

EXTENDING THE CONTEXTUALIZED RESILIENCE-AGILITY ARCHITECTURE: TEMPORAL AMBIDEXTERITY IN CONSUMER GOODS SUPPLY CHAINS

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Abstract: Consumer goods firms face a persistent tension between supply chain resilience and operating efficiency. Existing resilience research explains many of the capabilities firms require, but provides less guidance on when those capabilities should be activated as disruption conditions change. This study addresses that temporal gap by extending the Contextualized Resilience-Agility Architecture (CRAA) through a temporal ambidexterity perspective. Using a sequential multi-method design, the study combines a comparative multiple-case analysis of five U.S. and Chinese consumer-goods firms with longitudinal analysis of the 2026 U.S. import environment. Phase I identifies four recurring resilience mechanisms: selective slack, digital visibility linked to executable options, appropriately distributed decision rights, and ecosystem-level coordination. Phase II shows that the value of these capabilities is time contingent because sensing, plan revision, decision authorization, and physical execution operate on different horizons while operational choices become progressively less reversible. The study develops temporal ambidexterity as the ability to advance, delay, accelerate, or sequence supply chain commitments under uncertainty. It further introduces temporal selective slack, forecast revision capacity, temporal optionality, and temporal alignment to explain how firms preserve and exercise operational choices within narrowing decision windows. The resulting framework extends CRAA from a capability architecture toward a temporally contingent explanation of resilience and reframes resilience as the ability to preserve efficiency while committing neither too early nor too late.

Keywords: Supply chain resilience; Temporal ambidexterity; Temporal optionality; Selective slack; Dynamic capabilities; Consumer goods; Decision windows

1 INTRODUCTION

1.1 Background and Research Problem

Supply chain resilience is commonly discussed in terms of the capabilities firms possess to withstand disruption, including visibility, alternative suppliers, inventory buffers, flexible capacity, logistics options, and decision authority. Yet capability possession does not guarantee capability effectiveness. These resources contribute to resilience only when they remain actionable as operating conditions change [1]. This issue is particularly important in consumer goods supply chains, where resilience cannot be pursued by abandoning efficiency. Broad product portfolios, high service expectations, cost pressure, short planning cycles, and, in some categories, perishability continue to reward disciplined inventory management, high asset utilization, and standardized operations. The first phase of this research therefore rejected a simple shift from just-in-time toward generalized just-in-case buffering. Instead, the comparative cases indicated that firms preserved efficiency while concentrating selective slack around critical constraints and combining visibility with executable options and decision authority. These mechanisms were integrated into the Contextualized Resilience-Agility Architecture (CRAA), organized around sensing, absorption, response, and adaptation.

The unresolved problem is temporal. Supply chain capabilities operate on different clocks: policy signals may change within days, purchase orders may be committed months in advance, ocean transportation takes weeks, logistics capacity may require advance reservation, and demand continues to evolve throughout the planning cycle. A firm may therefore possess appropriate resilience capabilities and still respond poorly if those capabilities are activated too early, too late, or in the wrong sequence.

This creates a recurring trade-off between commitment and reversibility. Early commitment can secure supply, capacity, or transportation, but may lock the firm into assumptions that later prove inaccurate and transfer uncertainty into inventory, working capital, storage, or markdown exposure. Waiting allows more information to become available and preserves flexibility, but becomes costly when the remaining execution window is too short to implement a revised decision.

The 2026 U.S. import environment illustrates this challenge. Sequential forecasts repeatedly revised the expected timing of import activity. Between the August 7 and September 9 Global Port Tracker releases, the September forecast increased from 2.16 million to 2.31 million loaded import TEUs. The importance of this change lies not only in the volume revision, but in the instability of the operating calendar itself.

The central research problem is therefore not simply whether firms can forecast accurately or respond quickly. It is how firms can preserve operating efficiency while deciding when to commit, when to wait, when to accelerate, and when to preserve reversibility as disruption windows shift.

1.2 Research Gap

Existing supply chain resilience research explains many of the capabilities firms require to withstand disruption, including flexibility, visibility, selective slack, collaboration, decision authority, and adaptive reconfiguration [2]. Dynamic capabilities research similarly explains how firms sense change, mobilize resources, and transform operating systems. What remains less developed is how the timing of capability activation affects the value of those capabilities.

Two gaps are particularly important. First, sensing, plan revision, decision authorization, and physical execution operate on different time horizons. Delay at any stage can consume the period in which an operational option remains feasible. Second, response speed is not equivalent to resilience. Faster action may reduce latency, but premature commitment can reduce reversibility and increase inventory or capital exposure. Conversely, preserving flexibility may improve decision quality but becomes ineffective once execution windows close.

The missing explanation is therefore not simply whether time matters, but how firms preserve and exercise operational options as information improves and decision windows narrow.

1.3 Research Questions

To address this gap, the study asks three related questions:

RQ1. How do consumer goods firms configure sensing, selective slack, decision rights, and adaptation to reconcile supply chain resilience with operating efficiency?

RQ2. How does temporal alignment between sensing, decision-making, and physical execution affect the effectiveness of CRAA capabilities under shifting disruption windows?

