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Research Article

Theoretical Understanding of International Relations and Structural Transition of the International System: Perspectives from Natural and Social Sciences

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Abstract: A trend of extreme division could be seen in the research of social science and natural science, which has caused different degrees of negative impact on numerous subordinate disciplines of social science, and thus, resulting in no substantial breakthroughs in the research process of their basic theories. The purpose of this research is to explore the relationship between the state and society through the epistemological development of ontology, in order to solve a series of problems brought about by the relatively chaotic disciplinary theoretical system of international relations, area studies, and social science theories on the development of grounded theories, so as to break through the status quo of no paradigm. Therefore, in this paper, the author proposes to use natural science theories to perceive the social sciences and to analyse the evolution of the international system through natural science theories. Overall, this study puts international relations in a systemic perspective to carry out comprehensive and well-rounded research, and analyses the patterns and rules that exist in the international system. At the same time, the article also reveals the law of entropy change of the international system and analyses some decisive key elements within the system.

Keywords: International system; international order; social science perception; entropy increase

1. Introduction

The epistemological constraints inherent in ontological presuppositions preclude the establishment of consensual frameworks for conceptualising objective reality in social sciences, and therefore, there is no paradigm or broad consensus for an extended period of time. This has resulted in the separation of various disciplines from each other and the apparent fragmentation of different fields within a single discipline. Some conceptions derived from microphysics, however, could offer scholars a potential pathway to overcome the dualism in the social sciences and to broaden our perception of concepts in social reality as a way to develop some kind of paradigm. Following the quantum revolution, microphysics falsified classical materialism as the conventional conception of matter collapsed at the subatomic level, while large-scale revisions of microscopic theories in natural sciences propelled advancements in physics, with theoretical innovations in microphysical frameworks reciprocally driving research progress across scientific domains [1].

At the micro-level, the ultimate composition of reality extends beyond matter and energy, which merely represent its manifestations. Because the process of development inherently involves latent influences or dynamics that, while transcending material substrates, achieve unification through their dialectical interplay. Consequently, epistemic engagement with reality remains inherently indirect and iterative. In physics, M-theory posits dimensionality as an emergent phenomenon, given that “string theory dualities demonstrate increasing spatial dimensions under amplified interaction strengths among strings” [2]. Spatial dimensionality thus lacks invariance, and space itself does not exist a priori. This is analogous to the fact that temperature does not exist at the molecular level either, because molecules move randomly, which makes the value of the energy of the molecule itself wobbly and impossible to determine precisely. However, when the number of molecules reaches a certain level, an approximation averaged over their energy can be obtained. Therefore, the temperature we observe is only an average measure of the energy carried by the molecules, which is itself a phenomenon, but an absolute reality. The heat and cold that humans feel are only a secondary concept of molecular motion [3].

Based on the aforementioned natural science theories, M-theory has, to some extent, laid the foundation for systematizing superstring theory in physics. And the perfection of the superstring theory, in turn, helps to reflect the relevant theories in other fields of natural science, such as the thermodynamics-related theories in physics exemplified above. As an ultimate theory, M-theory not only unifies five string theories and eleven-dimensional supergravity but also constitutes the most fundamental form of superstring theory itself. Witten [4] Its emergence has deepened materialism to more microscopic levels, propelling natural sciences into profoundly subtle domains—developments bearing significance for nuanced advancements in social sciences and philosophy. As a consequence, the research in social sciences should not be solely confined to the inherent objective cognition, but should break through the theoretical shackles between different disciplines and seek holistic development

In recent years, constructivist scholar Professor Wendt asserted: “Mind and social life are macroscopic quantum mechanical phenomena, and since social phenomena depend on mind, they cannot be directly perceived”[5]. However, late 20th-century Japanese scholars argued: “Quantum mechanics applies only to atomic behaviour, not to large-scale galactic or cosmic expansion” because the assumptions of mankind represent potential realities rather than determinate ones [6]. This raises the question: What underlying logic ought to guide research in international relations and the broader social sciences?

