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Accounting for Structural Interdependence: A Network-Adjusted Framework for Systemic Fiscal Exposure in Critical Food Supply Chains - Evidence from Egypt

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ABSTRACT

Purpose: Modern economic systems increasingly operate as interconnected networks where fiscal vulnerability arises not only from realized expenditures but also from structurally embedded exposure patterns that propagate across supply chains. This study develops a structural interdependence accounting framework capable of identifying topology-conditioned fiscal exposure in critical food supply systems. It examines how systemic risk propagates across interdependent supply-chain nodes and how collective fiscal value is reconfigured under correlated macroeconomic and operational shocks. By embedding network topology into accounting measurement, the framework captures structural exposure patterns that remain invisible within conventional transaction-based accounting systems.

Design / Methodology / Approach: Using monthly panel data for 2020–2025 from Egypt's wheat import system, the study integrates fixed-effects estimation, dynamic System-GMM modeling, network centrality metrics, and Monte Carlo simulation with 10,000 iterations. A novel Network-Adjusted Fiscal Exposure Index (NAFEI) is constructed to capture nonlinear amplification, persistence, and topology-weighted systemic exposure across interconnected supply-chain nodes.

Findings: Results show that exchange-rate centrality dominates systemic transmission within the supply network and explains a significant share of fiscal exposure variance. Correlated shocks generate nonlinear amplification beyond additive effects, producing measurable erosion in collective fiscal value. Higher network density and exposure concentration accelerate cascade dynamics, revealing structural fragility in tightly interconnected supply systems.

Originality / Value: The study advances accounting research by embedding network topology directly into measurement design. It extends accounting beyond transaction-based recording toward a structural interdependence paradigm capable of identifying systemic exposure patterns in critical commodity networks.

Implications: Exposure-sensitive metrics such as NAFEI enable accounting systems to detect systemic fiscal vulnerability earlier. For policymakers, the framework provides an analytical tool for monitoring transmission nodes—particularly exchange-rate channels—and designing more resilient fiscal stabilization strategies under global commodity volatility.

KEYWORDS: Structural Interdependence; Systemic Risk; Network-Adjusted Accounting; Systemic Fiscal Exposure; Critical Food Supply Chain; Network Economics; Food Security Systems

1. REFRAMING ACCOUNTING IN INTERDEPENDENT SUPPLY NETWORKS

1.1 The Structural Transformation of Supply Systems

Over the past two decades, global supply systems have undergone a profound structural transformation. Traditional vertically integrated production chains have evolved into complex, multi-layered networks characterized by cross-border interdependence, financial integration, and synchronized risk exposure (Antràs, 2020). This transformation has reshaped the dynamics of vulnerability and resilience in critical commodity systems in highly interconnected economic environments, fiscal vulnerability does not arise solely from isolated financial transactions but from structurally embedded exposure patterns that propagate across networked supply systems.

Production networks today operate through dense inter-firm and inter-country linkages, where shocks propagate through indirect channels rather than direct contractual relationships (Carvalho & Tahbaz-Salehi, 2019). Empirical evidence from global

crises demonstrates that supply disruptions no longer remain localized; instead, they ripple across network nodes, amplifying systemic fragility (Bonadio et al., 2021).

Food-import systems represent a particularly sensitive case of networked interdependence. Commodity price volatility interacts with exchange-rate dynamics and domestic fiscal structures, creating layered exposure architectures (World Bank, 2023). In such systems, vulnerability is determined not solely by import volume, but by the topology of transmission channels.

Recent macroeconomic research highlights that network structure can transform micro-level shocks into macro-level instability (Acemoglu et al., 2012; Baqaee & Farhi, 2022). Central nodes exert disproportionate influence, while interconnected pathways amplify disturbances.

These developments challenge linear models of supply chains. Systems are no longer chains; they are networks with dynamic centrality shifts, threshold effects, and regime-dependent propagation elasticities (Jackson, 2021).

Importantly, structural transformation is not merely logistical — it is informational. Decision-making frameworks must adapt to interdependent architectures where exposure materializes through indirect transmission.

Yet, while economic theory has incorporated network-based thinking, accounting frameworks remain predominantly entity-centered.

1.2 The Accounting Blind Spot

Accounting systems are traditionally built upon three foundational principles:

1. Recognition of realized transactions
2. Measurement within defined reporting boundaries
3. Linear aggregation of financial outcomes

These principles presume separability and proportionality. However, networked supply systems violate both assumptions. Exposure arises before transaction recognition. Shock amplification depends on cross-node elasticities. Fiscal outcomes reflect propagation architecture rather than isolated cost elements.

Recent debates in accounting scholarship acknowledge increasing environmental complexity and uncertainty (Barth, 2018; Wagenhofer, 2022). However, the dominant response has been expanded disclosure rather than structural redesign.

Financial reporting standards incorporate fair value measurement and risk disclosures, yet they do not embed topology-adjusted exposure modeling (IASB, 2018). As a result, systemic vulnerability remains partially invisible within accounting systems.

Meanwhile, systemic risk research in finance demonstrates that entity-level reporting failed to detect cascading instability prior to global crises (Adrian & Shin, 2010; Haldane & May, 2011). Macroprudential frameworks emerged precisely because traditional accounting frameworks lacked systemic perspective.

A similar blind spot exists in sovereign supply networks. Import-dependent food systems combine commodity exposure, currency volatility, and fiscal constraints. Yet accounting treatment of import costs remains transaction-bound rather than propagation-aware.

This gap creates informational asymmetry between economic structure and accounting representation. The core question therefore emerges: Can accounting remain transaction-centric in economies structured by network interdependence?

This research argues that it cannot. Instead, accounting must be reconceptualized as a structural exposure architecture capable of mapping systemic vulnerability across interconnected economic networks.

1.3 Research Objectives and Central Questions

Against the backdrop of structural transformation in supply systems and the persistent accounting blind spot, this research pursues a fundamental objective:

To reconceptualize accounting as a structural architecture embedded within networked interdependence rather than as a transaction-recording mechanism. Specifically, the study aims to:

1. Develop a formal model of accounting interdependence grounded in network topology.
2. Identify the mechanisms through which systemic risk propagates in import-dependent supply networks.
3. Examine how centrality and amplification alter fiscal exposure.
4. Introduce the concept of collective value reconfiguration under network shocks.
5. Reposition accounting theory within systemic economic structures.