RQ3. Under what conditions does preserving temporal optionality provide greater resilience value than making early anticipatory commitments?

Together, the questions move from the capabilities firms require, to when those capabilities remain effective, and finally to when firms should commit resources versus preserve options.

1.4 Contributions

This study makes three contributions.

First, it extends CRAA by adding an explicit temporal dimension. CRAA explains resilience through sensing, absorption, response, and adaptation; the present study examines how the effectiveness of those capabilities depends on whether they are activated within appropriate decision windows.

Second, it distinguishes response speed from temporal optionality. Rather than assuming that faster action is always more resilient, the study examines the value of preserving executable and reversible choices while uncertainty remains unresolved, provided those choices are exercised before physical or contractual constraints make them unavailable.

Third, it develops a more operational explanation of the resilience–efficiency trade-off by linking signal recognition, forecast revision, decision authority, execution lead time, and remaining decision windows. This provides a basis for understanding when firms should advance, delay, accelerate, or sequence supply chain commitments.

The central argument is that supply chain resilience depends not only on possessing appropriate capabilities, but also on activating and sequencing them while they can still influence operational outcomes.

2 LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 Supply Chain Resilience, Agility, and Viability

Supply chain resilience is generally understood as the ability to prepare for, absorb, respond to, recover from, and adapt after disruption. Agility is related but distinct, emphasizing the speed and effectiveness with which supply chains detect and respond to changing market or operating conditions [3]. Viability extends the discussion to a longer horizon by asking whether a supply network can maintain essential functions under persistent or structurally changing conditions [4].

These concepts capture different aspects of adaptive performance. Resilience concerns continuity and recovery, agility concerns responsiveness, and viability concerns sustained functioning over time. In consumer goods supply chains, all three must coexist with high service requirements, broad product portfolios, cost pressure, and, in some categories, perishability. The relevant problem is therefore not whether efficiency should be replaced by resilience, but how adaptive capacity can be embedded within an economically disciplined operating system.

2.2 Dynamic Capabilities and Supply Chain Resilience

Dynamic capabilities theory provides an important foundation because it shifts attention from the resources firms possess to the processes through which those resources are sensed, mobilized, and reconfigured. The

sensing–seizing–transforming logic explains how organizations identify change, commit resources, and modify operating structures as conditions evolve [5]. In supply chain settings, these processes correspond broadly to risk detection, resource reallocation, and network or governance redesign.

Supply chain resilience, however, adds an operational requirement: continuity often must be maintained while reconfiguration is still underway. The first phase of this research therefore distinguished four functions—sensing, absorption, response, and adaptation—to capture how firms detect change, maintain critical service, execute operational adjustments, and modify the underlying system after learning.

The comparative cases also indicate that capability configuration is context dependent. The U.S.-headquartered consumer-goods firms emphasized standardized planning, analytics, simplification, and network reconfiguration, whereas the Chinese dairy cases relied more heavily on traceability, ecosystem coordination, and integration across farms, production, logistics, and channels. Dynamic capabilities therefore provide a higher-order explanation, while the operational form of resilience varies with network structure and category characteristics.

2.3 Capability Configuration: Selective Slack, Visibility, and Decision Rights

A central issue in resilience research concerns the apparent trade-off between efficiency and redundancy. Lean systems are often associated with fragility, while resilient systems are associated with additional buffers. Yet neither relationship is automatic. Standardization, short lead times, and transparent flows can improve responsiveness, while excess inventory, duplicated suppliers, or spare capacity may add cost without meaningful protection when they are poorly positioned or difficult to activate [6].

The first-phase study therefore emphasized selective slack rather than generalized redundancy. Selective slack refers to inventory, capacity, supplier alternatives, logistics options, or time preserved around critical points where disruption would create disproportionate service or recovery consequences. Across the five cases, firms continued to pursue productivity and cost efficiency while retaining additional options around high-consequence constraints.

Digital visibility represents a second capability dimension. Analytics, traceability, integrated planning, and real-time monitoring can reduce information latency, but visibility alone does not create resilience. Information becomes operationally valuable only when it can alter sourcing, production, logistics, inventory, or allocation decisions.

Decision rights determine whether such information and available options can be translated into action. Excessive centralization may slow adjustment, while decentralized action without common data or prioritization rules may fragment enterprise decisions. The first-phase findings therefore point toward arrangements in which shared standards coexist with bounded authority to reallocate resources.

Taken together, these capability dimensions suggest that resilience depends not simply on possessing information or backup resources, but on whether firms can connect visibility, usable options, and decision authority.

2.4 Temporality, Decision Windows, and Reversibility

Time is implicit in most resilience processes, but it is often treated as a background condition rather than as a factor that changes capability value. In practice, supply chain commitments operate on different clocks. Policy information may change within days, purchase orders may be committed months ahead, transportation requires weeks, capacity may require advance reservation, and demand continues to evolve throughout the planning cycle.

This creates a problem of decision windows. Operational choices remain adjustable only for limited periods. Purchase orders, production plans, transportation bookings, and inventory positions become progressively less reversible as execution approaches. New information may therefore improve understanding while contributing little to resilience if the associated operational choice can no longer be changed.

