

Article

Evolution and Ecological Activation Mechanisms of Chinese Electric Vehicles' International Image: A Complex Adaptive Systems Perspective

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Highlights

Please indicate how your work links to systems science via your contributions to systems practice, theory, and/or methodology.

- This study integrates Complex Adaptive Systems (CAS) theory with Competitive Framing theory to conceptualize global digital discourse as an emergent, non-linear network driven by continuous user feedback loops.
- Methodologically, it introduces a closed-loop computational framework combining unsupervised machine learning, Large Language Models (LLMs), and Social Network Analysis (SNA) to mathematically bridge micro-textual semantics with macro-structural network evolutions.

What are the main findings and/or the implications of the main findings?

- Empirical findings reveal that international audience perceptions of Chinese Electric Vehicles (EVs) have transcended traditional “low-cost” stereotypes, spontaneously forming a composite cognitive schema dominated by smart ecosystems and design experiences.
- The research demonstrates that positive technological frameworks and negative geopolitical risks engage in fierce adversarial contestation within a volatile network topology, offering a quantitative paradigm for targeted cross-border public opinion governance and global brand empowerment.

Abstract

Amid the accelerated global transition toward sustainable electromobility, Chinese Electric Vehicles (EVs) have forged a complex, evolving communication ecosystem across overseas social media platforms. Conceptualizing global digital discourse as a complex adaptive system (CAS), this study integrates CAS theory with Competitive Framing theory to systematically elucidate the thematic configurations, framework dynamics, and ecological activation mechanisms underlying the international image of Chinese EVs. By integrating unsupervised BERTopic modeling, Large Language Model (LLM) semantic mapping, the Entropy Weight Method (EWM), and Social Network Analysis (SNA), this inquiry operationalizes a comprehensive computational communication framework to mine large-scale behavioral and textual data from YouTube. The empirical findings unveil that: (1) international audience perceptions have broken through the traditional “low-cost manufacturing” stereotype, spontaneously giving rise to a multidimensional, composite cognitive schema centered on smart ecosystems and design experiences; (2) driven by the

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interplay of rational and irrational user feedback loops, the ecological activation efficiencies across diverse discursive dimensions exhibit pronounced nonlinear variances, characterized by a “strong activation of intelligent ecosystems versus a long-tail stagnation of cost-effectiveness salience”; and (3) positive technological frameworks and negative geopolitical or regulatory risks engage in fierce, adversarial contestation and structural hybridization within a highly volatile network topology, culminating in a unique “dual-core” configuration. Theoretically, this study enriches the scholarly understanding of country-of-origin and corporate brand images through a complex systems lens; methodologically and practically, it offers a high-fidelity, actionable quantitative paradigm for global brand empowerment and targeted cross-border public opinion governance.

Keywords: EVs; international image; dynamic evolution; social network analysis; design globalization

1. Introduction

Amidst the accelerated global expansion and green transition of the new energy vehicle industry, Chinese Electric Vehicles (EVs) have increasingly emerged as the focal point of intense discourse within international public opinion arenas [1–3]. Chinese EVs serve as a highly relevant focus for this inquiry because their rapid technological advancement and global market penetration have not only disrupted traditional automotive hierarchies but also triggered complex geopolitical and trade debates worldwide. In the decentralized digital media ecosystem, ordinary users on global social media platforms—such as YouTube, X, and TikTok—have radically mutated from passive recipients of information into active producers, diffusers, and contenders of discourse [4,5]. Consequently, the formation of international brand images has decoupled from centralized corporate control, transforming into a complex, dynamic communication process driven by multi-agent, hierarchical, and affect-driven interactions [6,7]. Within this networked milieu, divergent discursive themes engage in a continuous, zero-sum contestation for user attention, emotional alignment, and platform algorithmic resource allocation, while audience interactive affordances—such as liking, commenting, sharing, and secondary propagation—further amplify or suppress the systemic energy and topological visibility of specific narratives [8].

However, the extant literature on international product or country images exhibits two critical theoretical and methodological lacunae when confronting this nascent digital reality. The first is the fracture between Micro-Topics semantics and macro-network topologies. Traditional image paradigms predominantly rely on static textual content analysis or qualitative sentiment coding, which typically conceptualize international images as fragmented, cross-sectional aggregates of isolated attributes or dimensional scores [9,10]. Such reductionist approaches are inherently unequipped to capture the latent “conceptual drifts” embedded within volatile digital text streams. Crucially, struggle to track how different narratives interact, shift, and group into broader overarching themes and topological structures over time. The second is the pronounced misalignment between communicative volume and ecological activation efficacy. Current quantitative communication frameworks frequently operate under the unverified assumption of homogeneous thematic weighting, or exclusively rely on raw volume metrics—such as term frequency or post counts—to determine public salience. This “volume-as-effect” presumption fatally neglects the varying intensities of linear and nonlinear feedback loops embedded in user-interactive behaviors (e.g., liking, commenting, and sharing) [11]. Within a digital ecosystem, these behavioral interactions act as systemic energy signals that dynamically modulate narrative trajectories. Consequently, volume-centric methodologies fail to

rigorously quantify the differential capacity of diverse discursive frameworks to mobilize public engagement and to engineer framework alignment—a systemic phenomenon conceptualized herein as “ecological activation energy”.

To bridge these research gaps, this study conceptualizes the digital discourse surrounding EVs as a complex adaptive system (CAS). By integrating CAS theory with Competitive Framing theory, we argue that the international image of EVs is not a passive mirror of corporate messaging, but an emergent property driven by continuous feedback loops between positive frameworks (e.g., technological innovation, smart ecosystems) and negative frameworks (e.g., geopolitical risks, regulatory barriers). Accordingly, this paper introduces a comprehensive computational communication framework to systematically adjudicate the following interlocked Research Questions:

RQ1: What distinct discursive dimensions constitute the international image of EVs on global social media, and how do their ecological activation efficiencies vary under the influence of user feedback loops?

RQ2: How do international audiences’ cognitive focal points and discursive networks structurally evolve and exhibit conceptual drifts across successive developmental stages?

RQ3: In what structural configurations do positive and negative discursive frames contest, intersect, and hybridize within the topological discourse network?

Methodologically, this inquiry adheres to a robust, closed-loop analytical trajectory: Computational Identification → Semantic Sublimation → Efficiency Quantification → Structural Evolution. We operationalize an interdisciplinary approach blending unsupervised machine learning, Large Language Models (LLMs), and mathematical optimization. Specifically, the BERTopic model is deployed to execute vector clustering on large-scale audience commentaries to identify micro-level topics. Subsequently, an LLM is harnessed to map these discrete topics into macro-discursive dimensions, achieving semantic sublimation. Moving beyond frequency-centric constraints, the Entropy Weight Method (EWM) is utilized to construct an Ecological Activation Index (EAI) that objectively weights user interaction behaviors as system energy signals. Finally, Social Network Analysis (SNA) delineates the longitudinal topological properties and boundary contestations of the discourse network. By integrating these research objectives, this study contributes a comprehensive, high-fidelity empirical framework to the domain of international product image analysis within global digital media environments, ultimately empowering the global discourse ecosystem of EVs to enhance its sustainable vitality and strategic resilience in the digital era.

2. Literature Review

To construct the theoretical foundation for this study, a comprehensive literature search was conducted utilizing databases such as Web of Science and Scopus. The search was anchored by keywords including “Electric Vehicles,” “International Image,” “Complex Adaptive Systems,” and “Competitive Framing”. While this study is an empirical computational analysis rather than a Systematic Literature Review (SLR), strict selection criteria were applied. Initially, over 120 relevant articles were screened. Articles were primarily rejected or excluded if they focused exclusively on the mechanical engineering or battery chemistry of EVs without addressing public perception, or if they fell entirely outside the domains of communication, social sciences, or brand management. Ultimately, 61 highly relevant academic sources were utilized across the entire manuscript, with approximately 40 core articles directly shaping the theoretical paradigms in this section.

2.1. International Image Research and Digital Product Communication

International image has long stood as a foundational construct within the domains of international communication, public diplomacy, and strategic brand management

[12,13]. Before analyzing specific brands, it is important to understand general public perceptions of Electric Vehicles (EVs). Previous studies show that consumer attitudes toward EVs largely focus on practical issues like range anxiety, battery life, and charging infrastructure, as well as environmental benefits [3,5]. However, as the digital world has grown, these basic perceptions have become more complex. Conventional scholarship predominantly conceptualizes international images as relatively static, enduring cognitive structures, the formation of which heavily relies on centralized state-led communication, mainstream media narratives, and deeply entrenched cultural stereotypes [14,15]. Within the classic theoretical paradigm of country-of-origin image (COI), the “Made in China” label has historically been tethered to reductionist configurations such as “low-cost manufacturing”, “price-driven commodities”, and “large-scale industrial output” [16].

However, the rapid mutation of the global digital media ecology has radically transformed the underlying mechanisms of image formation [17]. The proliferation of decentralized social media platforms—such as YouTube, X, and Reddit—has effectively democratized international communication, empowering ordinary users to mutate into pivotal co-creators of international discourse. Consequently, international images are no longer exclusively engineered via monocentric corporate projections; instead, they are increasingly shaped through decentralized interactions, emotional participation, and platform-mediated algorithmic amplification [18,19].

Against this backdrop, Chinese Electric Vehicles (EVs) have increasingly emerged as a highly visible and heavily contested anchor of global digital discourse [1,5,20]. Extant studies indicate that overseas deliberations surrounding Chinese EVs have progressively transcended simplistic price-advantage attributions, expanding into multi-dimensional thematic configurations including autonomous driving, intelligent in-car ecosystems, industrial design aesthetics, green transition pathways, and global brand globalization strategies [2]. Concurrently, adversarial discourses focusing on data security vulnerabilities, intellectual property litigations, market access barriers, and geopolitical friction have intensified. As a result, EVs have evolved far beyond mere industrial commodities, mutating into symbolic communicative vessels that encapsulate global technological rivalries and international geopolitical contestations.

2.2. Complex Adaptive System (CAS) Theory and Digital Discourse Ecology

Complex Adaptive System (CAS) theory, which originated in complexity science [21], offers a robust ontological and methodological framework widely deployed across ecology, economics, organizational behavior, and contemporary communication research [22]. CAS theory posits that social systems are inherently non-linear, dynamic networks comprising distributed, autonomous agents who continuously interact, adapt, and co-evolve based on localized feedback loops. These micro-level behavioral adaptations eventually drive the entire system to spontaneously give rise to macro-discursive dimensions and emergent structures through self-organization [23,24].

Within contemporary computational communication, social media environments are increasingly conceptualized as prototypical complex adaptive systems [25]. High-frequency, multidirectional interactions continuously transpire among user networks, platform algorithms, discursive themes, media shocks, and external macro-political structures, collectively shaping a fluid, evolving discursive ecology [26–29]. Diverging from linear, top-down communication paradigms, opinion evolution in online networks exhibits distinct characteristics of decentralization, self-organization, non-linear feedback, and continuous structural reconfiguration [30–32].

From a CAS perspective, discursive themes within social media are not static ideological fixtures; rather, they are continuously generated, amplified, contested, and dissi-

pated through agent-based interactive feedback loops. Specific narratives may achieve exponential structural expansion driven by emotional resonance, structural social polarization, or platform algorithmic recommendations, whereas other themes may suffer long-tail marginalization in the absence of interactive energy feedback. Furthermore, external environmental shocks—such as geopolitical conflicts, trade sanctions, or technological controversies—can act as critical system perturbations, triggering structural transitions that violently reorder public attention and network topologies [33–35]. While an increasing body of computational literature leverages complexity theory to model online opinion dynamics, information diffusion, and network topologies [36,37], a critical epistemic gap remains: traditional paradigms consistently fail to mathematically bridge micro-textual semantics with macro-structural network evolutions.

To bridge this chasm, this study anchors its analytical lens in CAS theory, conceptualizing the international digital discourse surrounding Chinese EVs as a dynamic, complex communication system. Within this unified architecture, discursive themes are operationalized as “emergent structures” of the system [21], while user interactive affordances (such as liking, commenting, and sharing) function as the core “ecological activation mechanisms” that drive non-linear system feedback [25]. Recognizing that static cross-sectional volume metrics (e.g., term frequency) are fundamentally unequipped to capture such dynamic system vitality, this study introduces a robust mathematical optimization paradigm to translate multi-dimensional audience behaviors into an objective, quantitative measure of system energy. This integration provides the definitive theoretical and empirical justification for deploying the Entropy Weight Method (EWM) to construct the Ecological Activation Index (EAI).