These objectives lead to four central research questions:

RQ1: How does network topology condition fiscal exposure in critical supply systems?

RQ2: Do exchange-rate and commodity-price shocks propagate nonlinearly in sovereign import networks?

RQ3: Can collective value deterioration be modeled as a topology-adjusted function rather than a direct cost outcome?

RQ4: What theoretical redesign is required for accounting to internalize structural interdependence?

These questions situate the research at the intersection of network macroeconomics, systemic risk theory, and accounting architecture.

Recent literature has emphasized the need to integrate production networks into macroeconomic analysis (Antràs, 2020; Carvalho et al., 2021). At the same time, financial stability research underscores the importance of systemic mapping beyond entity boundaries (Financial Stability Board, 2022; BIS, 2023).

However, no comprehensive framework has formally embedded accounting measurement within network propagation structures. This research addresses that gap.

1.4 Research Significance and Scholarly Contributions

The significance of this study is threefold: theoretical, methodological, and policy-oriented.

(1) Theoretical Contribution

The study advances a structural accounting paradigm grounded in network theory. While prior accounting research has examined risk disclosure and fair value dynamics (Laux & Leuz, 2009; Barth et al., 2021), it has not integrated formal propagation architecture into measurement design.

By constructing a topology-adjusted exposure model, this research extends accounting theory beyond transaction recognition toward systemic mapping.

It also contributes to production network literature by introducing accounting as a stabilizing or amplifying node within economic systems (Baqaee & Farhi, 2022).

(2) Methodological Contribution

The research introduces:

- Network-based exposure modeling
- Monte Carlo stress simulation integrated with fiscal metrics
- Centrality-adjusted accounting indicators

These methods align with advances in stochastic modeling and spillover analysis (Demirer et al., 2020; Kroese et al., 2022).

Such methodological integration moves accounting research toward quantitative systemic modeling rather than conceptual abstraction.

In addition, the study introduces a Network-Adjusted Fiscal Exposure Index (NAFEI) as a topology-conditioned accounting metric that integrates macroeconomic shocks, transmission centrality, and fiscal dependency into a unified measure of systemic exposure. The index extends conventional accounting measurement by capturing exposure before full cost realization and by making structurally transmitted vulnerability visible within critical supply networks.

(3) Policy Contribution

Import-dependent food systems face heightened exposure to global shocks. Commodity price volatility, exchange-rate fluctuations, and fiscal rigidity interact to shape vulnerability (IMF, 2023; World Bank, 2024).

This research provides a framework for policymakers to:

- Map systemic exposure ex ante
- Quantify nonlinear amplification
- Design topology-aware fiscal buffers

Thus, accounting becomes an instrument of systemic governance rather than retrospective reporting.

1.5 Structure of the Research

The remainder of this research is structured as follows:

2. critically reviews competing theories of interdependence and identifies the accounting blind spot within networked economies.
3. develops a formal structural model of accounting interdependence and derives empirically testable hypotheses.
4. outlines the research design, data architecture, and network-adjusted estimation framework.
5. presents empirical findings, demonstrating risk propagation dynamics and collective value reconfiguration.
6. discusses theoretical implications, governance consequences, and the repositioning of accounting within systemic economic architectures.
7. concludes with forward-looking research trajectories and implications for networked economies.

2. INTERDEPENDENCE, NETWORK FRAGILITY, AND THE ACCOUNTING BLIND SPOT

Modern economic systems increasingly operate as interconnected networks, while accounting frameworks still rely largely on entity-bound and transaction-based measurement principles. This divergence creates an analytical blind spot: systemic exposure generated by network interdependence remains insufficiently visible within conventional accounting systems. This chapter reviews the main theoretical perspectives explaining structural interdependence and systemic fragility and shows how they reveal a persistent gap between economic structure and accounting representation.

2.1 From Linear Supply Chains to Networked Production Architectures

For decades, economic and accounting models treated supply systems as linear chains characterized by sequential value addition. Under this view, shocks move proportionally across direct transactional links, and exposure can be approximated through bilateral relationships. Contemporary research, however, has moved decisively beyond this framework, recognizing production systems as complex, multi-layered networks (Carvalho & Tahbaz-Salehi, 2019).

This transition from linear chains to networked production architectures changes how exposure is understood. In linear systems, vulnerability accumulates along sequential transactional links. In networked systems, by contrast, exposure emerges from the topology of interconnections and must be understood as a structural property of the system rather than a feature of isolated transactions.

Acemoglu et al. (2012) show that aggregate volatility can originate from micro-level interconnections even without large exogenous shocks. This finding challenges linear supply-chain thinking by demonstrating that instability may arise from interdependence itself. Recent empirical work confirms that supply disruptions propagate through network topology rather than simple sequential dependency (Baqaee & Farhi, 2022; Bonadio et al., 2021). During global crises, even small disturbances at central nodes can trigger system-wide instability because shocks move through multiple interconnected channels (Baldwin & Freeman, 2022).

Network density and degree centrality therefore shape propagation elasticity. More connected systems exhibit greater amplification potential (Jackson, 2021; Newman, 2018). This logic is particularly relevant in sovereign food-import systems, where exposure depends on the interaction of global price nodes, exchange-rate channels, and domestic fiscal structures.

The global value-chain literature also shows that fragmentation and cross-border integration increase vulnerability to external shocks (Miroudot, 2020; UNCTAD, 2022). Food-import systems are especially exposed because they combine commodity dependence, currency sensitivity, and fiscal obligations linked to food security.

Despite this shift in economic thought, much of accounting theory still relies on entity-bound, transaction-based measurement frameworks that assume separability and proportionality. As a result, accounting systems often fail to capture structural exposure embedded within networked economic architectures.

2.2 Network Topology and Amplification Theory

Network theory provides a formal basis for understanding how shocks propagate across interconnected economic systems. In weighted directed networks, node influence depends not only on size but also on structural position and connectivity (Elliott, Golub, & Jackson, 2014; Ma et al., 2024).