The second-phase research distinguishes among signal latency, revision latency, and execution lead time. These components consume different portions of the available window. Faster sensing cannot fully compensate for slow organizational revision, and rapid approval cannot compensate for physical lead times that exceed the remaining decision window.

Reversibility is equally important. Flexible purchase-order windows, postponement points, optional production slots, and reserved but uncommitted transport capacity can preserve room for adjustment as uncertainty evolves. Such arrangements suggest that resilience may depend not only on acting quickly, but also on preserving choices long enough for additional information to remain useful.

The temporal problem is therefore one of balancing information value against the progressive loss of reversibility. Waiting may improve decision quality, but waiting also reduces the set of actions that remain feasible.

3 THEORETICAL FRAMEWORK

3.1 Contextualized Resilience-Agility Architecture

The Contextualized Resilience-Agility Architecture (CRAA) provides the capability foundation for this study. Developed in Phase I, CRAA organizes supply chain resilience around four connected functions: sensing, absorption, response, and adaptation. Sensing identifies emerging changes in demand, supply, logistics, or risk; absorption maintains critical service while disruption is active; response reallocates resources and executes operational adjustments; and adaptation modifies suppliers, networks, processes, or governance after learning.

CRAA rests on two principles. First, resilience depends on selective slack rather than generalized redundancy: inventory, capacity, supplier alternatives, logistics options, and other forms of flexibility are concentrated around critical constraints rather than distributed uniformly. Second, visibility, executable options, and decision authority are interdependent. Information contributes to resilience only when firms retain feasible alternatives and can authorize their use.

The architecture is contextual because the appropriate configuration varies with category, perishability, geography, regulation, channel structure, and network design. CRAA therefore explains what capabilities firms require; the temporal extension developed below addresses when those capabilities remain effective.

3.2 Temporal Ambidexterity

This study defines temporal ambidexterity as the organizational ability to preserve operating efficiency while deliberately adjusting the timing, sequence, and reversibility of supply chain commitments under uncertainty.

The concept extends CRAA by adding an activation logic to its capability architecture. CRAA specifies the available resilience capabilities; temporal ambidexterity governs how those capabilities are exercised as uncertainty and decision windows evolve.

Four temporal actions are central:

Advance a commitment when disruption is sufficiently credible and delay would threaten execution;

Delay commitment when additional information remains valuable and meaningful options are still open;

Accelerate execution when a preferred option is ready but its remaining window is narrowing;

Sequence commitments so that earlier decisions preserve later choices.

Temporal ambidexterity is therefore not synonymous with faster response. Its central concern is the fit between information quality, reversibility, and execution feasibility.

3.3 Temporal Selective Slack

Temporal selective slack refers to deliberately preserved, time-bounded flexibility around critical supply chain commitments. It extends the Phase I concept of selective slack from the location of buffers to the timing of commitment.

Examples include flexible purchase-order windows, postponement points, optional production slots, reserved but uncommitted transport capacity, and prequalified alternative routings. These arrangements preserve adjustability without requiring firms to commit inventory, capacity, or transportation uniformly in advance.

Its value is greatest when uncertainty remains material and the cost of preserving flexibility is lower than the cost of premature commitment. Temporal selective slack therefore preserves room to act; it does not guarantee resilience by itself.

3.4 Forecast Revision Capacity

Forecast revision capacity is the organizational ability to recognize that the expected operating calendar has changed, revise the planning assumptions that follow from that change, and translate the revised view into downstream commitments before critical options expire.

This construct differs from forecast accuracy. Under volatile conditions, an initially reasonable forecast may become obsolete because policy, demand, logistics, or supply conditions change after it is produced. A revised forecast has limited resilience value if transportation bookings, production schedules, labor, or inventory positions can no longer be altered.

Forecast revision capacity therefore links sensing to response and depends on both organizational authority and remaining execution time.

3.5 Temporal Optionality

Temporal optionality refers to the extent to which critical commitments remain both reversible and executable while uncertainty continues to evolve. It is related to temporal selective slack but is not identical to it: slack describes the arrangements used to preserve flexibility, whereas optionality describes the resulting decision state.

A firm may possess spare capacity but have little usable optionality if contractual, qualification, or organizational constraints prevent timely activation. Conversely, flexible order terms or transport arrangements may preserve meaningful optionality without permanently high physical redundancy.

Temporal optionality is most valuable when uncertainty remains unresolved, additional information may materially improve the decision, and sufficient execution time remains. It should not be maximized indiscriminately, because preserving options can create fees, underutilization, coordination costs, or delayed convergence around a common plan.

3.6 Temporal Alignment and Decision Windows

Temporal alignment refers to the fit among information arrival, plan revision, decision authorization, physical execution, and the time remaining before a critical commitment becomes effectively irreversible.

Three temporal components are central:

Signal latency: time between an external change and internal recognition;

Revision latency: time between recognition and approval of a revised plan;

Execution lead time: time required to convert the revised decision into physical change.