2.3. Competitive Framing Theory and Global Technological Discourse Rivalry

Framing theory asserts that communicative actors and media institutions strategically select and emphasize specific attributes of reality to construct interpretative schemata for the public [38,39]. Framing inherently dictates not only the parameters of public visibility (“what to think about”) but also the structural cognitive pathways of interpretation (“how to understand it”). Divergent frames routinely engage in a fierce contestation for interpretive dominance, actively modulating public cognition, affect, and risk evaluation through localized problem definitions, causal attributions, and moral judgments. Within globalized digital media networks, platform configurations enable a heterogeneous array of global actors to concurrently participate in international image construction, converting global communication into a multi-agent, hyper-localized, and values-driven competitive framing game [40,41].

The international discourse enveloping Chinese EVs serves as a prototypical empirical manifestation of this competitive framing mechanism. On one hand, positive frameworks strategically highlight technological innovation frontiers, intelligent connectivity ecosystems, industrial value-chain upgrading, sustainable green transitions, and globalized brand equity [20,42,43]. On the other hand, negative frameworks aggressively mobilize risk-centric narratives focused on data privacy vulnerabilities, market entry barriers, intellectual property infringements, geopolitical threats, and competitive industrial containment [44,45]. These adversarial frames continuously engage in zero-sum contestations across global social networks, collaboratively shaping the composite, dialectical cognitive structures of international audiences.

However, current framing scholarship predominantly relies on qualitative textual criticism or traditional content analysis. While highly capable of deconstructing specific narrative logics, these static methods are structurally incapable of capturing the dynamic evolutionary trajectories of competitive framing at scale across volatile digital ecologies. More fatally, the majority of existing frameworks omit the quantitative evaluation of user-

interactive feedback loops, leaving the underlying mechanisms through which specific frames mobilize superior communicative energy and emotional capital largely unexplained [46–48].

2.4. Research Gaps and Integrated Analytical Framework

In sum, historical inquiries into international product images consistently suffer from a critical deficit in system-wide, dynamic perspectives. To resolve this epistemological limitation, this study operationalizes a comprehensive, integrated analytical framework (Figure 1). We chose to hybridize CAS and Competitive Framing theory to bridge the gap between text meaning and network behavior. This framework utilizes Competitive Framing theory as its qualitative deconstructive anchor, guiding the automated extraction and semantic categorization of positive and negative discursive frames via BERTopic (utilizing the class-based TF-IDF procedure) and LLMs. Concurrently, it deploys CAS theory as its foundational mathematical logic to model network topological evolution, utilizing EWM to quantify non-linear interactive energy and Social Network Analysis (SNA) to map macro-structural network trajectories. By synthesizing these dual theoretical domains with computational communication methodologies, this inquiry achieves a closed-loop empirical integration from micro-level textual semantics to macro-discursive dimensions of system dynamics.

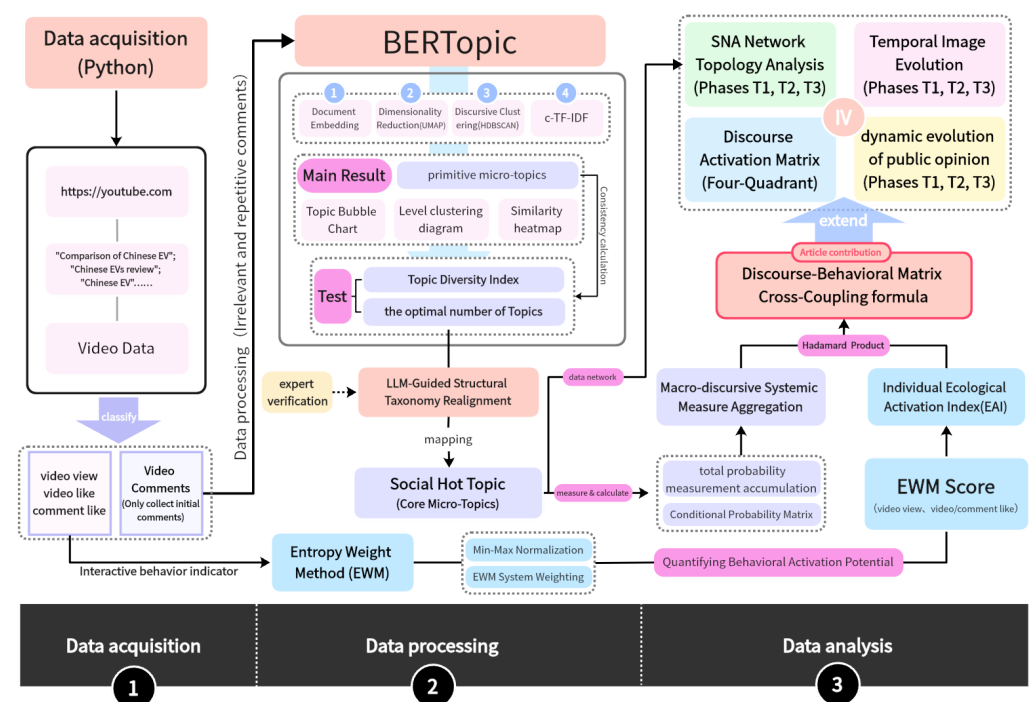


Figure 1. Study framework.

3. Methodology and Analytical Framework

This study constructs a multi-layered, dynamic analytical framework designed to quantitatively decode the discursive evolution and ecological activation mechanisms operating within social media video commentary spaces regarding electric vehicles (EVs). Chronologically, the research architecture operationalizes a cohesive, high-fidelity computational paradigm formulated as: computational identification → semantic sublimation → efficacy quantification → topological evolution.

3.1. Data Acquisition and Preprocessing

Empirical granular text corpora were harvested via the YouTube Data API v3 (<https://developers.google.com/youtube/v3> (accessed on 15 March 2026)) from the video commentary spaces of high-traction and viral video corpora concerning Chinese EVs on YouTube (<https://www.youtube.com>) because unlike platforms that feature short-form, rapid reactions, YouTube's focus on long-form review formats fosters the deep-text, deliberative comments essential for precise semantic clustering.

To guarantee an unbiased selection and prevent skewing toward specific influencers or polarized channels, we executed platform-wide queries utilizing neutral keywords (e.g., “Chinese EV review”, “Chinese electric cars”). We then objectively selected the top videos ranked by aggregate view counts and highest engagement rates across a diverse range of independent automotive review channels. The longitudinal observation window for these selected videos was strictly locked between December 2025 and May 2026. This specific timeframe was selected because early 2026 saw a massive surge in both review videos and high-heat public discussions regarding Chinese EVs. We limited our observation window to this exact period to accurately capture these intense shifts in public opinion, as expanding the timeframe would have diluted the data with irrelevant background noise from inactive periods. Furthermore, from these videos, we exclusively collected top-level comments and filtered out nested replies. This was done to prevent overly emotional arguments and endless debates from skewing our subsequent data analysis.

Following a rigorous, multi-stage data purification workflow—which comprised the elimination of duplicate string items, the extraction of uninformative textual components, spam remediation, the containment of malicious commercial redirection links, bot-generated commentary filtering, and the exclusive retention of English-language scripts—a clean and valid corpus of 6672 discrete comment nodes was retained. Each data item preserves critical interactive metadata, including localized timestamps, raw text strings, secondary reply counts, and user-mediated like volumes, providing an empirical bedrock for subsequent dynamic social network analysis (SNA).

3.2. Computational Methods

3.2.1. Unsupervised BERTopic Modeling Pipeline

To unearth the latent, deep-layer semantic themes embedded within the highly unstructured social media commentary, this study deploys the BERTopic modeling pipeline. The choice of BERTopic over traditional bag-of-words or latent Dirichlet allocation (LDA) architectures is predicated upon its capacity to leverage deep contextual embeddings via pre-trained Transformer architectures [49]. This allows the model to overcome the critical limitations of severe semantic fragmentation and contextual rupture that typically undermine short-text computational processing [50,51]. The thematic extraction pipeline executes across three core mathematical sequences:

First, a deep pre-trained Transformer architecture is operationalized to project raw comment strings into a high-dimensional continuous semantic vector space, thereby securely capturing the nuanced, non-linear contextual representations of the discourse.

Second, to address the “curse of dimensionality” inherent in high-dimensional embedding vectors and to optimize downstream clustering, Uniform Manifold Approximation and Projection (UMAP) is applied to perform nonlinear dimensionality reduction. Subsequently, the Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) algorithm is operationalized upon the lower-dimensional manifold vector space. This density-based clustering configuration is designed to capture irregularly shaped semantic boundaries and discard background conversational noise, thereby identifying distinct theme clusters with high internal semantic cohesion and strict mutual exclusivity.

Third, the class-based TF-IDF (c-TF-IDF) algorithm is deployed to extract high-salience diagnostic keywords from each generated document cluster, mathematically formalizing highly interpretable, explicit thematic representations. The mathematical expression of the c-TF-IDF algorithm is formalized as follows:

$$W_{t,c} = tf_{t,c} \times \log \left(1 + \frac{A}{tf_t} \right) \quad (1)$$

where $W_{t,c}$ denotes the c-TF-IDF weight, $tf_{t,c}$ denotes word frequency within cluster c , tf_t represents global frequency, and A is the average document length per cluster. To ensure strict scientific rigor and methodological objectivity in parameter selection, this study conducted a comprehensive grid-search optimization traversal across the empirical topic-count spectrum. By tracing the localized mathematical trajectories of the thematic semantic consistency, a resolution threshold of 15 distinct micro-topics was derived as the optimal granularity for model convergence. The resulting thematic mapping underwent rigorous multi-dimensional empirical evaluations. Computational metrics establish that the global model achieved a robust Coherence Score (C_v) of 0.3624 and a Topic Diversity Index of 0.8867 [52,53]. These standardized evaluation diagnostics mathematically validate that the 15 extracted core discursive topics possess excellent semantic interpretability, profound structural validity, and minimized clustering redundancy.

3.2.2. Large Language Model (LLM)-Driven Semantic Enhancement and Dimensional Mapping

Under the conceptual paradigm of Complex Adaptive Systems (CAS), the international image of a product within social media networks does not manifest as a static, pre-configured artifact; rather, it operates as a fluid, multi-layered discursive configuration that is continuously synthesized, contested, and evolved through the non-linear interactions of heterogeneous user agents. Consequently, this study deploys the BERTopic pipeline to perform dynamic thematic identification, explicitly capturing the property of topological emergence embedded within digital public opinion ecosystems.

Crucially, distinct discursive themes do not exist in isolation; instead, they undergo continuous dynamic friction, competitive framing contestation, and semantic reconfiguration driven by ongoing user-interactive loops and platform-mediated information diffusion. To decode these complex dynamics, this research introduces a Large Language Model (LLM) to engineer a human-in-the-loop hybrid computational paradigm [54]. By executing semantic enhancement and multi-dimensional scaling mapping, this framework facilitates a rigorous epistemological ascension from raw algorithmic data clustering to high-level, macro-social discursive dimensions [55]. The formalized operational sequence is articulated as follows:

The keyword vector sets extracted from each topic cluster via the unsupervised BERTopic pipeline were operationalized as targeted prompts for the LLM. Leveraging the model’s advanced contextual synthesis and deep semantic decoding capabilities, the LLM

executed granular contextual reconstruction on the inherently fragmented lexical topologies, ultimately refining the raw data points into 15 micro-topics (Topic 0–Topic 14).

Building upon this foundation, this study formalized a consolidated matrix of macro-systemic discourse dimensions, denoted as C . The LLM was employed to categorize the BERTopic-derived micro-topics into three macro-cognitive dimensions according to their latent semantic characteristics. Under the conceptual lens of Competitive Framing Theory, these dimensions extend beyond conventional thematic classifications and represent competing cognitive paradigms that contend for interpretive dominance within the global digital public sphere.

