trajectories under Realist Providers

This synthesis section provides a comprehensive overview of the strategic patterns and implications observed across hypergames where the **Provider perceives itself as realist** (i.e., G3 or G4 as the Provider's actual game). A consistent pattern emerges: the Provider's realist intent decisively shapes the strategic interaction, often leading to defensive or mirrored behaviour from the User, regardless of the User's own paradigm.

Key Takeaways by Hypergame Configuration:

G3–G1 (Realist Provider vs. Liberal User): Strategic Exploitation Meets Vulnerability.

- **Payoff-Based:** The Realist Provider (G3) chooses V2 (Control) to maximise gain, while the Liberal User (G1) chooses V1 (Openness) expecting reciprocity. This results in **(V2, V1; 4, 2)** in the Combined Reality, where the Provider effectively exploits the User's liberal stance. The User experiences a substantial missed opportunity.

- **Risk-Based:** Both the Realist Provider (G3) and the Liberal User (G1) converge on **mutual control (V2, V2; 3, 3)** due to risk aversion. The Provider secures a guaranteed payoff, and the User sacrifices potential cooperation for security.

- **Insight:** A Realist Provider's assertiveness can consistently undermine a Liberal User's cooperative intent. Whether driven by gain or risk, the Provider's realist perception leads to outcomes where the User's openness is either exploited or met with defensive containment.

G3–G2 (Realist-Liberal Provider vs. Liberal-Realist User): Reciprocal Misreading and Strategic Defensiveness.

- **Payoff-Based & Risk-Based (Identical Outcome):** Both actors believe the other is liberal (Provider sees User as G2; User sees Provider as G3) and attempt to assert sovereignty (V2) to gain advantage. This results in **mutual control (V2, V2; 3, 2)** in the Combined Reality.

- **Insight:** A missed opportunity arises from **mutual overconfidence** and defensive assumptions. Despite each believing the other is liberal, their strategic caution leads to a suboptimal stalemate, where cooperation collapses into containment.

G3–G4 (Realist Provider vs. Realist User): Strategic Assertion and Reinforced Realism.

- **Payoff-Based & Risk-Based (Identical Outcome):** The Provider (G3) attempts to assert strategically, while the User (G4) anticipates this assertion and acts pre-emptively (V2). This results in **mutual control (V2, V2; 3, 2)** in the Combined Reality.

- **Insight:** This hypergame illustrates a structural impasse where opportunistic realism encounters defensive realism. Both actors play V2 due to perceived risk, leading to a stable but inefficient equilibrium, where cooperation is strategically implausible.

G4–G1 (Realist Provider vs. Liberal User): Realist Control Meets Cooperative Optimism.

- **Payoff-Based:** The Realist Provider (G4) chooses V2 (Control) for security, while the Liberal User (G1) chooses V1 (Openness) expecting reciprocity. This results in **(V2, V1; 3, 2)** in the Combined Reality. The User's cooperation is met with defection.

- **Risk-Based:** Both the Realist Provider (G4) and the Liberal User (G1) converge on **mutual control (V2, V2; 2, 3)** due to risk aversion.

- **Insight:** A profound mismatch where the Realist Provider's entrenched perception consistently leads to outcomes where the Liberal User's openness is either directly exploited or met with defensive containment, highlighting a significant missed opportunity for mutual benefit.

G4–G2 (Realist Provider vs. Liberal-Realist User): Realist Entanglement under Asymmetric Defensiveness.

- **Payoff-Based & Risk-Based (Identical Outcome):** Both actors frame the interaction strategically, but with different assigned roles. The Provider (G4) acts defensively (V2). The User (G2), believing the Provider is liberal, also ultimately chooses V2 (Control) for security. This results in **mutual control (V2, V2; 2, 2)** in the Combined Reality.

- **Insight:** This highlights how interlocking misperceptions and asymmetric defensiveness can generate a suboptimal equilibrium that neither side initially sought. The User's assumption of a double-realist game, even if only for themselves, effectively blocks mutual cooperation.

G4–G3 (Realist Provider vs. Realist-Liberal User): Strategic Realism Meets Defensive Liberalism.

- **Payoff-Based & Risk-Based (Identical Outcome):** The Provider (G4) perceives a fully realist interaction and chooses V2 (Control). The User (G3), believing the Provider is realist and acting defensively, also chooses V2 (Control). This results in **mutual control (V2, V2; 2, 3)** in the Combined Reality.

- **Insight:** Both actors act from risk aversion rather than aggression, producing a gridlocked equilibrium. Cooperation is impossible not because of conflicting preferences, but because both players assume the other will defect first.

Cross-Cutting Themes and Implications:

1. **Strategic Exploitation is Possible but Rarely Realised:** In games like G3–G1 or G4–G1, the Provider has a clear opportunity to extract value by asserting against a cooperative User. Yet, these exploitative outcomes rarely recur in subsequent rounds, because Users tend to revise their expectations, and defensive paradigms spread. The realism of the Provider induces realism in the User over time.