A decision window is the period during which an operational option remains meaningfully changeable. Conceptually, revised information can affect the physical outcome only when enough time remains for revision and execution:

Remaining Decision Window > Revision Latency + Execution Lead Time

From the point of the external event, the broader condition becomes:

Decision Window > Signal Latency + Revision Latency + Execution Lead Time

These expressions are conceptual rather than deterministic. Their purpose is to clarify why sensing speed, planning responsiveness, and physical flexibility should not be evaluated independently.

3.7 Research Propositions

The framework yields four propositions.

P1. Temporal Alignment. The resilience value of forecast revision increases when the remaining decision window exceeds the revision and execution time required to alter the relevant operational commitment.

P2. Temporal Optionality. Under unresolved uncertainty, selective preservation of temporal optionality is more likely to improve the resilience-to-cost balance than uniform anticipatory commitment when meaningful operational options remain executable.

P3. Decision Rights. Temporal ambidexterity improves resilience when decentralized decision rights operate within shared enterprise data standards and common prioritization rules.

P4. Synchronization Risk. The resilience benefits of anticipatory action diminish when firms respond synchronously to common signals and thereby intensify shared capacity constraints. Because the current Phase II evidence is aggregate, this proposition remains exploratory and requires firm-level validation.

Taken together, the framework positions CRAA as the capability architecture and temporal ambidexterity as its activation logic. Temporal selective slack preserves adjustability, forecast revision capacity updates the operating plan, temporal optionality preserves feasible choices, and temporal alignment determines whether those choices remain executable.

4 METHODOLOGY

4.1 Research Design

This study adopts a sequential multi-method design combining a comparative multiple-case study with longitudinal event analysis. Phase I examines how consumer-goods firms configure resilience capabilities across different operating contexts, while Phase II examines how the value of those capabilities changes as disruption windows and operating calendars shift.

The design is sequential rather than parallel. Phase I establishes the capability architecture that informs the temporal questions examined in Phase II. The objective is theory elaboration rather than statistical representation: the case analysis identifies recurring and contrasting resilience mechanisms, while the longitudinal analysis examines how changing external conditions affect capability timing.

4.2 Phase I: Case Selection and Documentary Analysis

Phase I uses a qualitative comparative multiple-case design based on theoretical replication. Five firms were selected: Procter & Gamble, Colgate-Palmolive, Kimberly-Clark, Yili Group, and China Mengniu Dairy. Selection followed four criteria: leadership in a major consumer-goods category, exposure to complex supply networks, evidence of post-pandemic operational transformation, and sufficient public disclosure for transparent analysis.

The three U.S.-headquartered firms represent geographically distributed consumer-goods networks characterized by standardized enterprise planning. Yili and Mengniu provide contrasting dairy cases in which upstream agricultural supply, processing, perishability, cold-chain operations, and traceability are more tightly integrated. The comparison is intended for theoretical contrast rather than national-level generalization.

Phase I relies primarily on annual reports, regulatory filings, sustainability reports, investor presentations, official corporate materials, and peer-reviewed literature. Corporate disclosures were not treated as neutral observations; claims were compared across document types and reporting periods, with emphasis placed on recurring evidence rather than isolated promotional statements.

A hybrid deductive-inductive coding process was used. Initial codes included visibility, forecasting, traceability, supplier diversification, inventory buffers, capacity flexibility, logistics alternatives, decision rights, cross-functional integration, and supplier development. These were consolidated into broader dimensions covering sensing and visibility, sourcing and ecosystem governance, absorption, network and logistics design, organizational response, and adaptation. Each case was summarized in a structured matrix and compared through cross-case pattern matching.

4.3 Phase II: Longitudinal Event Analysis

Phase II adopts a longitudinal event design to examine how resilience capabilities operate when the expected timing of disruption changes. The unit of observation is a dated change in the expected or realized supply-chain calendar. Relevant events include trade-policy announcements, material forecast revisions, major routing or weather disruptions, and meaningful changes in port volumes, supplier-delivery conditions, new orders, inventories, or prices.

The initial observation window runs from January 2026 through September 2026. Sequential forecasts are preserved by release date to avoid hindsight reconstruction. Core data streams include the Global Port Tracker, Port of Los Angeles statistics, ISM Manufacturing PMI indicators, trade-policy events, and relevant company disclosures. These sources are used to reconstruct changes in the external operating calendar rather than to infer firm-level causal effects directly.

Three temporal measures structure the analysis:

Signal latency: time between an external change and internal recognition;

Revision latency: time between recognition and approval of a revised plan;

Execution lead time: time required to convert the revised decision into physical change.

Temporal optionality, inventory displacement, and recovery quality are used conceptually in the present study, while fuller operational measurement would require firm-level data.

4.4 Triangulation and Evidence Boundaries

Triangulation occurs across both sources and analytical levels. In Phase I, evidence is compared across document types and reporting periods. In Phase II, sequential forecast releases are compared with realized port activity, manufacturing indicators, policy events, and company disclosures. The two phases are also triangulated theoretically: Phase I identifies the capability architecture, while Phase II examines how the usefulness of those capabilities changes under shifting temporal conditions.