To operationalize the cross-level transformation from micro-level semantic topics to macro-level cognitive dimensions, an LLM-driven semantic classification function was constructed as:

$$F: T \rightarrow C \quad (2)$$

where T denotes the set of 15 BERTopic-derived micro-topics and represents the set of macro-discursive dimensions. The mapping function assigns each micro-topic (k) to a unique macro-discursive dimension (C_j), such that:

$$F(k) = C_j \quad (3)$$

where $j \in \{1, 2, 3\}$ represents the index of the three macro-dimensions. To convert this qualitative classification process into a computable analytical structure, an indicator function was further defined:

$$I(k, j) = \begin{cases} 1, & F(k) = C_j \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

where indicates whether the k -th micro-topic belongs to the j -th macro-cognitive dimension. To ensure classification reliability, the LLM-based mapping procedure was repeatedly validated through multi-round prompt interactions and consistency checks. The finalized topic-to-dimension mapping rules were subsequently compiled into a standardized JSON configuration file, which served as the computational basis for automated matrix construction and subsequent quantitative analyses implemented in Python (version 3.9) using the PyCharm IDE.

3.2.3. Construction of the Discourse Ecological Activation Index Based on the Entropy Weight Method and Multi-Level Mapping

From the perspective of Complex Adaptive Systems (CAS), user interactions such as likes, comments, and shares do not merely represent feedback behaviors; rather, they function as “adaptive interaction energy” within the digital communication ecosystem. Differences in interaction behaviors across distinct discourse themes reflect the mechanisms of information selection, emotional amplification, and cognitive reinforcement inherent in the system. Therefore, this study employs the Entropy Weight Method (EWM) to construct the Ecological Activation Index (EAI), thereby quantifying the adaptive diffusion capacity of various topics within a complex communication ecology.

1. Objective Ecological Weighting of User Interaction Behaviors Based on the Entropy Weight Method (EWM)

To objectively quantify information dispersion and eliminate arbitrary subjective biases in multi-criteria weighting, this study invokes the foundational tenets of Shannon’s information theory [56]. According to this mathematical paradigm, the statistical entropy of an indicator serves as an inverse measure of its data dispersion and informational vi-

tality. To quantify the discursive energy embedded in internet user interactions on overseas video-based social media, this study selects three micro-behavioral indicators as proxies for the social mobilization effect of the audience: Video Views, Video Likes, and Comment Likes [57].

Let the total sample size be M , and let x_{ij} denote the original observed value of the i -th data point on the j -th behavioral indicator, where $i = 1, 2, \dots, M$ and $j = 1, 2, 3$. To eliminate the influence of different dimensions and scales on the evaluation results, the min-max normalization method is applied to the raw data:

$$x_{ij}^* = \frac{x_{ij} - \min(x_{.j})}{\max(x_{.j}) - \min(x_{.j})} \quad (5)$$

Furthermore, the contribution projection ratio p_{ij} , which represents the proportion of the i -th data point's contribution to the total contribution under the j -th indicator is calculated as follows:

$$p_{ij} = \frac{x_{ij}^*}{\sum_{i=1}^M x_{ij}^*} \quad (6)$$

According to information theory, the information entropy of each interaction indicator depends on the logarithmic adjustment of the total sample size. To resolve mathematical singularities arising from a large number of zeros in the matrix—which would otherwise cause logarithmic calculations to fail—this study introduces a machine-epsilon smoothing factor into the engineering computation. The information entropy and the systemic information utility coefficient for each indicator are defined as:

$$e_j = -\left(\frac{1}{\ln M}\right) \sum_{i=1}^M p_{ij} \ln(p_{ij} + \delta), \quad d_j = 1 - e_j \quad (7)$$

where δ is a machine-epsilon smoothing factor (a negligibly small constant, e.g., 10^{-6}) introduced to prevent mathematical singularities when $p_{ij} = 0$.

By calculating the proportion of each indicator's information utility relative to the total utility value, the objective systemic weight coefficients— α , β , and γ —for video views, video likes, and comment likes within the global overseas public opinion ecosystem are scientifically determined:

$$W_j = \frac{d_j}{\sum_{j=1}^3 d_j} \Rightarrow (\alpha, \beta, \gamma) \quad (8)$$

Based on these objective weights, the continuous mathematical expression of the individual Ecological Activation Index (EAI_i) carried by the i -th data point is formulated as:

$$EAI_i = \alpha \cdot Views_i^* + \beta \cdot Video_Likes_i^* + \gamma \cdot Comment_Likes_i^* \quad (9)$$

where $Views_i^*$, $Video_Likes_i^*$, and $Comment_Likes_i^*$ represent the min-max normalized values of the respective interactive behavioral indicators for the i -th data point. The theoretical significance lies in its ability to eliminate the subjective bias of researchers through mathematical optimization and machine learning mechanisms. It extracts the social mobilization energy released by each data point in the public opinion field based entirely on empirical audience engagement and interaction metrics on overseas social media platforms.

2. Probability Mapping and Aggregation from Micro-Topics to Macro-Discursive dimensions

After computing the behavioral energy (Ecological Activation Index, EAI_i) of individual data points, it is necessary to condense, reduce the dimensionality of, and structurally merge the raw micro-semantic features, which are typically highly sparse and noisy. Let the human-in-the-loop mapping function from micro-topics to macro-discursive dimensions be defined as $F: T \rightarrow C$, where T represents the index set of 15 micro-topics, and $C = \{C_1, C_2, C_3\}$ denotes the aggregated set of macro-perceived discourse dimensions.

For any given data sample ($i = 1, 2, \dots, M$), the model outputs a conditional probability vector recording the baseline probability that the text belongs to micro-topic k , denoted as $P(\text{Topic}_k | \text{Doc}_i)$. Based on the law of total probability and measure aggregation logic, the condensed probability $P(\text{Topic}_k | \text{Doc}_i)$ that datum i belongs to the macro-perceived dimension ($j = 1, 2, 3$) is formally defined as the sum of the conditional probabilities of all micro-topics assigned to that dimension. Introducing an indicator function $\mathbb{I}(\cdot)$, the mathematical formula for dimensional compression and reduction is expressed as:

$$P(C_j | \text{Doc}_i) = \sum_{k=0}^{14} P(\text{Topic}_k | \text{Doc}_i) \cdot \mathbb{I}(f(k) = C_j) \quad (10)$$

where the academic indicator function satisfies the following filtering condition:

$$\mathbb{I}(f(k) = C_j) = \begin{cases} 1, & \text{if micro-topic } k, \text{ mapped to } C_j \\ 0, & \text{otherwise} \end{cases} \quad (11)$$

3. Calculation of the Comprehensive Discourse Dimension Score Integrating Behavioral Weights

To infuse the static text semantic space with behavioral mobilization capabilities and ecological vitality, this study cross-couples pure semantic macro-perceptual measures with behavior-driven ecological activation mechanisms. Utilizing a Hadamard Product approach, the individual behavioral energy of a datum is matrix-reconstructed by multiplying it with its macro-perceived dimensional probability $P(\text{Topic}_k | \text{Doc}_i)$. The final Ecological Activated Score ($\text{Score}_{i,j}$) of the data sample on the macro international image perception dimension is calculated as:

$$\text{Score}_{i,j} = EI_i \times P(C_j | \text{Doc}_i) \quad (12)$$

By substituting the user behavior entropy weight formulation and the probability dimensional aggregation formula into the equation above, the core, comprehensive stream-data integration measurement model of this methodology is derived:

$$P(C_j | \text{Doc}_i) = \sum_{k=0}^{14} P(\text{Topic}_k | \text{Doc}_i) \cdot \mathbb{I}(f(k) = C_j) \quad (13)$$

where V_i^* , $L_{v,i}^*$, and denote the normalized behavioral feature proxies for video views, video likes, and comment likes of the data sample i , respectively; α , β , and represent the system's objective weight coefficients calculated via the Entropy Weight Method.

3.2.4. Social Network Analysis (SNA)

From a CAS perspective, the international product image network on social media exhibits prominent "self-organizing" characteristics. The co-occurrence relationships among different discourse themes do not emerge randomly; instead, they evolve into dynamic network structures through continuous interactions among a massive user base. Therefore, this study adopts Social Network Analysis (SNA) to examine the discursive

topological structures across different stages, aiming to identify the dynamic coupling relationships and structural reconfiguration processes among international image frameworks [58,59]. The core utilities are as follows:

- **Mapping “Cognitive Maps”:** Isolated topics extracted via topic modeling are converted into network nodes and mapped into a comprehensive “cognitive map” based on their co-occurrence relationships. Node sizes are dynamically scaled using their Ecological Activation Index (EAI), and edge weights are mathematically determined by the Pearson correlation between topics multiplied by the mean EAI of the specific timeframe. This approach not only demonstrates what is being discussed but also reveals how these topics establish logical associations within the public psyche.
- **Quantifying Structural Attributes:** By utilizing mathematical metrics such as centrality and density, ambiguous public opinions are converted into precise structural properties. Specifically, by calculating node degrees, the algorithm structurally isolates highly connected topics into a central core subgraph, while mathematically pushing inactive nodes to an outer peripheral boundary. This enables the identification of core versus peripheral agendas within the public opinion arena, thereby delineating the power loci of image construction.
- **Capturing Topological Evolution:** By comparing the network topologies across different temporal windows (e.g., T1, T2, T3), this method captures shifts in core agendas and variations in connection strengths, which are computationally mapped to dynamic edge widths and visual opacities to explicitly track systemic energy shifts over time. Consequently, it characterizes the evolutionary trajectory of the international image of Chinese products as it transitions logically from a “fragmented” state to a “systematized” structure.

4. Results and Analysis

4.1. Computational Identification and Semantic Coherence Verification of the International Discourse Field

4.1.1. Granularity Optimization of Discursive Themes

Initially, unsupervised topic modeling was applied to the collected corpus of audience commentaries, yielding 62 primitive micro-topics. Because listing all 62 raw topics would introduce significant analytical noise, we needed to identify the core “major” ones. To scientifically ascertain the optimal classification granularity of the thematic model, a comprehensive parameter space optimization was conducted based on the Semantic Coherence metric across a rigorous testing interval $K \in [5, 50]$ [60].

The experimental trajectory illuminates that (Figure 2), with the iterative compression and merging of the number of topics, K , the C_v score exhibits a state characterized by non-linear fluctuations. Crucially, the overall C_v index of the model reaches its global mathematical maximum when the number of topics is precisely constrained to 15, yielding a peak value of 0.4075, as illustrated in Figure 2. Consequently, this study empirically establishes these core topics as the definitive micro-level data foundation for all subsequent longitudinal reconfigurations and evolutionary analyses of the international image. Additionally, the left panel of Figure 2 illustrates the Inter topics Distance Map projected via multi-dimensional scaling, showcasing the 62 primitive micro-topics initially generated by the unconstrained model. In this topological space, the size of each circle represents the marginal thematic prevalence of these raw clusters, and the spatial distances indicate their semantic relationships prior to the rigorous optimization down to the 15 core topics.

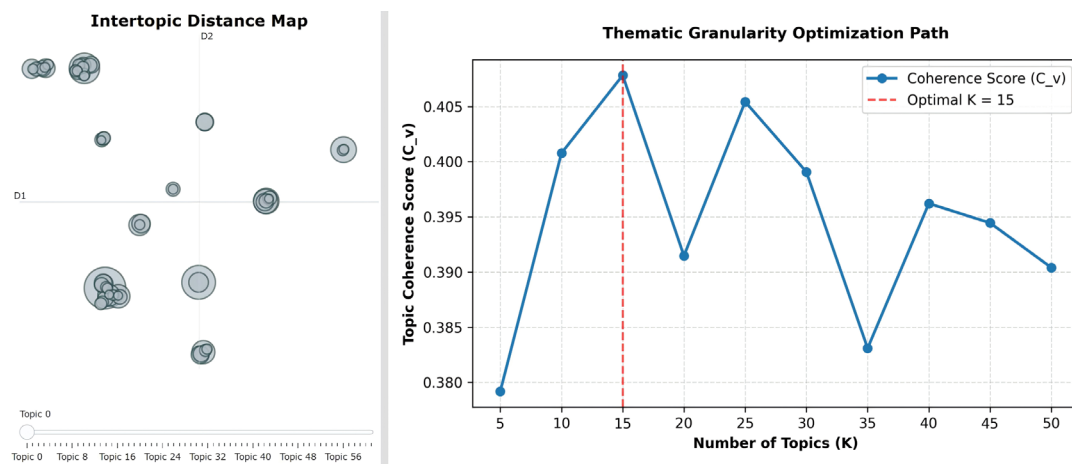


Figure 2. BERTopic topic clustering and optimal topic distribution.