Spillover indices and connectedness measures quantify the direction and magnitude of shock transmission (Diebold & Yilmaz, 2014; Barigozzi & Hallin, 2020). Research in financial networks shows that highly connected nodes contribute disproportionately to systemic volatility because disturbances originating at such nodes affect a larger share of the system (Demirer et al., 2020).

Network topology therefore affects both the direction and the intensity of transmission. In dense systems, multiple channels make reinforcement more likely than dissipation. Amplification emerges when feedback loops and cross-elasticities generate nonlinear propagation effects. Bardoscia et al. (2021) show that once interdependence exceeds certain thresholds, shock magnitudes expand convexly rather than proportionally. Likewise, production network models indicate that higher-order interactions amplify aggregate outcomes (Carvalho et al., 2021), undermining the assumption that exposure can be estimated through isolated marginal effects.

Exchange-rate pass-through research reinforces this logic. Gopinath et al. (2020) show that dominant currency pricing creates asymmetric transmission mechanisms in global trade systems. In import-dependent economies, exchange-rate shocks therefore travel across multiple economic channels simultaneously. From a macroeconomic perspective, network-adjusted multipliers alter conventional transmission channels, making shock elasticity topology-dependent rather than constant (Baqaee & Farhi, 2022).

This intuition can be expressed conceptually as:

$$SFE_i = \Sigma\, w_{ij} \cdot \varepsilon_j$$

where SFE_i denotes systemic fiscal exposure associated with node *i*, w_{ij} captures the network-weighted interdependence between nodes *i* and *j*, and ε_j represents the shock affecting node *j*. This formulation shows that fiscal exposure arises not only from direct transactions but also from indirect propagation through interconnected supply structures.

Food security systems illustrate these dynamics clearly. The World Bank (2023) shows how commodity-price volatility, exchange-rate movements, and domestic demand jointly shape food-import exposure in emerging economies. Yet accounting scholarship has largely remained confined to measurement within institutional boundaries rather than network boundaries. Economic systems are increasingly modeled as networks, while accounting systems remain predominantly linear.

2.3 Contagion, Fragility, and Systemic Thresholds in Interdependent Economic Networks

While interdependence describes structural connectivity across economic systems, fragility arises when shock propagation becomes nonlinear. Contagion theory explains how disturbances move across interconnected balance sheets, markets, and production networks, linking structural interdependence with systemic instability.

Early financial contagion models showed that interconnected balance sheets can transmit localized shocks across institutions (Allen & Gale, 2000). Subsequent work formalized threshold effects in financial networks, demonstrating that once exposure exceeds certain levels, cascade dynamics dominate linear adjustment (Elliott, Golub, & Jackson, 2014).

Recent studies show that similar contagion mechanisms operate in supply-chain networks. Xue, Li, and Wang (2024) demonstrate that network topology significantly influences disruption propagation across supply chains. Highly connected networks are particularly vulnerable because disturbances can move through multiple transmission channels simultaneously.

Research on systemic financial risk further indicates that contagion depends not only on exposure size but also on interconnection density and leverage structures (Glasserman & Young, 2016; Bardoscia et al., 2021). These findings suggest that fragility arises from the architecture of the network rather than from the magnitude of individual shocks.

Production network literature reports similar threshold dynamics in real-sector systems (Carvalho & Tahbaz-Salehi, 2019). Dense input–output linkages allow even moderate shocks to generate disproportionate aggregate outcomes. Fragility therefore depends on topology rather than shock size alone.

Import-dependent economies face compounded fragility because multiple vulnerability channels interact simultaneously:

- External commodity price shocks
- Currency volatility
- Domestic demand rigidity

Empirical evidence from global commodity markets shows that joint price and currency shocks generate convex fiscal consequences in emerging economies (IMF, 2023; World Bank, 2024).

Nonlinear propagation also implies that vulnerability may remain latent until critical thresholds are reached. Below these thresholds, disturbances appear manageable and accounting projections based on linear expectations remain relatively accurate. Once exposure accumulates beyond tipping points, however, systems may experience rapid escalation in fiscal pressure and supply instability.

Yet fragility is rarely incorporated into accounting measurement models. Conventional cost recognition assumes proportional pass-through and predictable budgeting effects. Contagion research contradicts this assumption by demonstrating that correlated shocks may generate nonlinear escalation.

Consequently, accounting projections based solely on expected values may underestimate tail risk in networked economic systems. In such environments, fiscal exposure reflects structural propagation dynamics rather than realized costs alone.

Resilience research further suggests that buffering capacity depends on structural redundancy rather than isolated strength (Hosseini et al., 2021). Domestic production capacity and strategic reserves can act as buffering nodes in sovereign food systems, but they only partially mitigate external shock propagation.

Thus, fragility in interdependent systems depends primarily on three structural factors:

1. Centrality distribution
2. Elasticity magnitude
3. Shock covariance

This architecture contrasts with traditional accounting approaches that treat cost exposure as a deterministic outcome rather than a structural vulnerability embedded within economic networks.

2.4 Collective Value and Systemic Welfare Dynamics in Fiscal Systems

Beyond risk propagation, interdependence also affects collective welfare structures within economic systems. Collective value refers to the stability of fiscal sustainability, supply adequacy, and price containment across interconnected economies. Unlike firm-level profit measures, collective value reflects systemic outcomes influenced by network dynamics.

Recent macroeconomic research shows that network spillovers influence aggregate welfare through distributional channels (Baqaee & Farhi, 2022). When shocks propagate across production and trade networks, their effects are unevenly distributed across sectors and households.

Food security studies similarly show that commodity volatility disproportionately affects lower-income households (Wright, 2022; FAO, 2023). In import-dependent economies, fluctuations in global prices and exchange rates can therefore translate directly into domestic fiscal pressure and price instability.

Collective value in such systems depends primarily on three factors:

- Fiscal exposure volatility
- Supply gap persistence
- Shock transmission elasticity

Network-based welfare models demonstrate that welfare losses depend on topology-adjusted multipliers rather than simple price movements (Jackson, 2021; Zhou et al., 2025). When disturbances propagate through multiple economic channels, their aggregate effects may be significantly amplified.