The Phase II protocol also includes firm and industry interviews designed to connect external event timelines with internal planning and execution decisions. However, a systematic interview dataset has not yet been incorporated into the present evidence base. Interviews are therefore treated as a future validation extension rather than as completed empirical evidence.

The study matches the strength of inference to the evidence available. Phase I supports comparative conclusions about capability configuration, while Phase II supports longitudinal analysis of changing decision windows. Aggregate co-movement is not interpreted as evidence of firm-level causality.

4.5 Reliability and Validity

Construct validity is supported by linking theoretical concepts to observable indicators, including visibility systems, operational options, decision structures, dated signals, forecast revisions, and execution lead times. Internal validity is addressed through explanation building and consideration of rival explanations, including demand conditions, freight rates, seasonal mix, and route economics.

External validity relies on theoretical rather than statistical generalization. Findings are intended to inform resilience architectures and temporal decision mechanisms rather than represent all consumer-goods firms. Reliability is supported by a documented coding structure in Phase I and date-stamped data collection in Phase II, with forecasts and realized outcomes kept analytically distinct.

5 FINDINGS I: CONTEXTUAL RESILIENCE ARCHITECTURE

Phase I identifies four recurring mechanisms across the five consumer-goods cases: selective slack, digital visibility linked to executable options, appropriately distributed decision rights, and ecosystem-level coordination. Their specific form varies across operating contexts, but together they explain how firms preserved resilience without abandoning efficiency.

5.1 Selective Slack

Across the five cases, the evidence does not support a broad shift from lean operations toward generalized redundancy. Firms continued to emphasize productivity, standardization, automation, route efficiency, and cost discipline while preserving additional inventory, capacity, supplier, or logistics options around points where disruption would have disproportionate operational consequences. The recurring pattern was therefore not “more buffer everywhere,” but selective slack positioned around critical constraints.

The form of slack differed across contexts. In the U.S.-headquartered cases, resilience was more often associated with network flexibility, alternative sourcing, process standardization, portfolio simplification, and modular operating structures. In the Chinese dairy cases, resilience depended more heavily on upstream continuity, cold-chain coordination, quality control, farm-level stability, and flexible production across a more tightly integrated ecosystem.

Despite these differences, the higher-order pattern was consistent: slack created value when it protected constraints that materially affected service continuity, recovery cost, or quality risk. The findings therefore suggest that resilience and efficiency were not treated as opposing operating modes. Firms retained lean discipline in routine operations while preserving additional options where failure would have the greatest consequences.

5.2 Digital Visibility and Executable Options

Digital visibility appeared across all five cases, but the object of visibility differed substantially. The U.S. cases emphasized enterprise planning, demand and inventory analytics, retailer and supplier integration, and standardized information systems. The Chinese dairy cases extended visibility further upstream and downstream through farm monitoring, smart production, quality traceability, cold-chain coordination, and consumer-level product information.

Cross-case evidence indicates that digitalization created resilience only when information could be converted into executable operational choices. Earlier detection of demand shifts or supply constraints had limited value if firms could not change production, sourcing, transportation, allocation, or channel priorities. Conversely, alternative resources that were not visible to decision makers could not be activated efficiently. The recurring mechanism was therefore the linkage between visibility, available options, and execution rather than digital technology itself [7].

The relevant information also depended on the structure of the underlying network. For U.S. consumer-goods firms, enterprise demand, production, inventory, retailer, and supplier data were central to coordinated planning. In the dairy cases, resilience required visibility into biological supply, upstream quality, production, cold-chain conditions, and downstream demand.

These findings show that sensing contributes to resilience only when information reaches the operational constraints that matter and can trigger feasible action.

5.3 Decision Rights

The cases further show that decision authority connects visibility and operational response. Standardized enterprise platforms and common planning processes improved coordination, but excessive centralization could delay adjustment when local conditions changed quickly. At the same time, decentralized action without shared data definitions or prioritization rules risked fragmented decisions and competing claims on common resources.

The recurring governance pattern was therefore neither full centralization nor unrestricted decentralization. Firms combined enterprise-level standards with bounded authority at regional, category, or operational levels. Common data and planning logic supported coordination, while local or functional authority enabled faster reallocation of supply, capacity, inventory, or channels when adjustment was required.

The importance of decision rights was most visible where relevant information and alternative resources already existed but action depended on organizational approval. In such settings, the value of both digital visibility and selective slack depended on whether the organization could authorize and coordinate their use.

The appropriate distribution of authority remained context dependent. Globally standardized networks benefited from common enterprise rules, while more vertically integrated or perishable networks required tighter coordination across farms, factories, logistics, and channels. The consistent principle was that decision authority had to match both the scope of the operating problem and the information available to the organization [8].

5.4 Ecosystem-Level Resilience

The final finding is that resilience frequently extended beyond the focal firm. This was most visible in the Chinese dairy cases, where upstream farms, biological assets, processing operations, cold-chain logistics, and downstream channels were highly interdependent. Supply continuity therefore depended not only on internal capabilities, but also on the stability and coordination of network partners.