4.1.2. Clustering Robustness and Low Redundancy Verification

To further validate the taxonomic mutual exclusivity and orthogonality of the 15 extracted topics, this study deployed a thematic similarity heatmap to execute a rigorous clustering robustness check. Quantitative evaluation reveals that the global Topic Diversity Index (TDI) of the model achieves a high-fidelity score of 0.8867 [53].

Within the topological structure of the similarity heatmap, this superior metric manifests as follows: excluding the main diagonal axis (where the autocorrelation coefficient is strictly 1.0), the overwhelming majority of the off-diagonal cells exhibit semantic similarity scores that are strictly confined within the light-colored intensity spectrum (with scores falling below the predefined threshold, score < 0.15 , Figure 3). This topological pattern empirically confirms that, following the joint pipeline of BERTopic vector space mapping and HDBSCAN density-based clustering, the identified core topics possess highly delineated semantic boundaries, effectively eliminating statistically significant clustering redundancy or conceptual issue overlap.

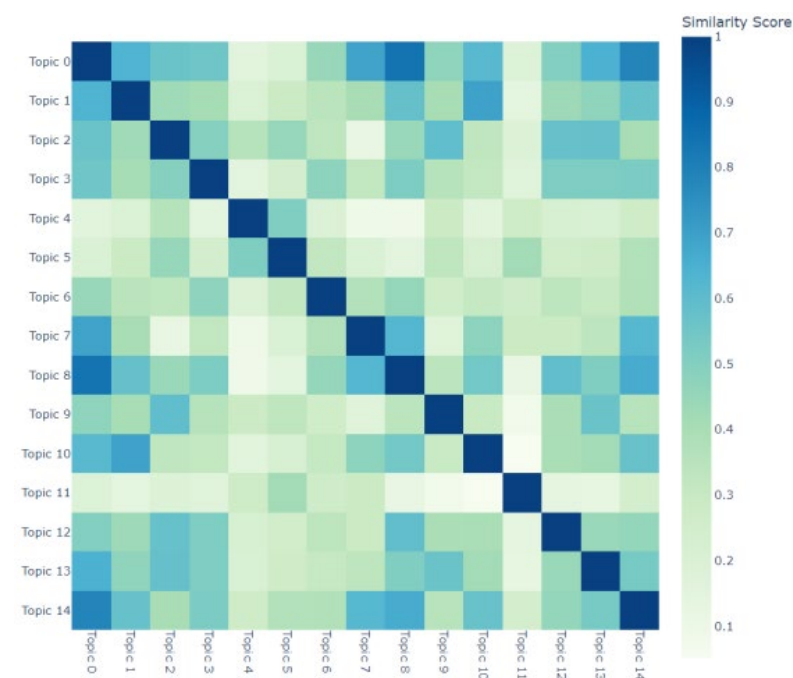


Figure 3. Topic similarity heatmap.

4.1.3. Micro-Level Thematic Identification and Decoupling Analysis

To clarify our conceptual hierarchy, we define “micro-topics” as the specific, algorithm-driven semantic clusters generated by BERTopic, whereas “macro-discursive dimensions” refer to the higher-order cognitive frameworks we will construct later. By leveraging the c-TF-IDF algorithm to extract localized semantic features across the 15 optimized topic clusters, the international discourse field exhibits a highly granular, multi-dimensional, and concrete topology. As explicitly visualized in Figure 4 (Core Theme Word Bar Chart), these 15 specific micro-topics and their corresponding keywords provide a comprehensive overview of the semantic architecture. The empirical results (Figure 4) demonstrate that global audience deliberations surrounding Chinese EVs have progressively decoupled from macro-discursive dimensions, abstract rhetorics, and anchoring instead upon industry-specific technological and market configurations:

(1) Technological Innovation Discourse Cluster

Epitomized by Topic 1, Topic 4, and Topic 10, the high-frequency feature vectors are heavily saturated with keywords such as “xiaomi_su_seven”, “yu7”, “huawei”, “best”, “premium”, and “buttons”. Within the hierarchical clustering tree topology, Topic 1 and Topic 10 exhibit a direct structural link, mathematically capturing the paradigm shift wherein the consumer electronics ecosystem empowers intelligent vehicular mobility. This topological configuration demonstrates that, within the cognitive schema of international audiences, these two cross-industry technology giants, migrating from the smartphone sector to the automotive market, have engineered a powerful technological synergy, collectively forging the “intelligent titan” label in the international image of Chinese EVs.

(2) Aesthetic Perception and Value Co-creation

Represented by Topic 2, Topic 5, Topic 9, and Topic 13, this dimension encapsulates salient textual nodes such as “beautiful”, “nice”, “interior”, “rollsroyce”, and adversarial counter-narratives including “ugly” and “copy”. These lexemes indicate that while Chinese EVs are structurally reconfiguring global aesthetic sensibilities through their “design globalization” strategy, they concurrently provoke intensive online contestations regarding the boundary between original premium design and legacy luxury brand equity. Within the hierarchical dendrogram (Figure 5), Topic 2, Topic 5, and Topic 9 rapidly converge onto an identical parental node branch at a minimal distance metric. This clustering morphology confirms that global praise for Chinese automotive aesthetics invariably co-exists with a rigorous audit of design overlap against classic Western models (e.g., Land Rover, Range Rover, Bentley), forming a highly strained, double-edged discursiveness wherein appreciation and copycat accusations are intrinsically intertwined.

(3) Market Barriers and Geopolitical Apprehensions

Composed of Topic 3, Topic 6, and Topic 11, the semantic vectors of this cluster frequently include critical tokens such as “price”, “market”, “usa”, “canada”, and “cooked”. This structural distribution demonstrates that the international expansion of Chinese EVs is confronting immense non-technical resistance precipitated by macro-discursive dimensions of trade politics, protectionist tariff policies, and national security anxieties. The hierarchical clustering architecture further unveils the macro-discursive scaffolding of this dimension (Figure 5): Topic 7 (characterized by “china”, “world”, “ahead”) and Topic 8 (characterized by “ev”, “eclectic”) initiate the primary hierarchical dendritic aggregation due to shared references to systemic policy resistance, subsequently merging with Topic 3 (tariffs and pricing) into a larger, higher-order macroeconomic and geopolitical branch. This structural convergence quantitatively demonstrates that in the cognitive stereotypes

of international audiences, tariff controversies surrounding Chinese EVs are highly contingent upon—and embedded within—the overarching narrative of Western trade protectionism and geopolitical containment. Consequently, global digital opinion rarely treats Chinese EVs as value-neutral technological artifacts; rather, it continuously audits them through a macro-historical lens of global industrial restructuring and economic hegemony reconfiguration.



Figure 4. Core Theme Word Bar Chart.

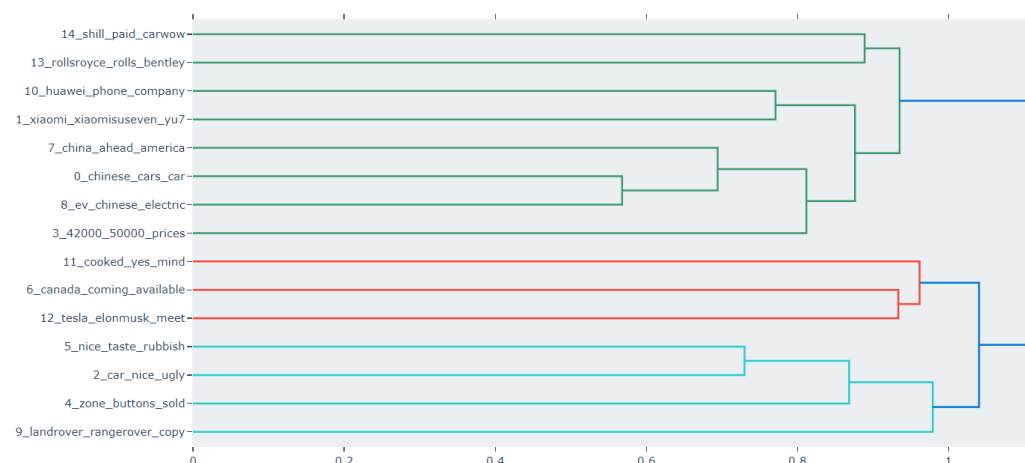


Figure 5. Topic level clustering diagram.

4.2. Reconstruction of Discursive Dimensions and Quantitative Evaluation of Ecological Activation Efficiency

4.2.1. LLM-Driven Semantic Sublimation Mechanism

Although the preliminary analytical phase utilizing BERTopic extracted 15 relatively autonomous micro-topic clusters, evaluating a highly fragmented and discrete bottom-up topology introduces considerable noise, which ultimately obfuscates the systemic deduction of macro-discursive dimensions of communication efficiencies across the public opinion field.

To achieve a rigorous granularity contraction and optimize interpretive high-fidelity, this study operationalized a “human–AI collaborative” paradigm. By leveraging the zero-shot classification affordances of Large Language Models (LLMs) synthesized with a double-blind expert consensus validation, the 15 discrete micro-topics were structurally mapped and sublimated into high-order, sociologically grounded macro-discursive dimensions. This alignment reconstructed the fluid boundaries of international audience deliberations into macro-discursive dimensions: the Technological Innovation Dimension (TI), the Cost-Effectiveness Dimension (CE), and the Compliance and Risk Dimension (CR), see Table 1.

Table 1. LLM Mapping of 15 Topics and 3 Dimensions.

Topic ID	Mapping Topics	Category
3	Price Competitiveness & Overseas Purchasing Power	The Cost-Effectiveness Dimension
5	Affective Attitudes & Subjective Evaluations	The Cost-Effectiveness Dimension
13	Premiumization Challenges & Residual Value Analysis	The Cost-Effectiveness Dimension
11	Perceived Industrial Threat under Geopolitical Rivalry	The Compliance and Risk Dimension
8	Market Expansion & Data Privacy Security Risks	The Compliance and Risk Dimension
6	Market Access Barriers & Regulatory Compliance	The Compliance and Risk Dimension
14	Trust Crisis & Media Manipulation Suspicions	The Compliance and Risk Dimension
9	Design Imitation & Intellectual Property Disputes	The Compliance and Risk Dimension
1	Cross-Sector Fusion & Smart Ecosystem	The Technological Innovation Dimension
12	Tesla as Competitive Benchmark in EV Market	The Technological Innovation Dimension
4	HMI (Human–Machine Interface) & Feature Configuration	The Technological Innovation Dimension
7	Perceived Global Status of Chinese Tech & Economy	The Technological Innovation Dimension
0	Global Design Strategy & Market Positioning	The Technological Innovation Dimension
2	Aesthetics Perception of Exterior & Interior Design	The Technological Innovation Dimension
10	Huawei Smart Driving Tech & Premium Market Layout	The Technological Innovation Dimension

4.2.2. Entropy Weight Method (EWM) Objective Weighting Configuration of Interactive Behavior

To objectively quantify the “mobilization potential” and “activation efficiency” across diverse discursive dimensions within overseas social media ecologies, this study deployed the Entropy Weight Method (EWM) to implement a non-subjective, mathematically driven weighting configuration for multi-dimensional social media interactive affordances. Specifically, this study operationalizes video view counts as a Consumption-Level Informational Affordance, video like counts as an Interactive-Level Behavioral Feedback, and comment like counts within the comment sections as an Adversarial-Level Collective Contestation. By calculating the marginal utility values and information entropy across each discrete indicator, the definitive objective weighting matrix was synthesized, illustrated in Table 2.

Table 2. Entropy Weight (EWM) Weighting Table for Video Interactive Behavior.