2. **The Equilibrium is Almost Always (V2, V2):** With few exceptions, the realist framing leads to convergence on mutual sovereignty. Whether via mirrored expectations (G3–G3, G4–G4 - *not explicitly analysed here but implied by base games*), opportunistic misreadings (G3–G2, G4–G2), or defensive convergence (G3–G4, G4–G3), **(V2, V2)** becomes the default endpoint: inefficient, but secure.

3. **Cooperation is Structurally Available, but Strategically Implausible:** Even when (V1, V1) is Pareto optimal in the Combined Reality, it is often ruled out due to realism-induced suspicion. The Provider’s paradigm filters out mutual openness as either naive, strategically risky, or politically unviable, especially when the User has superior technological capacity.

4. **Realism is Contagious:** Once the Provider adopts a realist posture, the User eventually mirrors it. Whether through direct exploitation (G3–G1), repeated containment (G3–G2), or failed overtures (G4–G3), liberal Users are consistently pushed toward defensive repositioning. This hypergame structure shows that realism, once introduced, is rarely contained to one actor.

Conclusion:

In hypergames where the Provider sees itself as realist, the strategic tone is set before the interaction begins. Users may enter with cooperative intent, but realist framings compress the space of acceptable behaviour, creating narrow corridors of stability (typically **(V2, V2)**). This framing produces structural deterrence: Users refrain from cooperation not because they oppose it, but because they cannot safely assume it will be reciprocated. The result is a world in which mutual openness is consistently avoided, not for lack of global benefit, but for lack of strategic feasibility. In the context of DSI governance, realist Providers mirror real-world behaviours by biodiversity-rich countries that, shaped by histories of extraction and marginalisation, pre-emptively assert sovereignty. Even when cooperative mechanisms exist, the fear of asymmetry and strategic dependency overrides their appeal. This synthesis highlights the need for institutional innovations that can de-risk openness, enhance verification, and rebalance trust asymmetries, or else realist framings will continue to drive DSI negotiations toward fragmentation, bilateralism, and missed opportunity.

Appendix C

Interview transcripts are safely stored and will not be made public in compliance with ethical standards by the TU Delft.

Appendix D: Alternative Standard Games: Payoff Structures

In the following appendix, the alternative games used for the sensitivity analysis are presented first. This is followed by plots illustrating the standard deviation and the average payoff achieved per player for each strategy.

D.1 Structures for alternative games

Table D.1: Asymmetrical Bully (G2)

Provider Strategy	User Strategy	Provider Payoff	User Payoff
V1	V1	4	2
V1	V2	1	4
V2	V1	2	1
V2	V2	3	3

Table D.2: Asymmetrical Bully G4

Provider Strategy	User Strategy	Provider Payoff	User Payoff
V1	V1	2	2
V1	V2	1	4
V2	V1	3	1
V2	V2	2	3

Table D.3: Benevolent Hegemon G3

Provider Strategy	User Strategy	Provider Payoff	User Payoff
V1	V1	2	4
V1	V2	1	2
V2	V1	3	3
V2	V2	2	1

Table D.4: Chicken Game (G4)

Provider Strategy	User Strategy	Provider Payoff	User Payoff
V1	V1	3	3
V1	V2	2	4
V2	V1	4	2
V2	V2	1	1

Table D.5: Principled Liberal (G1)

Provider Strategy	User Strategy	Provider Payoff	User Payoff
V1	V1	4	4
V1	V2	2	1
V2	V1	1	2
V2	V2	3	3

Table D.6: Symmetrical Bully G4

Provider Strategy	User Strategy	Provider Payoff	User Payoff
V1	V1	2	2
V1	V2	1	4
V2	V1	4	1
V2	V2	3	3

D.2: Sensitivity payoff heatmaps

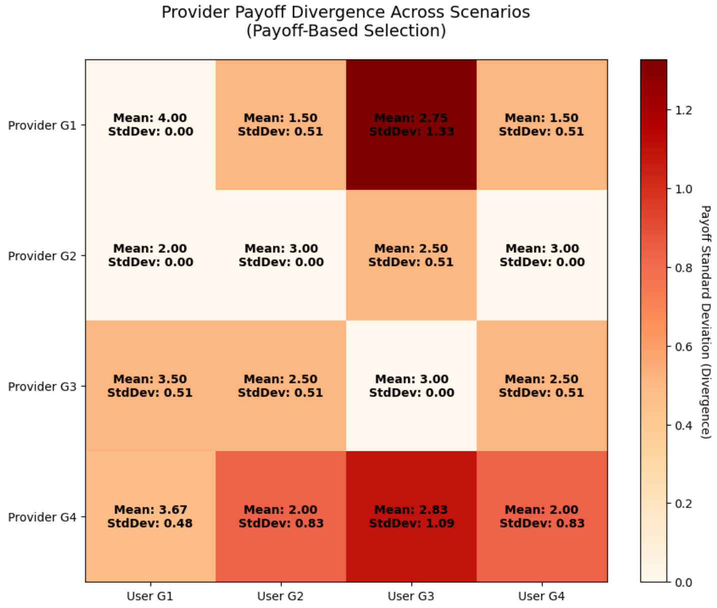


Figure D.1: Provider Payoff Divergence Across Scenarios (Payoff-Based)