A similar, although differently configured, pattern was present in the U.S. cases. Multinational consumer-goods firms depended on packaging suppliers, contract manufacturers, logistics providers, retailers, and other partners whose capabilities affected their ability to absorb and respond to disruption. Shared planning platforms, supplier development, information exchange, and coordinated scenario management therefore extended resilience beyond organizational boundaries.

The evidence consequently suggests that the effective unit of resilience may be the connected supply network rather than the focal firm alone [9]. Strong internal sensing, inventory, and decision capabilities may provide limited protection when critical suppliers or logistics partners remain fragile. Conversely, ecosystem coordination can widen the set of feasible response options available during disruption.

Taken together, Phase I identifies four recurring elements of contextual resilience architecture: selective slack, digital visibility connected to executable options, distributed decision rights, and ecosystem-level coordination. These findings answer RQ1 by showing how consumer-goods firms can preserve operating efficiency while retaining the capacity to absorb and respond to disruption. They also establish the capability foundation for Phase II, where the analysis shifts from what capabilities firms possess to when those capabilities remain effective as disruption windows change.

6 FINDINGS II: TEMPORAL RESILIENCE

Phase II examines how the value of resilience capabilities changes as the expected timing of supply-chain activity shifts. The longitudinal evidence from the 2026 U.S. import environment shows that uncertainty affected not only expected volume, but also when activity was expected to occur, creating moving rather than fixed decision windows.

6.1 Forecast Revision and Shifting Import Windows

The 2026 import cycle did not follow a stable peak-season calendar. Sequential forecasts were repeatedly revised as trade-policy uncertainty, transportation disruption, routing risk, and demand conditions altered the expected timing of import activity.

The Global Port Tracker revisions illustrate this instability. Between the August 7 and September 9 releases, the September forecast increased from 2.16 million to 2.31 million loaded import TEUs, an upward revision of approximately 150,000 TEUs, or 6.9%. August was also revised upward, while several later-month forecasts were reduced. The significance of these changes lies not only in total expected volume, but in the redistribution of activity across the operating calendar.

Realized gateway activity was consistent with an extended period of elevated flow. The Port of Los Angeles handled approximately 2.92 million total TEUs from June through August 2026, including about 1.53 million loaded imports. These data do not reveal how individual consumer-goods firms changed orders or inventory positions, but they confirm that planners operated under a moving rather than fixed import window.

This distinction matters because transportation bookings, warehouse capacity, labor, purchase orders, inventory financing, and production plans are tied to expected arrival and consumption periods. A forecast revision may therefore require operational replanning even when expected annual volume changes only modestly.

The relevant capability is not forecast accuracy alone, but the ability to recognize that the operating calendar has shifted and revise downstream commitments while those commitments remain adjustable.

6.2 Decision Windows and Execution Lead Times

The value of forecast revision depends on whether enough time remains to alter the underlying operational commitment. Phase II therefore distinguishes between better information and actionable information.

Supply-chain decisions operate across different horizons. Policy signals may change within days, while purchase orders may be fixed months in advance and international transportation may require several weeks. Logistics and warehouse capacity can also require advance reservation. As a result, new information may arrive after some choices have become difficult to reverse but while others remain open.

This temporal structure can be understood through three components:

Signal latency: the delay between an external change and internal recognition;

Revision latency: the delay between recognition and approval of a revised plan;

Execution lead time: the time required to convert the revised decision into physical change.

Delay at any stage reduces the time remaining for implementation. Early sensing therefore has limited resilience value if planning and approval are slow, while rapid revision has limited value if the physical network can no longer execute the change.

The 2026 forecast sequence illustrates this constraint without establishing firm-level response behavior. A material forecast revision may affect transport capacity, warehouse space, labor, or inventory financing, but whether a particular firm can respond depends on which commitments remain changeable at the time of revision.

The key temporal finding is therefore that visibility contributes to resilience only while a feasible operational option remains inside its decision window.

6.3 Temporal Optionality versus Early Commitment

The evidence also highlights a trade-off between early commitment and preserved flexibility. Anticipatory ordering can protect firms against expected tariffs, congestion, or capacity constraints by moving supply ahead of disruption. At the same time, earlier commitment reduces reversibility and can increase inventory, working-capital, storage, or markdown exposure if the disruption window later shifts.

The 2026 pattern is consistent with this tension. Elevated earlier activity did not eliminate later peak-season pressure; forecasts continued to shift expected import activity toward September. This does not establish whether individual firms benefited from anticipatory ordering, but it demonstrates that early commitment did not eliminate uncertainty about subsequent timing.

Anticipatory commitment and temporal optionality therefore address uncertainty differently. The former converts expected future risk into a current commitment; the latter preserves the ability to revise the commitment as information improves.

Their relative value depends on four conditions: disruption credibility, capacity scarcity, execution lead time, and the cost of premature commitment. Temporal optionality becomes more valuable when uncertainty remains unresolved and meaningful choices remain executable, whereas earlier commitment becomes more attractive as capacity tightens or execution windows narrow.

6.4 Cross-Event Temporal Patterns

Across the Phase II event sequence, three recurring patterns emerge.