Amid recent academic decentralisation, contemporary area studies and international relations research have shifted from systemic analyses to individual-level examinations. Paradigmatic interpretations through the lens of three major theoretical frameworks (realism, liberalism, constructivism) no longer dominate the field. For international relations, the primary unit of analysis may need to descend from states to individuals, as human actors ultimately drive interpersonal influence (Bogna et al., 2020). While human behaviour remains environmentally constrained, environments merely delimit decision-making parameters rather than determine specific choices. Thus, analogising individuals within specific groups to superstrings in quantum systems offers a more scientific approach to studying unit interactions within international systems. Der Derian and Wendt [7] However, should the research at the systemic level be abandoned or shifted?

Ipso facto, whether examining individuals, international actors, state

systems, or elements like the international order, all constitute components within broader systemic frameworks. Systemic perspectives abandoned the event-driven research model of traditional realist scholars of international relations, and thus, improving the research at the systemic level is of vital importance to the discipline of international relations and even the entire field of social sciences. Narizny [8] More essentially, the idea of the international system could strengthen international relations as an independent research field. Degterev and Istomin [9] To address these multifaceted issues, this study postulates: International systems share the homogeneous "operational mechanisms" with superstring (splitting and merging, D-branes and gauge fields, dualities and the unification of M-theory); International order is also similar to the order that maintains the operation of quantum system (the non-deterministic microscopic world and the international order have given rise to the deterministic classical world and international system). Der Derian and Wendt [7] Inasmuch as the superstring theory's incompleteness and international systems' inherent mutability, international relations analysis still cannot fully rely on post-collapse quantum system observations. Der Derian and Wendt [7] Therefore, based on improving the research on the international system, this study will conduct certain analyses in the sense of natural science on some important elements within the system.

2. Literature Review

In the early widespread recognition and in-depth discussions surrounding changes in the international system, a rise in the definition of the categories and ontology of the international system could be seen in the academia of Europe. In the 1960s, French scholar Raymond Aron first briefly outlined the concept of the "International System" in The Theory of International Relations [10]. This abstract discussion described the international system as a whole composed of political units and proposed that "the international system evolves from a homogeneous system adhering to the same policies into a heterogeneous system resorting to conflicting value systems, as its structure remains perpetually oligopolistic, with principal actors dominating systemic changes in each era". This laid the foundation for the study of the international system. In the same year, David Singer, based on systemic variables and employing statistical analysis, attempted to establish a systemic perspective on international relations, asserting that "every aspect of reality can be characterised in terms of interacting units that form a system" [11].

To consolidate the theories of the international system, over a decade later, Hedley Bull of the English School noted in his work The Anarchical Society that the international system refers to a "specific collectivity" formed by distinct states. Bull [12] However, in 1979, American scholar Kenneth Waltz, building on prior research, rejected Singer's theory in The Theory of International Politics [13]. He argued that "the level of descriptive analysis should be distinguished from the level of unit analysis" and substantially simplified Singer's statistical methodology. In essence, Singer postulated that the international system is dominated by its internal units, whereas Waltz assumed that the international system is governed by its structure; herein lies the contradiction[14]

In 1981, American scholar Robert Gilpin summarised existing categories of the international system in his book War and Change in World Politics, defining it as "an aggregation of diverse entities united by regular interaction according to a form of control"[15]. From this point, the analytical foundation for studying states within the systemic framework was established, leading to the emergence of numerous theoretical concepts and frameworks in systemic research, though most remained linked to the aforementioned paradigms.

Despite the meaningful interpretations of the international system's evolution provided by these scholars in their pioneering 20th-century studies, their theories were marked by significant temporal limitations due to the influence of the bipolar Cold War structure, and unconsciously confined by the "Westphalian straitjacket". These scholars homogenised the international system with international society, they failed to analyse how shifts in systemic order decisively shape the system's development. Instead, they narrowly framed the formation of the international system around interactions between states under bipolar dominance that were significant enough to influence behaviour. Furthermore, nearly all studies on the international system remained confined to unit-level analysis. For instance, Waltz's theory only explained why the international system exists, while Singer's merely described what occurs within it[16]