Systemic welfare deterioration occurs when propagation elasticity exceeds buffering capacity. Once transmission mechanisms dominate stabilization mechanisms, external shocks may produce persistent fiscal pressure and supply instability.

The global value-chain literature also distinguishes between robustness and resilience (Miroudot, 2020). Robust systems resist small shocks, while resilient systems recover from larger disruptions. Sovereign food-import systems often lack robustness because demand for staple commodities is relatively inelastic.

Consequently, disturbances in global commodity markets frequently translate into fiscal burdens associated with subsidy programs, strategic reserve management, or emergency imports. In such contexts, collective value becomes closely tied to fiscal exposure management.

Despite these insights, accounting literature rarely conceptualizes welfare as network-contingent. Financial reporting frameworks focus on recognition and disclosure within institutional boundaries (Barth, 2018; Wagenhofer, 2022). Even forward-looking disclosure initiatives emphasize entity-level risk rather than systemic topology.

This creates a conceptual blind spot in accounting research. While economic analysis increasingly models fragility and welfare through network structures, accounting systems do not internalize these network-based dynamics.

As a result, accounting measurement often lags behind the structural realities of modern economic systems. Economic research recognizes network propagation mechanisms, whereas accounting frameworks remain largely confined to transactional representation.

2.5 The Accounting Blind Spot: Transactional Logic in Networked Economies

While economic theory increasingly conceptualizes production and trade systems as interconnected networks, accounting theory remains largely anchored in transactional logic. Financial reporting frameworks are built around recognition events, measurement bases, and entity boundaries (IASB, 2018). Within this structure, economic exposure becomes relevant primarily when transactions are realized and recorded.

However, network-based economic systems generate exposure before transactions are formally recognized. Structural dependencies embedded in interconnected supply chains create propagation pathways through which shocks accumulate prior to financial recognition.

Recent debates in accounting research acknowledge the need for more forward-looking financial information (Barth et al., 2021; Wagenhofer, 2022). Yet most proposed reforms emphasize improved disclosure rather than structural redesign of measurement systems. Consequently, accounting frameworks continue to focus mainly on historical transactions and realized financial outcomes.

This transactional orientation limits accounting's capacity to represent exposure in networked economies. When accounting systems rely exclusively on realized transactions, they implicitly assume that vulnerability becomes relevant only once costs appear in financial statements. Network theory challenges this assumption by demonstrating that exposure accumulates through propagation mechanisms long before financial effects become observable.

The central proposition of this study is therefore that accounting can evolve beyond transaction recording into a structural diagnostic architecture capable of identifying systemic fiscal exposure embedded within interconnected economic networks.

The accounting blind spot arises from three implicit assumptions embedded in traditional accounting frameworks.

(1) Entity Separability

Accounting assumes that each reporting unit can be evaluated independently from the broader economic system. Financial statements therefore represent the financial position of individual entities rather than the systemic interdependencies connecting them.

Network theory rejects this separability assumption. Systemic outcomes depend on cross-node elasticities within interconnected networks (Acemoglu et al., 2022). In such environments, exposure cannot be attributed solely to individual entities because shocks propagate across multiple nodes simultaneously.

In import-dependent food systems, fiscal exposure is closely linked to exchange-rate dynamics and global commodity price movements. National fiscal stability therefore depends not only on domestic policies but also on structural positions within global trade networks.

(2) Linear Pass-Through

Budget forecasting models often assume proportional responses to price changes. Under this assumption, increases in commodity prices translate linearly into higher fiscal costs.

However, contagion literature demonstrates that correlated shocks may produce convex amplification effects (Bardoscia et al., 2021). When commodity prices and exchange rates move simultaneously, fiscal exposure may increase at an accelerating rate rather than proportionally.

Consequently, linear accounting projections tend to underestimate tail exposure in networked economic systems.

(3) Historical Recognition

Traditional accounting emphasizes recognition of past transactions rather than structural vulnerability. Financial reporting therefore focuses on realized costs rather than latent exposure embedded within network architecture.

Yet systemic risk emerges through propagation dynamics rather than isolated accounting events. Exposure accumulates across networks long before financial consequences appear in accounting records.

Financial stability research has already shifted toward macroprudential oversight because entity-level reporting proved insufficient to capture systemic fragility (Borio, 2014; Financial Stability Board, 2022). Accounting theory has not yet undergone a comparable transformation.

Accounting and Interdependence Debate

Recent scholarship has begun to explore accounting's role in complex economic systems (Quattrone, 2016; Power, 2021). These studies argue that accounting practices shape economic reality through calculative infrastructures that influence decision making. However, these contributions stop short of embedding accounting measurement within formal network propagation models. The gap therefore reflects not a lack of conceptual awareness but a lack of structural integration between accounting and network-based economic analysis.

2.6 The Unresolved Theoretical Gap

The literature reviewed in this chapter reveals a clear asymmetry between economic modeling and accounting representation. Production network theory models interdependence mathematically. Systemic risk research explains contagion and amplification mechanisms. Welfare economics analyzes collective stability under network spillovers. Accounting literature, however, remains primarily focused on measurement within entity-level boundaries.

Despite major advances in production network theory, systemic risk modeling, and welfare economics, accounting research still lacks an operational framework capable of translating network interdependence into measurable fiscal exposure signals. As a result, systemic vulnerability generated by interconnected supply systems remains recognized in economic models but largely unmeasured within accounting architectures. Three specific gaps emerge from this literature.

Gap 1: Absence of Topology-Adjusted Accounting Metrics

Existing accounting frameworks measure fiscal exposure using traditional financial indicators that do not incorporate network position or propagation elasticity. No established accounting framework adjusts exposure measures according to structural centrality.

Gap 2: Lack of Convex Risk Recognition

Accounting systems rarely incorporate nonlinear amplification arising from correlated shocks. Yet systemic risk research consistently shows that contagion dynamics generate convex escalation rather than proportional adjustment.

Gap 3: Failure to Model Collective Value

Accounting frameworks focus mainly on firm-level financial outcomes rather than systemic welfare stability. Collective value—defined as the joint stability of fiscal sustainability, supply adequacy, and price containment—remains outside the operational scope of accounting measurement.