First, uncertainty affected the timing of expected supply-chain activity, not only its volume. Second, revised information arrived after planning processes had already begun, meaning that some commitments were likely to remain more reversible than others. Third, the operational value of later information depended on whether sufficient decision and execution time remained.

The sequence can be summarized as:

Changing signal → revised operating calendar → narrowing decision set → commitment or preserved option → physical execution

These patterns also reveal three forms of temporal exposure: information exposure when change is recognized late; organizational exposure when revision or approval is slow; and execution exposure when a suitable response exists but physical lead time exceeds the remaining decision window.

These categories are analytical interpretations rather than directly measured firm-level outcomes.

Phase II therefore extends the Phase I findings in a specific way. Phase I identifies selective slack, executable options, decision rights, and ecosystem coordination as resilience capabilities; Phase II shows that the value of those capabilities is time contingent. Slack must remain available when needed, visibility must arrive before options expire, and decision authority must operate quickly enough to influence physical execution.

The combined evidence supports the central temporal argument of the study: resilience depends not only on possessing appropriate capabilities, but also on activating and sequencing them while they remain operationally meaningful.

7 INTEGRATED FRAMEWORK

7.1 Temporal Contextualized Resilience-Agility Architecture

The combined findings support a temporal extension of CRAA rather than a replacement of the original framework. Phase I identifies the capability architecture through which firms sense disruption, absorb its effects, respond operationally, and adapt structurally. Phase II adds a timing condition by showing that these capabilities create resilience only while the associated operational options remain feasible.

The resulting Temporal Contextualized Resilience-Agility Architecture integrates capability configuration with capability timing. CRAA specifies what resources and organizational mechanisms are available, while temporal ambidexterity governs when those mechanisms should be advanced, delayed, accelerated, or sequenced. Selective slack preserves flexibility, forecast revision updates the operating plan, temporal optionality preserves actionable choices, and temporal alignment determines whether those choices can still influence physical outcomes.

The integrated model therefore shifts attention from static capability possession toward the temporal coordination of capabilities under uncertainty.

7.2 Sensing → Option Preservation → Timed Response → Adaptation

The integrated process can be represented as:

Sensing → Option Preservation → Timed Response → Adaptation

Sensing captures the recognition of changes in demand, supply, policy, logistics, or other sources of disruption. Earlier recognition preserves a larger decision space, while late recognition may leave only downstream recovery actions available.

Option preservation extends CRAA's absorption function by keeping selected commitments adjustable through flexible order windows, postponement arrangements, optional production capacity, reserved logistics options, or alternative routings. The objective is not to maximize slack, but to preserve enough operational choice for later information to remain useful.

Timed response occurs when the firm converts revised information and preserved options into commitment. The appropriate action may be to advance, delay, accelerate, or sequence a decision depending on disruption credibility, the value of additional information, execution lead time, and the cost of premature commitment. Response quality therefore depends on temporal fit rather than speed alone.

Adaptation incorporates repeated experience into future operating structures and decision routines, including changes to suppliers, network design, planning horizons, approval processes, and the points at which flexibility is intentionally preserved.

The broader sequence is therefore:

External uncertainty → sensing → preserved options → revised plan → timed commitment → physical execution → adaptation

This sequence integrates the capability logic of Phase I with the temporal logic identified in Phase II.

7.3 Boundary Conditions

The value of temporal ambidexterity depends on operating context.

First, execution lead time affects the value of waiting. Long production or transportation lead times reduce the period during which new information can still influence action.

Second, reversibility affects the cost of early commitment. Where commitments can be changed at low cost, earlier action carries less downside; where they are difficult to reverse, preserving optionality becomes more valuable.

Third, capacity scarcity changes the cost of delay. When transport, production, warehouse, or supplier capacity is constrained, waiting may cause firms to lose access to the required option.

Fourth, category and network characteristics shape the appropriate temporal configuration. Perishability, product variety, supplier concentration, regulation, geographic dispersion, and channel structure influence both the cost of slack and the

time available for response. Phase I showed that similar resilience functions were implemented differently across standardized multinational consumer-goods networks and vertically integrated dairy ecosystems. Finally, shared capacity constraints can limit the benefits of anticipatory action. When multiple firms respond simultaneously to common signals, early ordering or capacity reservation may intensify congestion. This synchronization effect remains exploratory and requires further firm-level validation. The framework therefore does not imply that firms should always preserve optionality or always commit early. Its central claim is conditional: resilience improves when the timing of commitment is matched to uncertainty, reversibility, execution requirements, capacity conditions, and the structure of the supply network.

8 DISCUSSION

8.1 Theoretical Contributions

This study contributes to supply chain resilience research by shifting attention from capability possession to capability timing. Phase I identifies a contextual capability architecture based on sensing, absorption, response, and adaptation, supported by selective slack, executable options, decision rights, and ecosystem coordination. Phase II shows that the value of these capabilities is also time contingent: a capability may exist structurally yet contribute little if the associated operational option is no longer feasible when new information arrives.