After the Cold War, theories of the international system advanced further. Alexander Wendt, in his article Anarchy is What States Make of it: The Social Construction of Power Politics (1992), proposed that "state and system are mutually constituted, and the structure of the international system changes with international rules"[5]. Wendt's theory addressed the under-theorised aspects of Waltz's conceptualisation of the international system but still failed to construct a macro-historical perspective on its study. In addition, in international system research, Waltz's and Singer's theories remained fragmented, Wendt's and Waltz's theoretical positions were starkly opposed, while Bull and Gilpin sought to reconcile the severe cognitive fragmentation within existing systemic theories[13; 17]

Since the 21st century, to cope with the paradigm-free research status of the international system, British scholars Barry Buzan and Richard Little, in their work International Systems in World History, situated the international system within a broader world-historical framework. Their study builds on Buzan's 1991 proposition: "The international system can be defined as a patterned form of scaled interaction among states". In this earlier work, Buzan distinguished between strong and weak systems based on the premise that states, as constituent units of the international system, are defined by their intrinsic properties. In strong systems, the processes and structures generated within states significantly outweigh those between states, with domestic life primarily shaped by internal conditions. In weak systems, interstate processes and systemic structures exhibit strong, penetrative traits. In their book which was published in 2000, based on "socio-cultural systems will coexist with economic ones, and both of these will coexist alongside military-political systems", Buzan and Little proposed three fundamental types of international systems: "full international systems", "economic international systems", and "pre-international systems". These systems evolved through world history, transitioning per se from pre-international systems to ancient and classical international systems, and finally to the modern international system, ultimately forming the concept widely recognised today [14].

In 2012, Professor Yan Xuetong, in the thesis of The Shift of Power Centres and the Transformation of the International System, defined the international system as an anarchic society composed of states and clarified the necessary and sufficient conditions for systemic transformation, to wit: at least two of the three core elements "political actors, international structure, and international norms"—must change [18]. Additionally, by comparing historical international systems across global contexts and scholars' definitions of the theories of international systems, this study indirectly revealed the conceptual confusion within academia regarding the international system, offering valuable insights for subsequent research.

Overall, most contemporary studies in international relations theory remain "event-driven", tending to deduce causes from outcomes [19]. Nonetheless, in most circumstances, "A causes B" does not imply that B can inversely justify A. For instance, while sunrise causes roosters to crow, one cannot conversely assert that roosters crowing triggers the fact of sunrise. Although Buzan and Little developed richer historical explanations of international systems and refined related theories, the field of international relations still requires more research grounded in systemic or general perspectives[16]. Because only at the systemic level can patterns and rules revealing the existence of international systems be extracted from the countless events constituting international relations, which is essential for advancing the theoretical development of systemic frameworks in the discipline.

Historically, the international system has demonstrated transformative characteristics, evolving from the state of nature to the society of nations. Hence, most scholars treat the international system as the highest analytical level, adopting states as units of analysis within an event-driven framework. In an attempt to break the constraints of traditional international system analysis, this study endeavours to transcend the English School's state-centric concept of a "states-system" and the economically oriented, continuity-focused "world-system" framework proposed by Wallerstein. The premise of this study defines the international system as "the greatest conglomerate of globally interacting and interdependent units, along with all global events and elements". Here, "units" encompass entities ranging from large-scale nations, states, deep states, and regions to organisations and even individuals; "events" refer to all occurrences worldwide since the formation of the international system; and "elements" comprise critical factors within the system—such as balances of power between states, policies of states or international organisations, international order, etc.—as well as external factors that nonetheless exert influence on the system's internal dynamics [13].

3. The Entropy Change of the Overall System

According to the Second Law of Thermodynamics, the total entropy of an isolated system will continuously increase (increase of entropy), and as a result, this isolated system will become increasingly chaotic. Therefore, when states and other units form an international system, it is similar to building a sandcastle. Once it is established, it will go through a process from order to disorder and eventually collapse with a crash. Through observation, it could be known that a sandcastle built with sand

represents an ordered state, and when it collapses and turns into sand grains, it is in a disordered state. Similarly, states within a system are in an ordered state, and once the system collapses, the states with other units will also fall into a disordered and chaotic disarray [20].