These gaps are particularly important in sovereign food-import systems where multiple structural forces interact simultaneously:

- Commodity price volatility
- Exchange-rate fluctuations
- Domestic fiscal obligations

Addressing these gaps requires an analytical framework capable of recognizing network topology, quantifying propagation elasticities, integrating collective value metrics, and repositioning accounting as a systemic analytical architecture rather than a transactional record.

This requirement motivates the structural accounting framework developed in the following chapter.

Theoretical Closure of Chapter 2

This chapter has shown that modern economic systems operate as interdependent networks characterized by complex propagation dynamics. Network topology shapes shock transmission, while contagion mechanisms generate nonlinear amplification that may produce systemic fragility.

Collective value in such systems depends on the interaction between fiscal stability, supply adequacy, and propagation elasticity across interconnected economic nodes.

However, accounting theory remains largely anchored in entity-based measurement frameworks grounded in linear transactional logic. This orientation limits accounting's ability to capture structural exposure embedded within networked economic systems.

The resulting blind spot reflects the absence of a structural accounting architecture capable of modeling network-adjusted fiscal exposure.

Chapter 3 addresses this gap by constructing a formal analytical model of accounting interdependence embedded within propagation topology, providing the conceptual foundation for the Network-Adjusted Fiscal Exposure Index (NAFEI).

3 STRUCTURAL INTERDEPENDENCE AND THE NETWORK ARCHITECTURE OF FISCAL EXPOSURE

3.1 Structural Interdependence in Networked Economic Systems

Traditional accounting theory has historically treated economic entities as separable units whose financial positions can be evaluated independently of broader systemic structures. Financial reporting frameworks therefore focus primarily on transactions occurring within organizational boundaries. However, contemporary economic systems operate through complex production and trade networks in which exposure is distributed across interconnected nodes rather than confined to individual entities (Carvalho & Tahbaz-Salehi, 2019).

Structural interdependence describes a condition in which economic outcomes at one node depend on shocks transmitted through connected nodes. In production networks, these interconnections have been shown to amplify aggregate volatility even when individual disturbances appear modest (Acemoglu et al., 2012; Baqaee & Farhi, 2022). Consequently, measurement systems embedded within such networks inherit structural properties arising from connectivity patterns.

Recent macro-network research demonstrates that shocks originating at highly central nodes generate disproportionate systemic effects (Elliott, Golub, & Jackson, 2014; Acemoglu et al., 2022). Within sovereign food-import systems, this implies that accounting recognition of import costs is not purely transactional but structurally conditioned by upstream propagation channels.

Accounting therefore operates within interconnected macroeconomic transmission systems including exchange-rate dynamics, commodity-price movements, and fiscal stabilization mechanisms. In such environments, exposure arises from connectivity patterns rather than isolated economic events. In sovereign food-import systems, structural interdependence manifests through three principal channels:

1. Price transmission elasticity
2. Currency amplification
3. Demand scaling pressure

These channels form a tri-layer propagation structure whose topology determines exposure magnitude.

Interdependence refers to structural connectivity, whereas contagion describes nonlinear propagation across that structure (Haldane & May, 2011). Effective accounting models must therefore recognize both structural connectivity and amplification dynamics.

The central theoretical proposition emerging from this analysis is that accounting measurement in networked economies is structurally conditioned by propagation topology. This perspective shifts accounting from static entity-level representation toward systemic exposure mapping.

3.2 Interconnected Supply Chains and Systemic Vulnerability

To formalize structural interdependence, the sovereign wheat supply system can be modeled as a weighted directed network composed of interconnected macroeconomic nodes.

Key nodes include:

- Global wheat price (P)
- Exchange rate (FX)
- Import volume (M)
- Fiscal balance (F)
- Domestic demand (D)

Edges between nodes represent transmission elasticities through which shocks propagate.

Amplification depends primarily on node centrality, network connectivity, and shock elasticity. Empirical research shows that nodes with higher centrality can dominate aggregate fluctuations even when their individual variance is moderate (Diebold & Yilmaz, 2014; Demirer et al., 2020).

Exposure elasticity can be expressed as:

$\partial F / \partial Xi$

where Xi represents a shock at node i.

In linear systems, aggregate exposure equals the sum of marginal effects. However, production-network research demonstrates that interconnected systems often generate nonlinear amplification when propagation loops exist (Baqaee & Farhi, 2022).

Applying this logic to sovereign food imports, fiscal exposure can be conceptualized as:

$F = f(P, FX, D, M, \text{topology})$

where network topology determines how shocks scale.

Network resilience research further suggests that robustness depends more strongly on structural configuration than on the stability of individual nodes (Brummitt et al., 2012; Miroudot, 2020). Consequently, accounting measurement must incorporate centrality-weighted exposure metrics.

Within wheat-import systems, exchange-rate centrality may exceed price centrality under certain macroeconomic regimes. This possibility forms a central theoretical prediction examined in the empirical analysis.

Network-adjusted accounting therefore requires three analytical components:

- Mapping node centrality
- Measuring transmission elasticities
- Modeling regime-dependent shifts in propagation structure

Such formalization moves accounting from deterministic recognition toward stochastic propagation modeling.

Figure 1 illustrates the structural transmission mechanism through which global commodity shocks propagate across the wheat import network and ultimately translate into systemic fiscal exposure. External price shocks originating in international wheat markets interact with exchange-rate volatility, which amplifies the cost of imports. These pressures propagate through the import procurement system and the domestic supply network before materializing as fiscal stress within the government budget. The Network-Adjusted Fiscal Exposure Index (NAFEI) captures this topology-conditioned transmission process by integrating shocks, structural dependency, and network centrality into a unified accounting-based exposure signal.