A second contribution is the distinction between response speed and temporal optionality. Faster action may reduce delay, but premature commitment can also reduce reversibility and increase inventory, working-capital, or capacity exposure when uncertainty remains unresolved. Temporal resilience therefore depends not simply on acting earlier, but on preserving reversible choices while additional information remains valuable and exercising them before execution constraints eliminate those choices.

Third, the study extends dynamic capabilities theory by making the timing of resource commitment more explicit. The sensing–seizing–transforming logic explains how firms identify change, mobilize resources, and reconfigure operations, but supply-chain decisions often involve commitments that become progressively less reversible over time. Temporal ambidexterity refines this logic through four possible actions—advance, delay, accelerate, and sequence—showing that adaptive capability is not always expressed through faster commitment.

The findings also refine the resilience–efficiency trade-off. Resilience need not depend on permanently higher redundancy [10]. Selective slack can preserve options around critical constraints, while temporal optionality can preserve adjustability without requiring all resources to be committed in advance. The key question is therefore not how much redundancy a firm possesses, but which choices remain feasible, for how long, and under what conditions they should be exercised.

8.2 Managerial Implications

The framework suggests that resilience should be managed as a portfolio of time-sensitive operational options, rather than simply as a stock of backup resources.

Managers should assess four questions when disruption conditions change: how much uncertainty remains, which commitments are still reversible, how long those options remain open, and whether the cost of waiting exceeds the cost of early commitment. Depending on these conditions, the appropriate response may be to advance, delay, accelerate, or sequence a commitment rather than simply “respond faster.”

Planning systems should therefore monitor more than forecast accuracy. Relevant indicators include forecast revision latency, remaining decision-window length, execution lead time, and the proportion of critical commitments that remain adjustable. Similarly, backup suppliers, capacity, or transport options have limited resilience value if they cannot be activated within the available horizon.

Decision rights should also reflect temporal requirements. Enterprise-wide sourcing or capacity decisions may require centralized coordination, while local allocation or routing decisions may require bounded authority where response windows are short. Shared data and prioritization rules can support faster local action without sacrificing enterprise coordination.

8.3 Contextual Implications

The U.S.–China comparison should be interpreted as contextual rather than deterministic. The U.S.-headquartered cases more often embedded resilience in standardized planning, analytics, modular networks, and productivity-led transformation, while the Chinese dairy cases emphasized end-to-end traceability, ecosystem coordination, and integration across farms, production, logistics, and channels.

These differences affect how temporal resilience is implemented. In standardized multinational networks, temporal ambidexterity may rely more heavily on planning integration, contractual flexibility, modular capacity, and delegated authority. In tightly coupled dairy ecosystems, timing may be shaped more strongly by biological supply, perishability, cold-chain capacity, and coordination across interdependent stages.

The comparison does not imply that one model is inherently more resilient. It reinforces the contextual nature of the framework: the same temporal problem—when to preserve optionality and when to commit—can be resolved through different operational mechanisms depending on network structure and the location of critical constraints.

9 LIMITATIONS AND FUTURE RESEARCH

This study has four principal limitations.

First, Phase I relies mainly on corporate reports, regulatory filings, sustainability disclosures, investor materials, and other public documents. These sources provide useful evidence on strategy and network design but cannot fully capture failed initiatives, informal decision processes, or implementation difficulties.

Second, Phase II relies primarily on aggregate evidence. Sequential forecasts, port volumes, manufacturing indicators, and policy events show how the external operating calendar changed, but they do not reveal how individual firms altered orders, inventory, transportation bookings, or production schedules. The analysis therefore supports conclusions about temporal conditions and decision windows rather than firm-level causal effects.

Third, several temporal constructs—including signal latency, revision latency, execution lead time, and temporal optionality—require further firm-level validation. Future research should combine operational records with interviews to reconstruct decision sequences and measure these constructs more directly.

Fourth, the temporal analysis is concentrated on the 2026 U.S. import environment. Future studies should test the framework across additional ports, transportation modes, product categories, industries, and disruption types. The synchronization effect proposed in P4 also requires firm-level ordering and booking data before stronger causal claims can be made.

10 CONCLUSION

This study extends the Contextualized Resilience-Agility Architecture by introducing an explicit temporal dimension to supply chain resilience. The findings show that resilience depends not only on whether firms possess appropriate capabilities, but also on whether those capabilities remain actionable as decision windows narrow.

The central contribution is the concept of temporal ambidexterity: the ability to preserve operating efficiency while advancing, delaying, accelerating, or sequencing commitments as uncertainty, reversibility, and execution conditions change. This perspective distinguishes resilience from simple response speed and shows that selective preservation of options can sometimes create greater value than uniformly early commitment.

The integrated framework can be summarized as: Sensing → Option Preservation → Timed Response → Adaptation. CRAA explains the capability architecture; temporal ambidexterity explains how those capabilities are activated over time. Temporal selective slack preserves adjustability, forecast revision capacity updates the operating plan, temporal optionality preserves feasible choices, and temporal alignment determines whether those choices can still influence physical outcomes.

Supply chain resilience is therefore not synonymous with acting faster. It depends on preserving and exercising the right options within the decision windows in which they remain operationally meaningful.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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