The formation of the international system is an inevitable result of the historical development of the international community and is independent of human consciousness. In other words, the formation of an international system by units like states is a spontaneously formed process, and essentially, it does not actually require any intervention. This process is, de facto, also a process of entropy increase. For all things, even the entire time and space, or the entire universe, since their birth, the total entropy has been unrelentingly increasing and will eventually reach a state of thermal equilibrium. Human society follows a similar pattern [21]. When the international system, after repeated collapse and reorganisation, evolves into a cohesive, orderly, and unprecedented-scale whole encompassing the entire human world, it initiates a process of entropy increase, ultimately culminating in heat death (thermal equilibrium). Unlike the thermodynamic equilibrium of the universe, the onset of heat death in the international system manifests as a balance of power on the brink of demise—specifically, an overall equilibrium forged by ultimate deterrence [22].

This view does not seem to conform to the mainstream academic understanding and the current theories related to the international system, because all current and previous theories of the international system are not yet comprehensive and far from perfect. To be precise, most international systems in human society are non-isolated systems, which means they do not encompass the entire human society. And the entropy of a non-isolated system does not continuously increase, because it could obtain energy from the outside world to counteract the entropy increase within itself. For example, in the 1860s, the co-ordination mechanism of the Vienna-Metternich System, formed in Europe in 1814, was already difficult to maintain. However, as a non-isolated system, the units within the system could draw energy from outside the system, so the European powers began to carry out colonial plundering in Asia [23].

Intrinsically, colonial plunder is merely the extraction of energy from external actors outside the system to counteract entropy increase within the system. This is akin to rebuilding a collapsed sandcastle fortress with new sand rather than allowing waves and erosion to scatter it into disordered grains. Similarly, just as the process of building sandcastle fortresses consumes energy, the colonial plunder by major states within the international system against external states is also an energy-consuming process. Therefore, the method to reduce entropy increase is to continuously obtain energy from external sources, and the device to sustain the international system is to perpetually extract material resources from outside the system [24; 25].

Although states within the Vienna System repeatedly plundered external states to maintain a balance of power, aiming to preserve the stability and continuity of the international system, the entropy reduction within the system coincided with entropy increase in the external world. In other words, human society as a whole still undergoes a process of entropy increase, for while non-isolated systems reduce their entropy by acquiring energy from the external environment, this process simultaneously intensifies entropy increase externally. The asymmetry in entropy increase and reduction between the system's interior and exterior ensures that total entropy remains in a state of perpetual growth [26].

The Vienna System prolonged its existence through the colonial exploitation of underdeveloped states, maintaining internal order. This act equates to obtaining energy from the external environment during entropy increase, thereby reducing entropy internally. However, the entropy of those exploited external states increased. From the perspective of human society as a whole, total entropy also grew. Thus, the continuity of most international systems comes at the cost of entropy increase among external actors [27].

In summary, the total entropy of human society has consistently increased, inevitably leading to the heat death (thermal equilibrium) of the international system. When all systems collapse, all states perish, and all civilisations converge into a uniform state, the world will no longer exhibit any "heat" exchange, leaving the international society in lifeless stillness. Prior to systemic collapse, the effective mutual deterrence among major states constitutes the onset of heat death—a balance of terror shaped by ultimate deterrence. To analyse the diverse unit-level elements in the evolution and transition of the international system, this study adapts Shannon's information entropy formula to construct a formula for the power dissipation of state actor "i". In this formula, "p_j" represents the probability of elements such as technology, capital, and sovereign actor capabilities transferring to non-state actor "j". When $\mathrm{H}_i > 0.7$, traditional sovereign structures fail, and the international system enters a phase of pronounced entropy transformation.