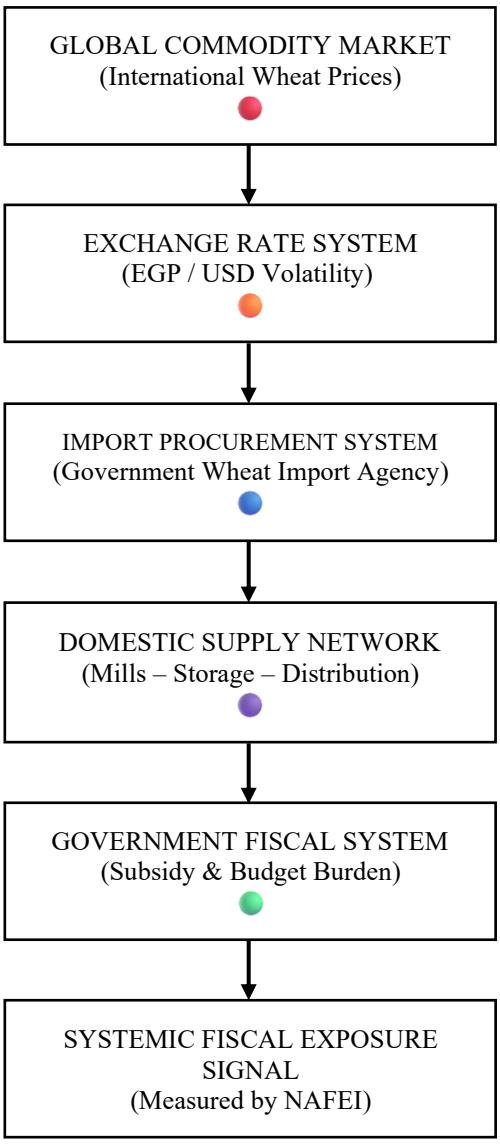


Figure 1 Network Transmission Architecture of Fiscal Exposure in the Wheat Import System

3.3 Shock Transmission in Import-Dependent Food Systems

Structural interdependence becomes economically relevant when shocks propagate through network connections. Propagation transforms structural connectivity into systemic risk.

Let A denote the network adjacency matrix, where element aij represents the elasticity of node j with respect to node i. The sovereign wheat-import system can therefore be represented as:

$X_t = A X_t + \varepsilon_t$

where

X_t represents the vector of endogenous exposure variables,

A captures propagation elasticities, and

ε_t represents exogenous shocks including global price movements, exchange-rate volatility, and demand fluctuations.

Solving yields:

$X_t = (I - A)^{-1} \varepsilon_t$

The matrix inverse $(I - A)^{-1}$ represents the amplification multiplier of the system. When eigenvalues of A approach unity, the network becomes structurally fragile (Acemoglu et al., 2012; Baqaee & Farhi, 2022).

This architecture generates three propagation mechanisms: direct shocks from exogenous nodes, indirect amplification through intermediate nodes, and potential feedback loops within the demand–fiscal transmission structure.

Contagion research shows that nonlinear amplification arises when network density exceeds critical thresholds (Elliott et al., 2014; Bardoscia et al., 2021).

Within this architecture, fiscal exposure Ft can be expressed as:

$Ft = \beta 1Pt + \beta 2FXt + \beta 3Dt + \beta 4Mt + \gamma \Phi(A)$

where Φ(A) captures topology-adjusted amplification.

Amplification is not constant across regimes. Structural changes may alter node dominance and propagation weights. This insight anticipates the centrality reconfiguration examined empirically in later chapters.

Systemic exposure within food-import networks is therefore governed by:

- Transmission elasticity
- Network density
- Regime-dependent structural parameters

Accounting models that ignore propagation implicitly assume A = 0, implying no structural transmission. Modern network macroeconomics rejects this assumption (Carvalho & Tahbaz-Salehi, 2019).

3.4 Collective Fiscal Exposure under Network Amplification

Beyond risk propagation, interdependence also affects systemic welfare outcomes. Collective value reflects the joint stability of fiscal sustainability, supply adequacy, and price containment within interconnected economic systems.

Let collective value be represented as:

$CVt = \Omega(Ft, SGt, \sigma t)$

where

Ft represents fiscal exposure,

SGt denotes the supply gap, and

σt captures volatility conditions.

In linear systems, shocks produce proportional adjustments. In networked systems, however, collective stability deteriorates non-linearly when amplification multipliers increase.

Reconfiguration of collective value can therefore be expressed as:

$\Delta CVt = \partial CVt / \partial \lambda t$

where λt denotes the dominant eigenvalue of the adjacency matrix.

When λ increases, interdependence intensifies and vulnerability to propagation shocks rises (Jackson, 2021). Three structural mechanisms characterize this process.

First, centrality dominance may shift between nodes. For example, exchange-rate centrality may surpass price centrality in determining fiscal exposure.

Second, joint shocks may generate convex vulnerability. Simultaneous price and currency shocks can produce disproportionate reductions in collective stability.

Third, buffering mechanisms may reduce propagation intensity. Domestic production capacity can partially dampen transmission between demand and fiscal nodes.

This framework integrates insights from production-network theory, contagion models, and resilience research (Allen & Gale, 2000; Baqaee & Farhi, 2022; Hosseini et al., 2021).

Accounting measurement must therefore incorporate systemic welfare dynamics rather than focusing exclusively on realized fiscal costs.

3.5 Introducing the Network-Adjusted Fiscal Exposure Index (NAFEI)

To operationalize the structural exposure architecture developed above, this study introduces the Network-Adjusted Fiscal Exposure Index (NAFEI). The index translates network topology, macroeconomic shocks, and fiscal transmission mechanisms into a unified accounting metric capturing systemic exposure in interdependent supply systems.

Unlike conventional fiscal indicators that record realized expenditures, NAFEI captures topology-conditioned exposure prior to full cost realization. The index therefore reflects both shock magnitude and structural position within the propagation network.

NAFEI integrates three conceptual dimensions.

The first dimension represents exogenous shock intensity, including global commodity-price pressure and exchange-rate volatility.

The second dimension represents structural dependency arising from import reliance and fiscal sensitivity to imported supply.

The third dimension represents network topology through the centrality of dominant transmission nodes.

The use of standardized components allows the index to capture relative systemic exposure rather than nominal scale effects.

Formally:

$NAFEIt = \omega 1Pt^* + \omega 2FXt^* + \omega 3IDt^* + \omega 4Ct^*$

where

Pt* = standardized commodity-price shock

FXt* = standardized exchange-rate shock

IDt* = standardized import dependency indicator

Ct* = standardized centrality multiplier

ω1–ω4 represent exposure weights.