Interactive Behavior	Interactive Effect Hierarchy	EWM Score
video view	Consumption-Level	α : 0.1034
video like	Interactive-Level	β : 0.1297
comment like	Adversarial-Level	γ : 0.7669

The quantitative weighting results demonstrate that the adversarial-level indicator (comment likes) commands an absolute structural dominance with a weight of 0.7669. This empirical distribution reveals that, within the international communication field of intelligent EVs, audiences' peripheral content ingestion (views) and low-threshold approval (video likes) contribute minimally to the reduction in systemic information entropy. Conversely, the micro-level dialectical contestations, emotional resonances, and secondary-level endorsement rivalries transpiring within the comment networks constitute the definitive thermodynamic core driving non-linear energy dissipation and reconfiguring the activation-mobilization capacity of brand images.

This phenomenon heavily instantiates the Adaptive Selection mechanism inherent to a Complex Adaptive System (CAS). Discursive frameworks embedded with higher emotional mobilization potencies and structurally controversial triggers are inherently favored by platform-mediated adaptive selection, selectively amplifying informational signals and capturing superior structural gravity and discourse weights within the digital communication ecology.

4.2.3. Quantitative Computational Modeling and Communication Efficacy Analysis of Macro-Discursive Dimensions

To comprehensively elucidate the aggregate kinetic potential and systemic activation dynamics of the international public opinion field regarding the international image of EVs, the individual Ecological Activation Index (EAI) configurations of the 15 micro-topics were mathematically aggregated and funneled into three macro-discursive dimensions—the Technological Innovation Dimension (TI), the Compliance and Risk Dimension (CR), and the Cost-Effectiveness Dimension (CE)—strictly adhering to the predefined LLM semantic mapping matrix (Table 3). Synthesizing the latest quantitative computational results, the internal structural distributions of sub-issues across the three macro-discursive dimensions exhibit a pronounced topological configuration of “dual-core co-existence and localized polarization”. The dynamic contestation logic within the international discourse environment systematically unfolds across a three-tiered structural architecture.

Table 3. Average EAI score for mapping topics.

Topic ID	Mapping Topics	Average EAI	Category
3	Price Competitiveness & Overseas Purchasing Power	0.125715561	CE
5	Affective Attitudes & Subjective Evaluations	0.063672326	CE
13	Premiumization Challenges & Residual Value Analysis	0.038900285	CE
11	Perceived Industrial Threat under Geopolitical Rivalry	0.191286562	CR
8	Market Expansion & Data Privacy Security Risks	0.168230568	CR
6	Market Access Barriers & Regulatory Compliance	0.149727847	CR
14	Trust Crisis & Media Manipulation Suspicions	0.07275663	CR
9	Design Imitation & Intellectual Property Disputes	0.041667994	CR
1	Cross-Sector Fusion & Smart Ecosystem	0.228718459	TI
12	Tesla as Competitive Benchmark in EV Market	0.188536139	TI
4	HMI (Human–Machine Interface) & Feature Configuration	0.156088675	TI
7	Perceived Global Status of Chinese Tech & Economy	0.106821351	TI
0	Global Design Strategy & Market Positioning	0.084834798	TI

2	Aesthetics Perception of Exterior & Interior Design	0.072616614	TI
10	Huawei Smart Driving Tech & Premium Market Layout	0.041654899	TI

Following the precise empirical calculation of the localized EAI for each of the 15 micro-topics, this study introduces the Ecological Activation Aggregate Index (EAAI) to evaluate macro-discursive dimensions of communication efficacy. To eliminate systematic sample biases generated by the mathematical imbalance in the number of micro-topics nested under divergent dimensions, the mathematical aggregation is operationalized via the following objective scaling formulation:

$$EAAI_{i,j} = \frac{1}{N_j} \sum_{k \in \Omega_j} \text{Score}_{i,k} \quad (14)$$

where $EAAI_{i,j}$ represents the Ecological Activation Aggregate Index for the i -th data sample (or temporal phase) within the j -th macro-discursive dimension; Ω_j denotes the discrete set of micro-topics operating under the structural jurisdiction of the j -th macro-discursive dimension; N_j corresponds to the exact cardinality (the total quantity) of micro-topics contained within the internal configuration of the j -th macro-discursive dimension; and $\text{Score}_{i,k}$ signifies the individual empirical activation score computed for the k -th micro-topic regarding the i -th sample.

By executing a rigorous arithmetic mean convergence across the 7 technological innovation topics, 5 compliance and risk topics, and 3 cost-effectiveness topics, the scale-normalization denominator, N_j , neutralizes the system-level sample variance induced by heterogeneous thematic densities. This mathematical decoupling yields an unbiased, equivalent measurement of the structural gravity and communication activation scores across the three macro-discursive dimensions.

$$\begin{aligned} EAAI_{CR} &= \frac{EI_{11} + EI_8 + EI_6 + EI_{14} + EI_9}{5} = 0.1247 \\ EAAI_{TI} &= \frac{EI_1 + EI_{12} + EI_4 + EI_7 + EI_0 + EI_2 + EI_{10}}{7} \approx 0.1256 \\ EAAI_{CE} &= \frac{EI_3 + EI_{13} + EI_5}{3} \approx 0.0761 \end{aligned}$$

To mathematically cross-validate the macro-discursive dimensions $EAAI$, this study utilizes the Micro-Topics coordinates mapped in Figure 6 to deconstruct the internal structural configurations and non-linear activation feedback loops across the macro-discursive dimensions:

As illustrated in Figure 6, the blue nodes (Technological Innovation) cluster primarily in Quadrant I (Core Focal Agendas). This quadrant indicates both a high discourse scale and peak engagement intensity. Specifically, Topic 1 achieves the highest individual score (0.2287), closely followed by Topic 0, Topic 5, and Topic 2. This strong performance gives the Technological Innovation Dimension ($EAAI = 0.1256$) a slight competitive advantage over the Compliance and Risk Dimension (0.1247). This confirms that international audiences' positive focus on disruptive EV technologies and smart ecosystems successfully withstands negative geopolitical narratives. Concurrently, the Compliance and Risk Dimension exhibits a potent $EAAI$ of 0.1247, positioning itself in a state of near-equilibrium with the innovation paradigm. The internal structure of this dimension displays a highly centralized topological configuration of "single-issue risk polarization". visually validated by the dense concentration of red nodes—primarily Topic 6, Topic 8, and Topic 11—within Quadrant III (Figure 6). Although these topics exhibit a restricted raw discourse scale, their significantly elevated coordinates on the vertical axis indicate a highly volatile reactive potential. Because compliance and regulatory risks inherently embody intense geopolitical tensions and non-technical containment psychological mechanisms, they

achieve a high-fidelity resonance with the adversarial-level interaction layer during platform-mediated propagation [61].

Conversely, the Cost-Effectiveness Dimension registers the lowest activation efficacy across the three macro-discursive dimensions ($EAAI = 0.0761$), with its underlying topics severely fracturing and rapidly losing engagement momentum, as shown by the green nodes scattering into Quadrant IV (Figure 6). Within traditional term-frequency content analysis, the textual baseline surrounding the “low cost and pricing advantages” of Chinese vehicles appears deceptively massive, pushing nodes far to the right along the horizontal axis. However, our objective mathematical calculation and quadrant projection illuminate that, except for Topic 3, which sustains a moderate conversational intensity of 0.1257, the activation trajectory encounters a catastrophic bifurcation in spatial distribution. The dynamic alignment collapses precipitously to 0.0636 for Topic 5 and plummets to a long-tail nadir of 0.0389 for Topic 13, sinking deeply into the lowest boundary of the dynamic activation axis. This empirical discrepancy unmasks a critical communicative reality: although cost-effectiveness constitutes the most visible product attribute of Chinese EVs during international expansion, it operates strictly as a utilitarian instrument devoid of emotional triggers or ideological contestation tension. From a sociological perspective, the “low-cost” label associated with Chinese manufacturing is a deeply entrenched historical stereotype; it is processed by Western audiences as a baseline expectation rather than a disruptive innovation, generating minimal cognitive friction or debate. Furthermore, against the backdrop of intensifying global trade protectionism, pricing advantages are rapidly politicized. When international audiences do engage deeply with the “low price” of Chinese EVs, the discourse is almost instantly hijacked by macro-political anxieties, such as state subsidy controversies and market dumping accusations. Consequently, the interactive energy is systematically siphoned away from the Cost-Effectiveness dimension and absorbed by the Compliance & Risk dimension. Consequently, while global audiences exhibit a high peripheral consumption-level interest (views) toward price-centric content, this attention fails to translate into systemic mobilization energy. It remains fundamentally incapable of engineering high-quality discursive contestations within interactive networks, ultimately manifesting as a stagnant communication trajectory characterized by “high superficial volume but zero system activation”.

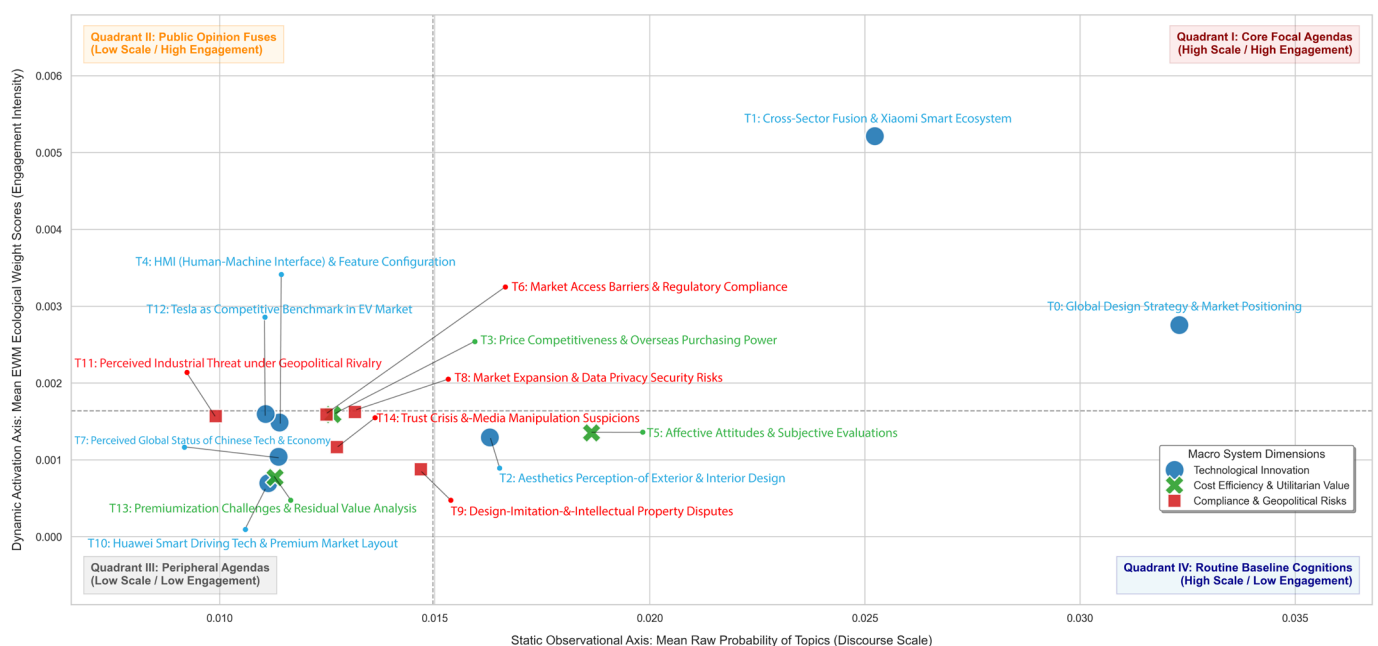


Figure 6. The Dynamic Four-Quadrant Matrix of Public Perception on Chinese EV.

4.3. Topological Analysis of the Image Discourse Space

4.3.1. Concept Drift in Data Streams and Evolutionary Streamgraph Analysis of Macro-Perception Dimensions

To dynamically characterize the shifting landscape of international audience perceptions toward Chinese EVs within global public opinion networks, this study introduces the theoretical lens of Concept Drift in Data Streams. Utilizing a rigorous and continuous observation window spanning from December 2025 to May 2026, a dynamic evolutionary streamgraph of the three macro-perception dimensions was constructed, as illustrated in Figure 7. To further deconstruct the underlying micro-dynamics, the temporal evolution of the 15 specific perception topics is concurrently mapped in Figure 8.