$$\mathrm{H}_i = -\sum_{j=1}^{n} p_j \log p_j$$

4. Stability and Disequilibrium of the System

Factors causing the disequilibrium of the international system are typically inherent to the system itself. These include units within the system that sustain its structural stability, historical events, elements such as balance of power, policies, and order, as well as external factors. Examples encompass sub-systems like states-system within the international system, pattern of equilibrium, international order, diverse actors including states, leaders of dominant powers like the U.S. President, oligarchs within multinational corporations, organisations and deep states such as the Illuminati that bypass state actor constraints, international institutions like the United Nations, and even extraterrestrial civilisations outside the system that might influence it…

To transcend conventional theoretical understandings in international relations, this study deconstructs and reconstructs the international system from a micro-natural science perspective. In "superstring theory", the vibrational modes of strings determine particle properties (e.g., mass, charge), while string splitting and merging (e.g., open string endpoints attaching to D-branes or topological changes in closed strings) correspond to energy and dimensional transformations. Similarly, the fragmentation and integration of state actors in the international system (e.g., state dissolution, federal reorganisation, alliance formation) alter power structures and interaction rules.

For instance, the collapse of the Soviet Union resembles the breaking of a string, redistributing the original "energy" (power) of a subsystem within the international system into multiple independent entities, thereby forming new "vibrational modes" (political institutions, diplomatic strategies). The integration of the European Union parallels string fusion, where European political actors create a higher-dimensional "D-brane structure" through shared norms like EU law, constraining member states' behaviours and generating synergistic effects. Recent NATO expansion reflects topological changes in strings, where adjustments to "interaction dimensions" (military cooperation, economic integration) maintain systemic stability [28].

Additionally, "D-branes" (extended objects in higher-dimensional spacetime) anchor open string endpoints, with their dynamics described by gauge fields. As "platforms", D-branes confine string motion, while gauge fields constrain string interactions through symmetries, analogous to international organisations or institutional frameworks (e.g., the UN, WTO). These provide a "higher-dimensional framework" (multilateral rules), curbing unilateral actions and fostering cooperation. Similarly, international law and institutional norms employ "symmetries" (e.g., sovereign equality, non-interference in internal affairs) to regulate state behaviour and maintain systemic order, aligning with the function of gauge fields. For example, WTO trade rules (gauge fields) coordinate member states' economic policies (string vibrations) via non-discrimination principles (symmetries). Notably, regional organisations (e.g., ASEAN) resemble low-dimensional D-branes focused on specific issues, while global institutions like the UN act as high-dimensional D-branes integrating multidimensional interactions.

The complementary pluralism of international relations paradigms mirrors the unification of dualities and M-theory. In superstring theory, dualities (e.g., T-duality, S-duality) reveal that distinct string theories (e.g., Type IIA and Type IIB) are fundamentally equivalent at a deeper structural level, while M-theory unifies all superstring theories through an 11-dimensional spacetime. This "unification of plural perspectives" closely parallels the phenomenon of paradigm competition and complementarity in international relations theory. For instance, realism's emphasis on power struggles and constructivism's focus on ideational shaping, though seemingly opposed, resemble T-duality in describing different dimensions of the same system—material power versus ideational structures [29]

The international system contains numerous sub-systems and critical analytical elements, among which the international order, as a key factor, differs fundamentally from the order sustaining quantum systems. "The state of a quantum system can only be defined concerning a larger whole, as quantum phenomena are irreducible and holistic". Currently, strings—existing at a scale more microscopic than quarks—are not directly observable, and many of their constituent particles exist independently of observation. The entanglement between subatomic particles and observational objects determines their final forms. Thus, the international system becomes fully formed and defined only when observed by external entities, implying that observers also co-create objective reality. This inherently introduces theoretical instability and definitional ambiguity [30].

If humans are analogised to strings and society to atoms, then states correspond to wave functions. "On account of the fact that a social structure

bounded territorially, the state is a potential rather than an actualized reality. Practically, the state is a localized manifestation of reality". Only after wave function collapse does the state become explicit, rendering the international system observable [31]. In other words, the state emerges solely through the interactions of its internal units; a territorially defined governance tool becomes observable only when such interactions occur. Consequently, extraterrestrial civilizations at significant spatial distances cannot perceive or observe human societal structures, as "the means to comprehend state ontology are inherently structural". While such civilizations might partially grasp the operational patterns of systemic units through technological surveillance, they remain external disturbances to the international system, perpetually unable to discern the essence of international order. Technological monitoring can only capture individual state actors—minuscule units within the system that alter configurations through order but lack substantive systemic impact. Just as changing a string's vibrational parameters alone cannot alter atomic structure unless its length, vibration, and shape all transform, the fundamental nature of a particle remains unchanged without comprehensive shifts.