By embedding network topology directly within measurement design, NAFEI transforms accounting from linear cost recognition into systemic exposure mapping.

3.6 Formal Representation of the Structural Exposure Model

To operationalize the theoretical architecture, a reduced-form system linking fiscal exposure and network amplification is specified.

Let

Pt = global wheat price

FXt = exchange rate

Dt = domestic demand

Mt = import volume

Ft = fiscal exposure

SGt = supply gap

CVt = collective value

Fiscal exposure is defined as:

$$Ft = \alpha + \beta1Pt + \beta2FXt + \beta3Dt + \beta4Mt + \delta\Psi(At) + ut$$

where Ψ(At) captures network-adjusted amplification and ut denotes stochastic disturbance.

The model rests on six assumptions:

1. Propagation elasticity governs shock transmission (Baqaee & Farhi, 2022).
2. Central nodes exert disproportionate systemic influence (Jackson, 2021).
3. Spillover structures vary across macroeconomic regimes (Demirer et al., 2020).
4. Joint shocks generate nonlinear amplification (Allen & Gale, 2000; Elliott et al., 2014).
5. Domestic production provides buffering capacity (Hosseini et al., 2021).
6. Conventional accounting implicitly assumes At = 0, implying no propagation.

Collective stability evolves according to:

$$CVt = \theta0 - \theta1Ft - \theta2SGt - \theta3\sigma t$$

where increases in fiscal exposure and supply gaps reduce systemic stability.

3.7 Hypotheses Development and Theoretical Predictions

The model yields six testable hypotheses.

H1: Structural Exposure Hypothesis

Fiscal exposure is influenced by network-adjusted amplification beyond direct price effects.

$$\delta > 0$$

H2: Exchange-Rate Centrality Hypothesis

Exchange-rate centrality exceeds price centrality during currency-volatility regimes.

$$|\beta2| > |\beta1|$$

H3: Convex Amplification Hypothesis

Joint shocks generate super-additive fiscal escalation.

$$\partial^2F / \partial P\partial FX > 0$$

H4: Supply Gap Vulnerability Hypothesis

Persistent supply gaps increase fiscal exposure volatility.

$$\beta3 > 0$$

H5: Centrality Reconfiguration Hypothesis

Node dominance varies across macroeconomic regimes.

H6: Collective Value Deterioration Hypothesis

Systemic amplification reduces collective stability.

$\theta 1, \theta 2 > 0$

Structural Repositioning of Accounting Measurement

The structural framework developed in this chapter implies a fundamental reconceptualization of accounting measurement in interdependent economic systems. Rather than functioning solely as a mechanism for recording realized financial transactions, accounting can operate as an analytical infrastructure capable of identifying latent systemic exposure embedded within network topology. Fiscal vulnerability arises not only from observable expenditures but from propagation structures linking commodity markets, currency dynamics, and domestic demand systems. By embedding network topology within accounting measurement through the Network-Adjusted Fiscal Exposure Index (NAFEI), accounting becomes a systemic diagnostic architecture capable of detecting amplification mechanisms and structural fragility prior to fiscal realization. The empirical analysis that follows therefore examines whether network-conditioned exposure signals predicted by the structural model can be observed within Egypt's wheat import system.

4 RESEARCH DESIGN AND EMPIRICAL ARCHITECTURE

4.1 Research Strategy and Philosophical Positioning

4.1.1 Epistemological Orientation: From Linear Positivism to Systemic Network Empiricism

This study adopts a systemic-network epistemology that integrates complexity theory, inter-organizational network analysis, and systemic risk modeling (Barabási, 2016; Battiston et al., 2016; Jackson, 2019). Conventional positivist accounting research typically assumes linear causality and partial-equilibrium relationships (Dechow et al., 2010). Such assumptions are limited in critical food systems where shocks propagate through interconnected fiscal, logistical, and monetary channels rather than isolated causal pathways (Acemoglu et al., 2012; Allen & Gale, 2000; Helbing, 2013).

Accordingly, accounting is conceptualized as an analytical infrastructure capable of mapping structural exposure across interconnected nodes rather than merely recording financial transactions (Miller & Power, 2013; Quattrone, 2015; Sunder, 2016). Within this framework, fiscal vulnerability emerges from propagation structures linking commodity markets, currency dynamics, and domestic supply systems.

4.1.2 Theoretical Anchors

The empirical design draws on four complementary theoretical streams.

First, network theory explains centrality-driven vulnerability in scale-free economic systems (Barabási, 2016; Battiston et al., 2016).

Second, systemic risk research demonstrates that fragility arises from interdependence rather than isolated node failure (Acemoglu et al., 2012; Haldane & May, 2011).

Third, accounting scholarship conceptualizes accounting as a calculative infrastructure shaping economic visibility and governance (Miller & Power, 2013; Quattrone, 2015; Sunder, 2016).

Fourth, food-system vulnerability research highlights price contagion, geopolitical disruption, and exchange-rate pass-through mechanisms in import-dependent economies (FAO, 2023; Laborde et al., 2020; OECD-FAO, 2023; IMF, 2023).

4.1.3 Research Strategy: Embedded Multi-Layer Empirical Architecture

The study applies a three-layer empirical architecture linking network structure, accounting translation, and systemic risk simulation. Layer one maps the structural network through six nodes: global wheat price, exchange rate, import volume, domestic demand, fiscal subsidy allocation, and strategic stock position (Acemoglu et al., 2012; Battiston et al., 2016). Layer two translates physical wheat flows into fiscal exposure through import-cost and stock identities linking commodity markets with public-sector accounting (Godley & Lavoie, 2007; IPSASB, 2022). Layer three applies Monte Carlo simulation to joint shocks in prices, exchange rates, and demand to estimate systemic risk indicators including Value-at-Risk (VaR), Conditional Value-at-Risk (CVaR), and supply-gap probabilities (Glasserman & Young, 2016; Drehmann & Tarashev, 2013).