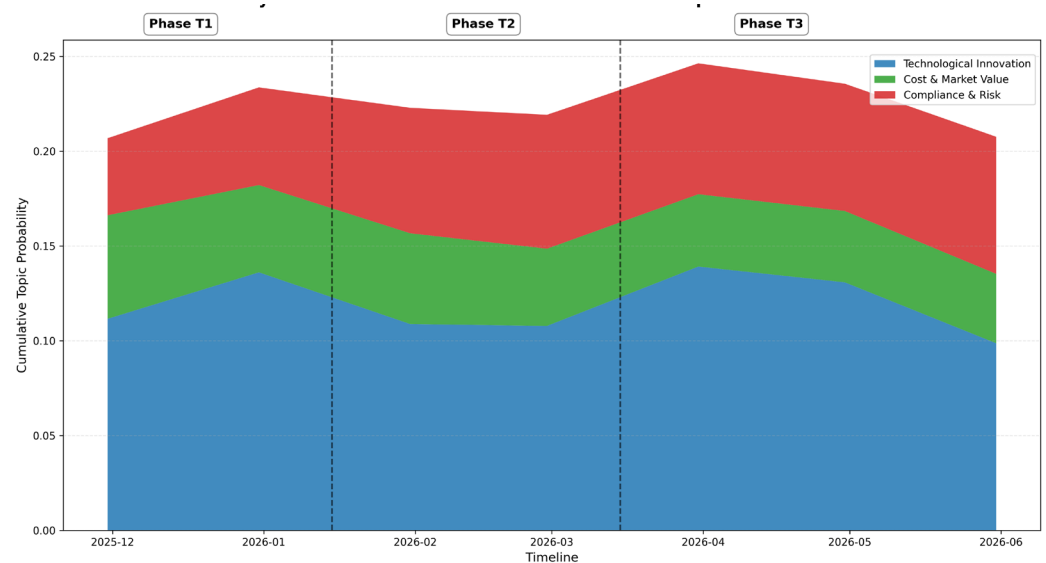


Figure 7. The dynamic evolution of the perception dimensions of the Chinese EV.

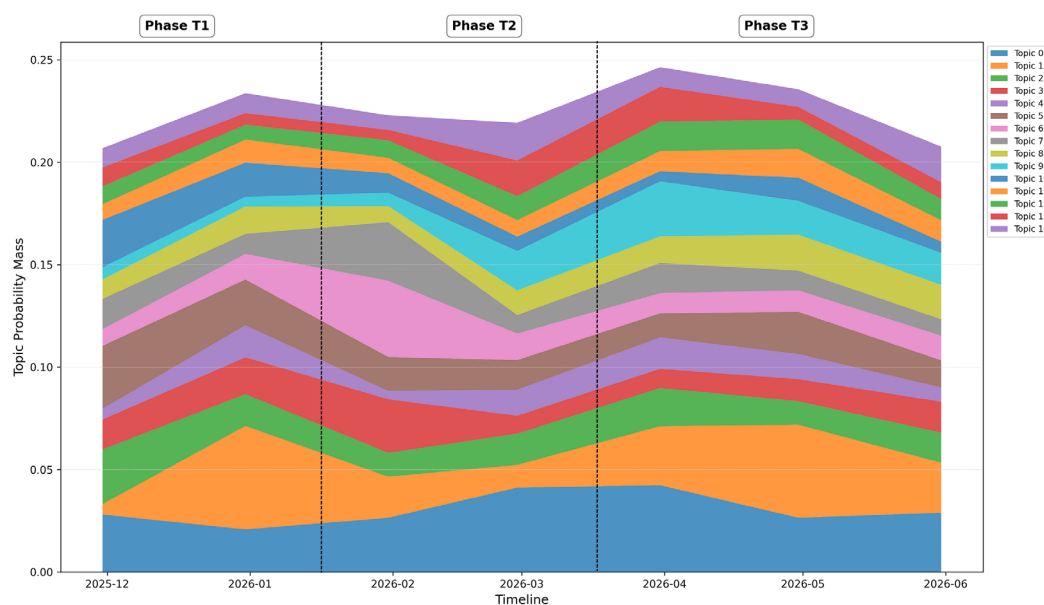


Figure 8. The dynamic evolution of Perception Topics.

The evolutionary streamgraph mathematically maps the systemic expansion and contraction of the aggregate communication volume through fluctuations in the total river width. More crucially, it visually decouples the attention-shifting mechanisms of international audiences through the fluctuating trade-offs exhibited by the vertical topological

thickness (the bandwidth parameter) of divergent color-coded stream bands. Importantly, the fluid topological architecture deployed in this research fundamentally diverges from conventional linear trendlines or absolute stacked bar charts. The structural gravity of each macro-perceptual dimension is not determined by its absolute coordinates or physical peak height at any specific chart cross-section (i.e., its upper boundary line); instead, it is quantified strictly by the localized vertical thickness of the stream band itself.

Throughout the temporal cycle, the cognitive trajectory of international audiences regarding Chinese EVs transitions through a non-linear topological morphing process: Technological Innovation-Driven Construction, Pragmatic Market-Rational Differentiation, Intense Adversarial Intertwining of Intelligent Technology and Compliance Risks. Based on morphology mutations across the stream cross-sections and corresponding communication efficiencies, the global discourse cycle is systematically partitioned into three distinctive evolutionary phases:

- (1) Phase T_1 : Intelligent Ecosystem Inception and Technology-Dominated Construction Period (December 2025–January 2026)

During the inception of this cycle, the streamgraph exhibits a highly asymmetrical topological morphology dominated heavily by the blue band (Technological Innovation). Concurrently, the left lateral margin of the streamgraph experiences rapid structural expansion, establishing the first systemic surge in aggregate river width across the entire observation period. A cross-sectional thickness comparison reveals that the localized vertical thickness of the blue band commands a decisive structural advantage. In contrast, the corresponding thicknesses of the green and red bands undergo severe structural compression.

The structural distribution matrix of the underlying micro-topics (as cross-referenced in Figure 8) provides robust empirical validation for this macro-topology. The data reveal that at the riverbed base, Topic 1 and Topic 4 exhibit a synchronized, wide-amplitude band-width expansion, while Topic 12—which serves as the industry competitive baseline—maintains an elevated structural weight within the communicative network.

This visual and statistical configuration indicates that during Phase T_1 , global social media discursive energy was highly concentrated upon the technology premium and intelligent connectivity configurations of Chinese EVs. Triggered primarily by the viral dissemination of cross-sector vehicular ecosystems engineered by Chinese consumer electronics giants and high-tier intelligent driving paradigms, the international discourse field constructed an explicit “technology-intensive” cognitive schema. Technical innovation clusters, including smart cockpits, vehicle-device synchronization, and on-board Large Language Models (LLMs), aggregated the critical mass of audience technical identification, functioning as the definitive kinetic core driving early-stage international image formation. Conversely, the red cluster, which indexes geopolitical frictions and regulatory barriers, remains restricted to a passive, long-tail diffusion state.

- (2) Phase T_2 : Cost-Effectiveness Consolidation and Informational Rational Differentiation Period (February 2026–March 2026)

During Phase T_2 , the global topological architecture of the streamgraph undergoes a pronounced structural contraction, with the communication system entering a manifest “discourse valley”. The localized vertical thickness of the blue technological stream constricts significantly, exhibiting a normative regression toward mean baseline levels. Concurrently, the green band (Cost & Market Value) demonstrates an outward expansion, while the red risk stream maintains a stable, observational plateau.

From the perspective of micro-thematic streams (Figure 8), the high-weight wave amplitudes of the preceding intelligent connectivity themes (Topic 1 and Topic 4) rapidly converge. In sharp contrast, Topic 3 and Topic 13, located in the upper-middle stratum of

the river architecture, exhibit considerable structural resilience, engineering localized counter-surges. Simultaneously, Topic 0 and Topic 2, which embody the reflexive audit of internationalization design practices, maintain a stable, normative distribution.

This morphological shift precisely captures the “information fatigue and rational sedimentation phase” following the initial discourse explosion. International audiences’ engagement with the high-frequency technological shocks induced by cross-sector automotive entries underwent a temporary cooldown. The public sphere shifted toward a pragmatic, utilitarian evaluation of the commercially viable attributes of Chinese EVs. Long-tail issues, such as domestic pricing competitiveness and the mechanisms by which internationalizing brands navigate residual value depreciation and premium market entry barriers, were steadily released within the green stream. This indicates that the international image was transitioning from an initial “cognitive expansion of technological frontiers” into a highly differentiated phase of “empirical market survival justification”.

(3) Phase T_3 : Regulatory Storm Mutation and Geopolitical Red-Stream Confrontation Period (April 2026–May 2026)

In the final phase, the right lateral boundary of the streamgraph witnesses the most violent concept drift and cognitive rupture recorded across the entire research cycle. The red band (Compliance & Risk) experiences a steep, explosive inflation in its localized vertical thickness, generating the most massive, high-amplitude peak of the entire timeline. Crucially, however, the underlying blue technological stream avoids being marginalized or submerged; instead, its vertical thickness experiences a powerful, synchronized re-expansion. The red and blue streams construct a high-density, wide-amplitude architecture of dual-stream parallelism and fierce confrontation on the right margin of the graph, driving the aggregate communication capacity (total river width) to its absolute global peak.

Viewed through the theoretical lens of Complex Adaptive Systems (CAS), the evolutionary trajectory of the international image exhibits robust non-linear dynamical traits. External disturbances—including regulatory shocks, trade frictions, new vehicular product rollouts, and global journalistic interventions—continuously compel the communication network to execute an Adaptive Restructuring of its internal discourse components, thereby driving continuous reconfigurations of framing weights [62]. A cross-sectional analysis of the micro-thematic streamgraph (Figure 8) unmask the localized generative mechanisms of this red–blue intertwined fluctuation. Within the red compliance sector, the localized vertical thicknesses of Topic 6, Topic 8, and Topic 11 undergo steep, discontinuous expansions. Amplified by localized surges in Topic 9 and Topic 14, the structural energy of geopolitical and regulatory risk framing reaches its historical maximum. Yet, symmetrically within the blue technological sector, Topic 10, Topic 0, and Topic 5—the latter indexing international audiences’ subjective agency evaluations—simultaneously experience robust, multi-centric bandwidth expansion.

The overriding macro-historical context of Phase T_3 is defined by intense geopolitical headwinds, including tariff barriers imposed by Western economies, heightened national security audits on foreign market access, and discourse shocks generated by authoritative global vehicle reliability rankings [63]. These institutional and structural conflicts serve as potent mobilization variables, instantaneously activating the compliance and risk clusters that previously occupied the network’s peripheral margins. Because of their intrinsic societal conflict triggers, risk-centric themes (Topic 6 and Topic 11) mobilized high-intensity interactive engagement among global netizens.

However, because international audiences’ cognitive schemas regarding Chinese intelligent driving and premium layouts (Topic 1, Topic 10) had already attained a structural sedimentation, these geopolitical and quality controversies did not suppress technological deliberation. Instead, acting as high-controversy discursive anchors, they countercentrally

compelled an influx of global netizens from heterogeneous political orientations and cognitive backgrounds. Supportive factions aggressively defended the technological hegemony and innovative leadership of Chinese EVs within interactive networks, while adversarial factions concentrated on data privacy vulnerabilities and regulatory compliance deficits. Micro-topologically, this manifests as a multi-thematic, synchronized expansion of divergent core streams, while macro-topologically, it shapes a unique, high-density public opinion field defined by the fierce, adversarial confrontation and intertwined compression of “high technological commendation” and “high regulatory risk”.

4.3.2. Longitudinal Anatomy of Discourse Evolution Based on Ecological Activation Metrics

To quantitatively validate the shifting structural modifications visualized within the temporal streamgraph and to further decipher the cross-period mobilization efficiencies of underlying micro-issues, this study deployed the Ecological Activation Index (EAI) to execute a rigorous cross-period mean comparison across three definitive empirical stages. By calculating the cross-sectional weighted mean values for individual micro-topics and macro-discursive dimensions within each temporal block, sample size baseline distortions were systematically neutralized, enabling a scientific evaluation of audience perceptual activation dynamics. Based on the aggregate weighting matrix and temporal slice computing, the stage-specific mean activation trajectories are synthesized as follows (Table 4):

Table 4. Average EAAI score for dimensions at different time periods.