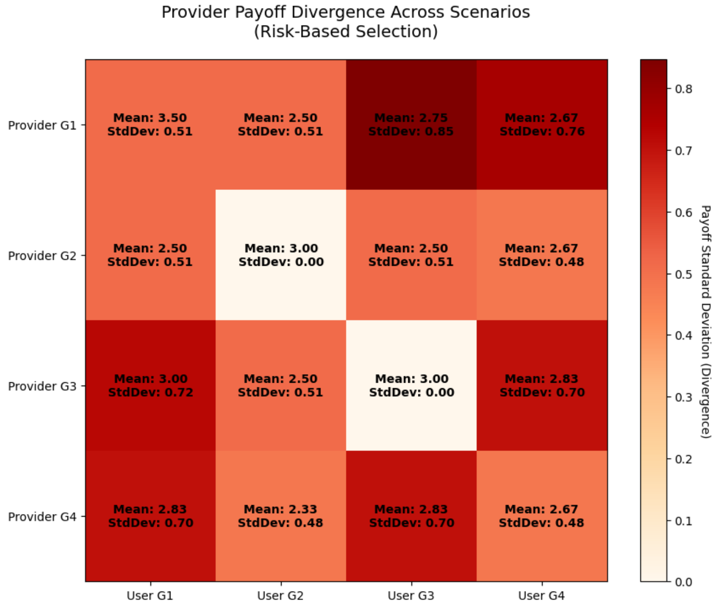


Figure D.2: Provider Payoff Divergence Across Scenarios (Risk-Based)

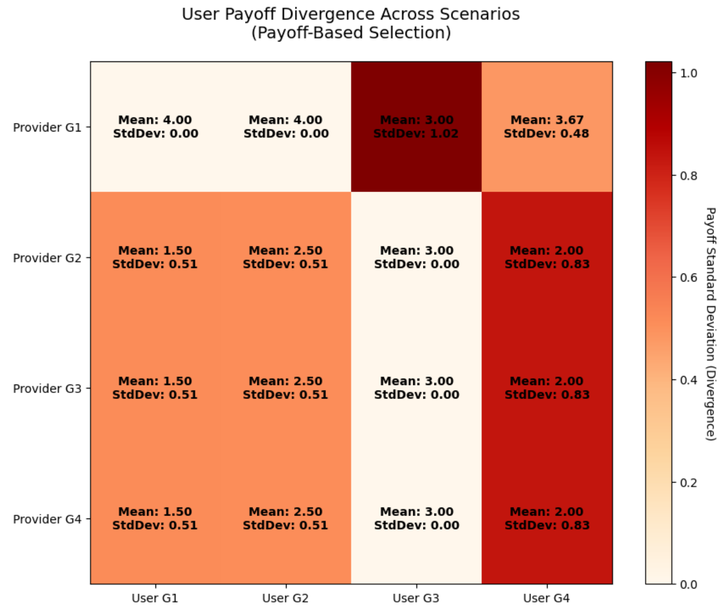


Figure D.3: User Payoff Divergence Across Scenarios (Payoff)

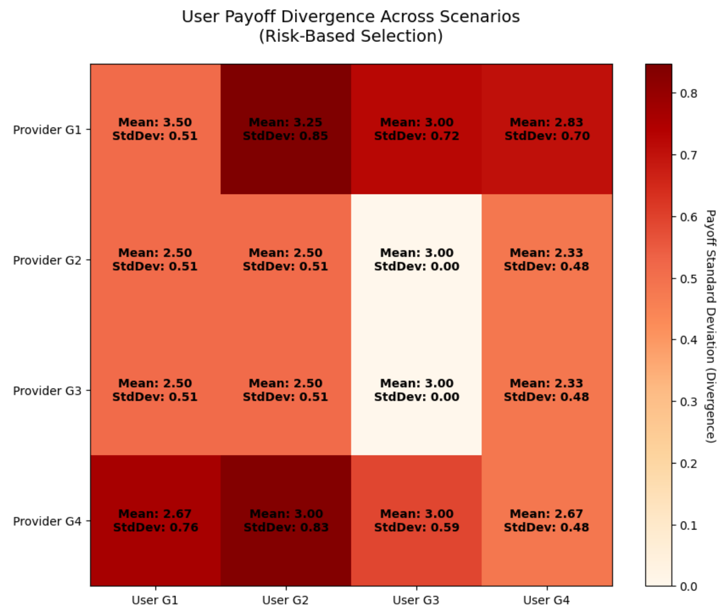


Figure D.4: User Payoff Divergence Across Scenarios (Risk)