In spite of the fact that the premise of the international system in this study comprises not only unit-level actors but also events and elements, it remains compatible with traditional definitions through an inclusive relationship. Thus, theories proposed by other scholars remain applicable here. In practice, the most common factor destabilizing the international system is internal conflict, as the system's anarchic foundation fosters configurations where "individuals, states, and the international system itself all contribute to war". Furthermore, the concept of the international system is not static but naturally constructed through historical evolution, with actors' interests emerging from social interactions within the system [33]. This does not necessarily imply, as constructivists argue, that shifts in social interactions among actors will transform social norms, rules, and legitimacy expectations, thereby altering the system's nature. States, as rational actors, remain constrained by the system. Technological advancements and economic interdependence have altered the costs and efficacy of military power. Yet, within the international system, the absence of communal normative ideals leads most actors to prioritise order over justice, viewing state interests as superior to international morality. The recurrent disregard for universal principles by powerful states further destabilizes the system's equilibrium.

5. Conclusion

This study employs natural science theories as analytical tools to deeply dissect the evolutionary patterns of the international system, by exploring the entropy transformation patterns of the international system, it reveals that the system resembles an entropy-increasing system. While its formation constitutes an entropy-increasing process and, as a non-isolated system, it temporarily resists entropy growth by acquiring external energy, the total entropy of human society continues to rise, leading the international system toward eventual heat death (thermal equilibrium). To quantify systemic entropy transformation, a formula for power dissipation among state actors was constructed. In examining systemic stability and imbalance, the study identifies multiple destabilising factors, utilises superstring theory to explain the impact of state actor transformations on the system, and clarifies that international organisations and institutions function analogously to D-branes and gauge fields in superstring theory. Furthermore, it demonstrates that the plural paradigms of international relations share similarities with the dualities of superstring theory and the unifying framework of M-theory.

Overall, the development of the international system is the result of the combined effects of various internal and external factors, and its process of transition is complex and characterised by uncertainty. Based on this, it is recommended that future research focus on how to utilise the normative roles of international organisations and institutions to optimise the structure of the international system and enhance its stability. Meanwhile, efforts should be made to strengthen the exploration of factors outside the system, such as the potential influence of extraterrestrial civilisations, to expand the boundaries of research. The international system exhibits the characteristic of dynamic evolution, and its stability is influenced by factors such as internal conflicts and changes in the interests of actors. Moreover, there are many similarities between it and natural science theories, which provide a direction for interdisciplinary research.

Most of the previous studies have deduced causes from results based on event-driven approaches, and there are deficiencies in research at the systemic level. Starting from a systemic perspective, this study analyses the existing patterns and rules of the international system, filling part of the lacuna in research at the systemic level. It provides a new perspective and reference for research methods for the development of international relations theories, which helps to promote the discipline of international relations to break through traditional research paradigms and construct a more complete theoretical system. It also offers interdisciplinary ideas for understanding international political phenomena and enriches the research methods of social sciences.

However, this study also has certain limitations. The superstring theory is still not perfect on the one hand. When applying it to the research of international relations, some analogies may not be rigorous enough, and the reliability of the theory needs to be further verified. On the other hand, the complexity of the international system far exceeds expectations, and it is difficult to cover all influencing factors in the research, so some analyses may not be comprehensive and in-depth enough. In the future, the way of combining the superstring theory with the research of international relations could be further improved to enhance the accuracy of theoretical application. More advanced research methods and technical means should be employed to conduct a comprehensive and systematic analysis of the international system, deeply explore various factors affecting the evolution of the system, continuously improve the research methods, and enhance the scientificity and reliability of the research.

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