Research Phase	EAAI Average (EI)	EAAI Average (CE)	EAAI Average (CR)
Phase T_1 : Intelligent Ecological Explosion Period (December 2025–January 2026)	0.0182	0.0043	0.0081
Phase T_2 : Cost effectiveness and differentiation period (February 2026–March 2026)	0.0107	0.0028	0.0064
Phase T_3 : Compliance and Policy Game Period (April 2026–May 2026)	0.0229	0.0061	0.0099

The longitudinal data unveil distinct quantitative traits governing public opinion evolution across divergent temporal boundaries:

During Phase T_1 , the communication network exhibits a pronounced asymmetric, technology-driven activation landscape. The mean EAI of the Technological Innovation Dimension (0.018236) significantly surpasses that of the Compliance and Risk Dimension (0.008098) and the Cost-Effectiveness Dimension (0.004317). During this cycle, global audience interactions (likes and secondary comment loops) cluster heavily around Topic 1 and Topic 4, confirming that cross-sector vehicular ecosystem paradigms and high-tier intelligent driving architectures command supreme potency for mobilizing discourse during the early dissemination phase. International audiences manifest a highly centralized affective convergence and technological alignment toward Chinese EVs, while negative containment discourses remain confined to a passive, long-tail diffusion state without triggering widespread audience anxieties.

Entering Phase T_2 , the aggregate communicative energy across the public sphere encounters a systemic retraction. The mean activation metrics for the technological innovation, compliance risk, and cost-effectiveness dimensions recede to 0.010699, 0.006355, and 0.002822, respectively. Macro-discursive dimensions’ structural compression empirically validates the transition of global audiences into an “information fatigue and rational sedimentation period” following high-frequency technological shocks, which diminishes the mean kinetic energy of discrete communicative nodes. During this observational window,

the preceding intelligence-centric fervor rapidly cooled down, whereas pragmatic, utilitarian topics such as Topic 3 and Topic 13 maintained stable structural weights. This distribution proves that public attention shifted toward long-tail market survival variables, including residual value retention and overseas purchasing capacities, placing the network system within a stable, risk-dormant plateau.

During Phase T_3 , the perceptual architecture experiences a violent, high-amplitude concept drift, driving mean activation metrics across all three macro-discursive dimensions to their absolute historical peaks. Crucially, the compliance risk and cost-effectiveness dimensions resurge steeply to 0.009885 and 0.006123, respectively, while the technological innovation dimension counter-centrally ascends to a peak of 0.022881, carving out a unique topological landscape characterized by a highly contentious, synchronized “red–blue dual-activation” morphology. Institutional and geopolitical external shocks—such as Western tariff enforcement and rigorous regulatory audits—serve as potent conflict-mobilization variables that deeply activate Topic 11 and Topic 6, thereby instantly provoking widespread regulatory apprehensions. Concurrently, quality-rating controversies incite intensive online debate, causing structural contestations surrounding Topic 10 and Topic 5 to reach a state of white-hot polarization. The extensive influx of heterogeneous global netizens ultimately locks “high technological commendation” and “high regulatory risk” into an inseparable, co-dependent structural matrix, driving individual message information capacities and multi-dimensional emotional mobilization potencies to their absolute systemic maximums.

4.3.3. Social Network Analysis (SNA) of Cross-Period Perceptual Topology Evolution

To unmask the localized spatial layout, structural intertwining, and topological morphing mechanisms operating among the 15 core topics across distinct evolutionary phases, this study constructed cross-period Pearson Correlation Matrices to capture the structural co-flux trends among divergent categories dynamically. These matrices were subsequently calibrated using the empirical mean EAI values as edge-weight variables. Within the topological network space, node diameters map the mean ecological activation of specific themes, while edge thicknesses and transparency levels index the structural correlation and co-occurrence weights between paired nodes.

During Phase T_1 , the topological structure of the global public sphere presents a highly asymmetrical, “mono-centric clustering with peripheral diffusion” configuration. The structural core of the network is exclusively occupied by the blue Technological Innovation cluster. Specifically, Topic 1 exhibits the most prominent degree centrality and node volume, establishing high-weight, heavy-density core edges with Topic 4 and Topic 12.

In sharp contrast, the red Compliance & Risk cluster (comprising geopolitical containment and regulatory friction nodes) is relegated to the absolute periphery of the spatial graph, displaying sparse connection densities and weak structural weights that manifest as isolated, hanging topological artifacts. This architecture mathematically demonstrates that global audience cognitive networks during this phase were strictly anchored upon the cross-sector intelligent mobility migrations engineered by Chinese consumer electronics corporations. Deliberative focus regarding high-premium tech frontiers constructed massive discourse cohesion at the geometric center of the network. At this juncture, external institutional hazards and regulatory risks had not yet penetrated the core associative cognitive schema of international audiences, leaving the network system in a highly polarized state driven entirely by early-stage technological dividends.

During Phase T_2 , the perceptual network undergoes a manifest “decentralization and multi-centric deconstruction”, characterized by a structural constriction of both ag-

gregate network density and localized node dimensions. The tightly bound blue innovation cluster experiences structural decoupling, as evidenced by the severe contraction and outward retreat of Topic 1 and Topic 4.

Conversely, the green Cost-Effectiveness cluster—predominantly Topic 3 and Topic 13—experiences a relative elevation in degree centrality. These nodes position themselves at the geometric crossroad of the topological graph, occupying a critical “structural hole” and functioning as an intermediary discourse bridge linking the blue technological commendations on the left margin with the red latent compliance hazards on the right margin. This structural morphology perfectly embodies the “normative rational sedimentation” mechanism following initial discourse shocks. The cooling of technological novelty compelled the audience’s cognitive grid to decompose absolute “technological myths” into pragmatic, utilitarian audits of vehicular residual values and real economic purchasing powers. The emergence of the green cluster as a critical network mediator absorbed the long-tail regression of tech-centric heat, providing an indispensable informational buffer and transitional zone for the system, which generated a multi-centric, highly differentiated, and stable observational architecture.

During Phase T_3 , the perceptual network encounters a violent structural reconfiguration, morphing into a high-density, tightly intertwined “red–blue dual-core confrontation” topology (Figure 9). The network violently transitions from its preceding mono-centric or multi-centric equilibrium into a classic adversarial dual-core architecture.

On the risk margin, Topic 6 and Topic 11 experience exponential geometric inflation, forcefully penetrating and anchoring themselves within the exact geometric center of the network. Symmetrically on the technology margin, Topic 10 and Topic 0 undergo simultaneous volumetric expansion. Most prominently, the red and blue core clusters forge exceptionally thick, high-density, and high-weight correlation edges, weaving a powerful co-occurrence network, whereas the green cost-effectiveness cluster is comprehensively marginalized.

This topological variation unmasks the structural mutation dynamics of the international image field under the impact of geopolitical headwinds. Geopolitical friction and institutional barriers, operating as high-intensity conflict mobilization variables, endow the red risk nodes with supreme centripetal gravity. Crucially, these institutional controversies do not suppress technological deliberation; rather, functioning as high-controversy discursive anchors, they counter-centrally compel an extensive influx of global netizens across heterogeneous ideological backgrounds. Within the cognitive schema of international audiences, Chinese EVs’ high-tier intelligent driving paradigms and premium market configurations have become permanently welded to data privacy vulnerabilities, tariff enforcement, and ideological anxieties. This cognitive coupling ultimately shapes a dynamic adversarial network wherein two opposing discursive forces aggressively intertwine and execute high-frequency compression within the same topological space.

The aforementioned structural evolutions quantitatively prove that the international image of Chinese EVs has progressively morphed into a classic competitive framing ecosystem. Divergent discursive frameworks continuously contest interpretive hegemony through platform-mediated interactive feedback loops, emotional contagion, and algorithmic recommendation architectures, thereby driving the continuous dynamic restructuring of the global network grid. This macro-evolutionary path—characterized by “multi-frame competition interactive amplification topological structural reconfiguration”—serves as a textbook instantiation of Complex Adaptive Systems (CAS) operating within decentralized digital communication environments.

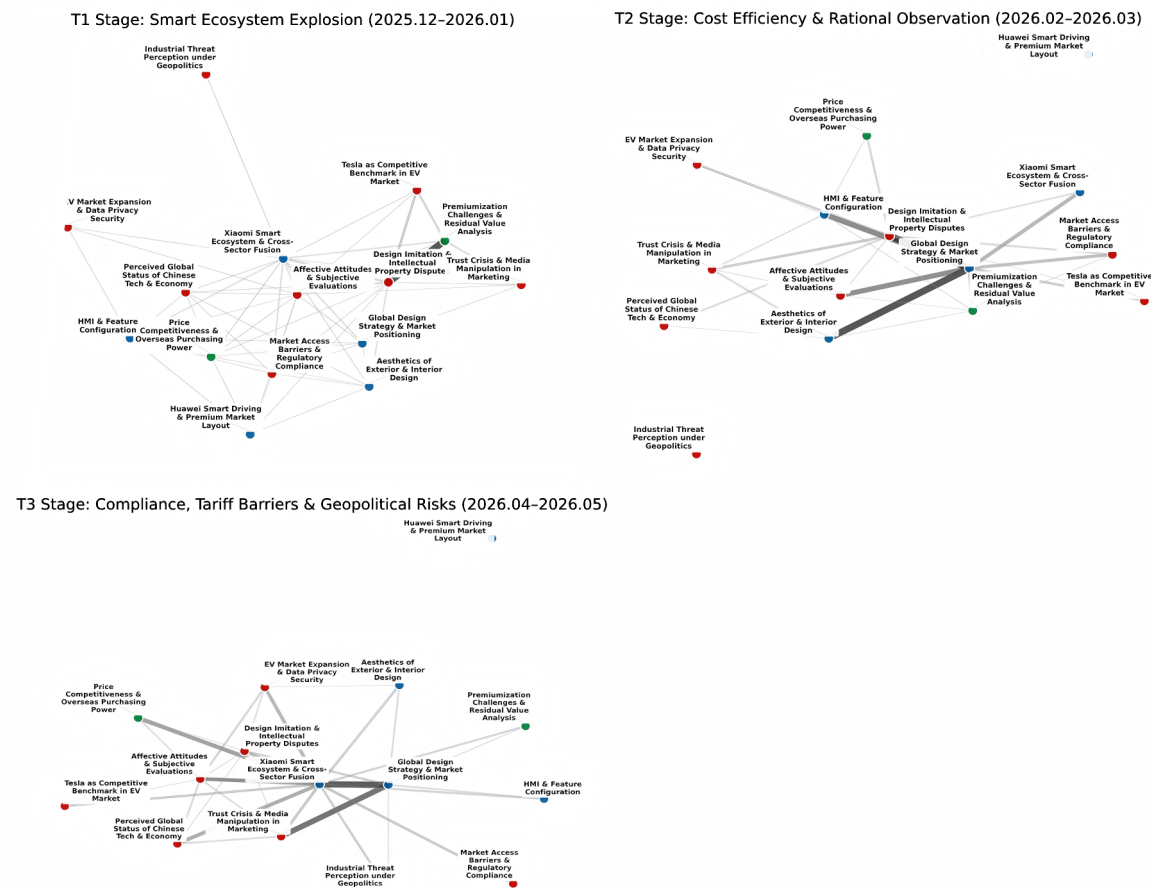


Figure 9. Cross-Period Perceptual Topology Evolution (note: the thickness of the edges represents the strength of structural correlation and co-occurrence weights between topics).

5. Discussion

5.1. Strategic Reconfigurations Within the Complex Global Discourse Ecology

The empirical findings of this study demonstrate that the international image of Chinese electric vehicles (EVs) is fundamentally distinct from a static, fixed cognitive artifact; rather, it operates as a highly dynamic, evolving communication ecosystem deeply embedded within a Complex Adaptive System (CAS). Heterogeneous discursive frameworks continuously engage in structural competition, diffusion, and adaptive restructuring within platform-mediated networks. Concurrently, user engagement vectors—comprising likes, text commentaries, and secondary feedback loops—subsequently amplify the internal adaptive selection and self-organization mechanisms of the system, culminating in the following core academic insights:

(1) Multi-Dimensional and Composite Topology of International Audience Perceptions

Our computational results establish that global social media audiences' cognitive schemata regarding Chinese EVs have systematically decoupled from the legacy, mono-centric stereotypes of “low-cost manufacturing” or “primitive cost advantages”. Instead, a highly intertwined, composite perceptual configuration has emerged, encompassing technological competencies, intelligent connectivity ecosystems, industrial design aesthetics, brand philosophy, green transitions, and geopolitical frictions.

This perceptual shift is highly contingent upon the macro-discursive dimensions of structural upgrades executed within China's automotive industry under strategic national frameworks such as Made in China 2025 and the New Energy Vehicle Industry Development Plan (2021–2035). These policies propelled the industrial trajectory from volume-

driven expansion to a technology-driven, brand-internationalization paradigm. Particularly in frontier sectors like power battery chemistry, advanced driver-assistance systems (ADAS), vehicle-to-everything (V2X) architectures, and cross-sector ecosystem integration, Chinese firms have engineered substantial global competitive gravity [64].

Viewed through the theoretical lens of CAS, this multi-dimensional perception matrix instantiates the mechanism of topological emergence. Heterogeneous user cohorts, institutional media organizations, and platform recommendation algorithms do not generate isolated inputs; rather, through continuous non-linear interactions, they structurally co-create the international cognitive schema of Chinese EVs. Compared to the centralist, uni-directional image dissemination characterizing the legacy mass media era, contemporary international product images are dynamically co-shaped by user agency, affective polarization, and algorithmic reinforcement mechanisms.

(2) The Dominance of “Intelligent Ecosystem” and “Aesthetic Design” as Core Discursive Anchors

A critical finding of this research is that the Technological Innovation and Aesthetics of Exterior & Interior Design frameworks have effectively superseded the traditional “cost-effectiveness” narrative, anchoring themselves as the dominant discursive configurations driving communication gravity in the global digital sphere. Historically, Chinese automotive brands anchored their internationalization paths upon cost-oriented strategies defined by low pricing and high-density feature configurations. However, driven by the aggressive upscale migration and intelligent mobility strategies deployed by vanguard enterprises such as BYD, Xiaomi, Xpeng, and Li Auto, international automotive critics and digital audiences have begun executing rigorous, cross-national comparative audits between Chinese EVs and legacy Western titans (e.g., Tesla, BMW, Land Rover). This shift indicates that Chinese EVs have transitioned from utilitarian “low-price substitutes” into the high-tier global technological brand hierarchy.

This morphological evolution directly aligns with the strategic reconfigurations of Chinese automakers’ global marketing portfolios. For instance, BYD repositioned its European identity as a premium “NEV Technology Brand” through high-profile sports sponsorship (e.g., UEFA Euro) and strategic entries into mature European markets; NIO articulates an elite lifestyle narrative centered on “user communities” and “service ecosystems”; while Xpeng rigorously emphasizes autonomous driving and software-defined mobility.

From the perspective of Competitive Framing Theory, the “Intelligent Ecosystem” framework (exemplified by Topic 1) achieved supreme structural dominance not merely due to its technical parameters, but because it possesses the capacity to activate intensive user interaction and affective engagement. Compared to pragmatic pricing narratives, intelligent mobility configurations function as highly potent communicative triggers that induce user content-sharing, digital debate, and user-generated evaluations. This interaction fuels platform-mediated algorithms, translating into superior visibility and higher objective weight within the network. Consequently, in our empirical EAI calculation, these intelligence-centric clusters commanded significantly higher interaction weights.

(3) Persistence of Regulatory Fragility, Geopolitical Containment, and Systemic Vulnerabilities

Despite the progressive and positive upward evolution of the international image of Chinese EVs, our timeline tracking unmask a parallel reality: institutional risks, market access protectionism, geopolitical frictions, and industrial threat perceptions continue to maintain elevated communicative velocity. These defensive frameworks frequently trigger violent, discontinuous concept drift during acute geopolitical event cycles.

Our mathematical models indicate that while topics indexing data vulnerabilities, privacy anxieties, national subsidies, and technological hegemony capture a relatively smaller aggregate text volume, their individual Ecological Activation Index (EAI) scores are significantly higher than those of positive, product-centric clusters. This empirical discrepancy unmasks an essential trait of digital communication: controversial and adversarial frames, despite lacking a massive conversational volume, possess extreme kinetic capacity to provoke high-intensity stance polarization and emotional contagion, thereby constructing “high-activation energy anomalies” within the digital ecosystem.

This structure is intrinsically bonded to the macroeconomic and protectionist headwinds blowing across the global automotive landscape. The continuous enforcement of trade investigations and industrial security audits by Western economies—such as the anti-subsidy investigations initiated by the European Union and the national security reviews regarding vehicular data transparency executed by the United States—has directly nourished the risk propagation frameworks in online networks. Consequently, “Chinese EVs” are continuously audited through a highly politicized lens of global economic hegemony and technology containment.

Symmetrically, Chinese automakers have initiated reflexive localized adaptation portfolios. For example, BYD accelerated localized European supply-chain integration and domestic employment architectures to neutralize the “industrial threat” and “dumping” counter-narratives, while NIO and Xpeng have systematically strengthened data compliance transparencies, localized server safety nets, and privacy policy disclosures.

From the vantage point of Competitive Framing Theory, “Technological Innovation” and “Geopolitical Risk” operate in a permanent state of asymmetrical framing contestation. Divergent stakeholders—including global news agencies, partisan netizens, state institutions, and corporate entities—continuously manipulate these competing frames to capture interpretive hegemony over the international cognitive domain [40].

(4) Transition into the Global High-Tier Brand Competition Paradigm

Finally, this research demonstrates that the communicative mechanism of Chinese EVs in the international public sphere has migrated from a basic “product-export narrative” into a complex “brand-equity competition paradigm”. Global online deliberations are no longer confined to isolated vehicular specifications; instead, they have ascended into higher-order structural evaluations regarding corporate brand equity, core technological roadmaps, systemic innovation capacities, and global industrial transformation leadership.

This trend exhibits tight structural alignment with the transnational branding portfolios executed by Chinese automakers. For instance, BYD’s global event-marketing architectures, NIO’s premium user-community ecosystems, Xpeng’s AI-defined mobility capabilities, and HIMA’s (Huawei Intelligent Mobility Alliance) positioning as an elite intelligent technology titan collectively drive the historical metamorphosis of Chinese EVs from “Made in China” to “Engineered by Chinese Tech Brands”.

Synthesizing these insights through the conceptual architecture of CAS, the international image of Chinese EVs has forged a manifest multi-centric competitive network. Heterogeneous corporate brands, technological paradigms, and media frames execute continuous non-linear interactions and structural recombination, forcing the global cognitive grid to constantly undergo adaptive restructuring. The control of the international image has escaped the jurisdiction of any singular centralized entity; instead, it operates as a self-organizing, emergent property jointly synthesized by platform algorithms, user agency, journalistic reporting, and corporate public relations.

Consequently, the definitive communicative challenge confronting Chinese EVs in the global arena has transcended basic product familiarity. The core imperative now lies

in the strategic engineering of enduring technical trust, solid brand resonance, and institutional legitimacy within highly volatile, fragmented, and decentralized digital networks. International competition for Chinese EVs is no longer merely an industrial and manufacturing race, but an enduring, strategic warfare for cognitive harmony within the global digital communication apparatus.

5.2. Limitations and Future Directions

Despite the systematic insights generated by deploying the cross-disciplinary frameworks of CAS and Competitive Framing Theory to dissect the dynamic evolution of Chinese EVs' international image, several critical limitations remain, which simultaneously chart fertile paths for future scholarly inquiries.

First, regarding the empirical data perimeter, this research was exclusively anchored upon text streams harvested from YouTube. While this corpus offers a high-fidelity proxy of the mainstream Western digital public sphere, it lacks sufficient semantic coverage over heterogeneous linguistic landscapes, cross-cultural cognitive schemas, and highly regionalized media ecologies. Netizens operating within the Global South—such as Southeast Asia, the Middle East, and Latin America—as well as non-English-speaking territories, may possess fundamentally divergent cognitive rationales and interpretative frameworks regarding Chinese EVs. Future research should consequently integrate multi-lingual text corpora and orchestrate multi-platform cross-examinations (e.g., X, TikTok, and localized forums) to construct a more inclusive, globally balanced comparative analysis matrix for international product images.

Second, from a methodological vantage point, this study relied primarily upon textual semantic extraction and user behavioral feedback loops, leaving the analysis of non-textual structural components—such as short-form videos, infographic representations, streaming visual content, and cross-modal communicative syntax—comparatively constrained. Given that visual rhetoric serves as a highly potent vehicle for emotional contagion and stance alignment in contemporary digital spaces, future inquiries should aggressively integrate multimodal computational frameworks and advanced computer vision architectures to deeply illuminate how cross-modal symbolic interactions reconfigure and calibrate international product identities.

Finally, in terms of theoretical abstraction, while this study deployed CAS and competitive framing paradigms to explicate the non-linear topology transformations of the discourse field, a deep, structural analysis regarding the structural logic of platform capitalism, algorithmic governance mechanisms, and macro-discursive dimensions of international political-economic frameworks remains marginalized. Future research should blend these computational findings with Platform Society Theory and critical political economy frameworks. Such integration will facilitate a higher-order structural critique of how corporate algorithmic statecraft and geopolitical-industrial protectionism co-shape the cognitive hegemony and competitive framing ecosystem of international product images within the global digital apparatus.

6. Conclusions

Utilizing granular data corpora harvested from the global social media platform YouTube, this study deployed the theoretical lenses of Complex Adaptive Systems (CAS) and Competitive Framing Theory to construct a computational analytical framework encompassing computational identification, semantic abstraction, efficacy quantification, and topological evolution. This framework enabled a systematic investigation of the dynamic evolution and self-organizing mechanisms underlying the international image of Chinese electric vehicles (EVs).

The empirical findings demonstrate that the global perceptual configuration of Chinese EVs has undergone a paradigm shift, systematically decoupling from legacy, mono-centric stereotypes of “low-cost manufacturing” to morph into a highly intertwined, multi-dimensional, and composite topological structure encompassing technological frontiers, intelligent connectivity ecosystems, and systemic compliance paradoxes. Specifically, the Intelligent Ecosystem and Design Aesthetics frameworks have emerged as the dominant discursive anchors commanding supreme communication velocity and interaction energy within digital networks. Symmetrically, regulatory vulnerabilities, market protectionism, and geopolitical anxieties continue to exert persistent structural containment effects upon the global cognitive grid of Chinese EVs. Overall, the international communication of Chinese EVs has shifted from a product-centered narrative toward a multi-centric brand competition characterized by continuous adaptation and nonlinear evolution.

Theoretically, this study extends Competitive Framing Theory into algorithm-driven digital communication environments and demonstrates the applicability of CAS for explaining how international product images emerge, evolve, and self-organize through decentralized audience interactions. Methodologically, by synthesizing unsupervised BERTopic modeling, the objective Entropy Weight Method (EWM), and cross-period Social Network Analysis (SNA) into a coherent analytical pipeline. Rather than functioning as independent tools, these methods complement one another by linking micro-level semantic discovery (BERTopic), semantic abstraction from topics to discourse dimensions (LLM), quantitative evaluation of audience interaction intensity (EWM), and macro-level structural evolution of discourse networks (SNA). This integrated workflow establishes a complete analytical chain from “semantic identification → semantic abstraction → interaction quantification → network evolution”. This integrated computational framework provides a continuous, multi-layered pathway that offers a novel computational communication paradigm for the reflexive audit of international image dynamics and public opinion ecosystems.

In summary, the international image of Chinese EVs should be understood as a continuously evolving digital ecosystem shaped by the co-evolution of platform algorithms, audience interactions, and global geopolitical contexts. Accordingly, sustainable international competitiveness depends not only on technological innovation and product quality, but also on building long-term technical trust, cultural resonance, and institutional legitimacy across decentralized global communication networks.

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