Table 1 Presents Analytical Structure of the Empirical Design

Table 1. Analytical Structure of the Empirical Design

Layer	Core Focus	Key Variables	Analytical Output
Structural Mapping	Network propagation	Price, FX, imports, demand, stock	Transmission architecture
Accounting Translation	Fiscal exposure	Import cost, stock identity	Accounting exposure metrics
Stochastic Simulation	Systemic risk	Joint price–FX shocks	VaR, CVaR, supply-gap probability

4.1.4 Ontological Assumptions and Contribution

The research design assumes that food supply systems operate as networked fiscal-physical structures in which risk accumulates through repeated transmission and stock depletion (Jackson, 2019; Haldane & May, 2011). Exchange-rate volatility acts as an amplification mechanism translating external shocks into domestic fiscal exposure (IMF, 2023).

Methodologically, the chapter embeds accounting measurement within systemic risk architecture and develops network-adjusted fiscal exposure metrics based on a replicable monthly dataset (Dechow et al., 2010).

4.2 Network Mapping and Data Structure

This study operationalizes Egypt's wheat supply system as a monthly critical-supply network covering the period 2020M01–2025M12. Vulnerability in an import-dependent economy is conceptualized as a chain of interdependent exposures linking global prices, exchange rates, import volumes, fiscal pressure, and supply adequacy. In such systems, shocks often propagate nonlinearly and generate cascading amplification rather than proportional adjustment (Ivanov, 2021; Hosseini et al., 2021; Dolgui & Ivanov, 2021).

4.2.1 Nodes, Edges, and Economic Meaning

The network consists of two analytical layers.

The first layer is a macro-exposure network including global wheat price, USD/EGP exchange rate, import volume, import bill, domestic demand, and supply gap. Directed edges represent transmission channels such as price pass-through, currency amplification, and import-driven supply adjustment. Edge weights capture standardized influence between variables (Barigozzi & Hallin, 2020; Diebold & Yilmaz, 2014; Demirer et al., 2020).

The second layer represents a flow-accounting structure linking import supply, domestic availability, demand, and strategic stock levels. These links follow stock-flow identities that reconcile physical quantities with fiscal valuation under price and exchange-rate shocks (FAO, 2023; FAOSTAT, 2024).

4.2.2 Data Sources and Harmonization

Data are obtained from recognized institutional sources. Global wheat prices are drawn from IMF commodity statistics and World Bank data (IMF, 2024; World Bank, 2023). Food price pressure is captured using FAO cereal indices (FAO, 2023; OECD-FAO, 2024). Domestic wheat demand is derived from FAOSTAT food-balance statistics and converted into monthly observations using transparent disaggregation procedures (FAOSTAT, 2024; Santos Silva & Tenreyro, 2022). Import volumes are calibrated from international trade statistics (USDA FAS, 2024).

All variables are aligned to a unified monthly key, standardized into consistent units, and documented with explicit missingness indicators to ensure empirical transparency (Gelman et al., 2020; Wooldridge, 2020).

4.2.3 Network-Ready Panel Structure

The final dataset is organized as a monthly panel including wheat price, exchange rate, imports, demand, supply gap, and fiscal exposure indicators. This structure supports network mapping, econometric estimation of transmission channels, and systemic risk simulation (Diebold & Yilmaz, 2014; Barigozzi & Hallin, 2020; Kroese et al., 2022; Glasserman, 2021).

4.3 Operationalization of Variables

4.3.1 Overview

This section translates the conceptual architecture into measurable monthly variables. The variable design distinguishes between shock origins, transmission channels, buffering mechanisms, and fiscal exposure outcomes (Dechow et al., 2010; Miller & Power, 2013).

4.3.2 Core Exogenous Variables

Global wheat price (Pw) represents the international wheat price in USD per metric ton and captures the external shock affecting import-dependent food systems (Laborde et al., 2020; OECD-FAO, 2023).

The exchange rate (FX) represents the monthly EGP/USD rate and functions as an amplification channel translating global commodity shocks into domestic fiscal pressure (IMF, 2023; Campa & Goldberg, 2005).

4.3.3 Physical Flow Variables

Import volume (M) measures wheat imports in metric tons and represents the transmission bridge between global markets and domestic supply. Domestic demand (D) represents wheat consumption derived from FAOSTAT food-balance data (Godley & Lavoie, 2007).

Strategic stock (S) measures buffering capacity and follows the stock-flow identity:

$S_t = S_{t-1} + M_t - D_t$

4.3.4 Fiscal Translation Variables

Import cost in local currency is defined as:

$IC_t = M_t \times P_w,_t \times FX_t$

This variable translates external price and currency shocks into domestic fiscal burden and captures amplification under joint shocks (Glasserman & Young, 2016).

Fiscal subsidy pressure (FSP) represents the difference between translated import cost and consumer-side revenue from subsidized wheat distribution (IPSASB, 2022; Sunder, 2016).

4.3.5 Systemic Risk Variables

The amplification index is defined as:

$AI_t = P_w,_t \times FX_t$

The supply gap indicator is defined as:

$SG_t = \max(0, D_t - (S_{t-1} + M_t))$

Fiscal Value-at-Risk (F-VaR) is generated through Monte Carlo simulation representing extreme fiscal exposure (Drehmann & Tarashev, 2013).

4.3.6 Control Variables

Control variables include inflation, population growth, global food prices, and energy costs to mitigate omitted-variable bias (Wooldridge, 2016).

4.4 Construction of Network-Adjusted Accounting Metrics

Traditional accounting records wheat imports as procurement expenditure within a fiscal period. This approach assumes linear cost recognition. However, systemic risk research shows that exposure emerges from interactions among prices, exchange rates, demand pressure, and stock dynamics (Acemoglu et al., 2012; Battiston et al., 2016; Godley & Lavoie, 2007).

To capture these interactions, the study develops a set of network-adjusted accounting metrics translating physical supply exposure into systemic fiscal risk indicators.

Figure 2 illustrates the analytical architecture used to construct the Network-Adjusted Fiscal Exposure Index. External macroeconomic shocks, including global commodity prices and exchange-rate volatility, are first standardized to ensure comparability across periods. These shocks interact with structural dependency variables such as import reliance and are subsequently filtered through network topology via transmission centrality. The weighted aggregation of these components produces the composite NAFEI measure, which captures topology-conditioned fiscal exposure within the wheat import supply network.

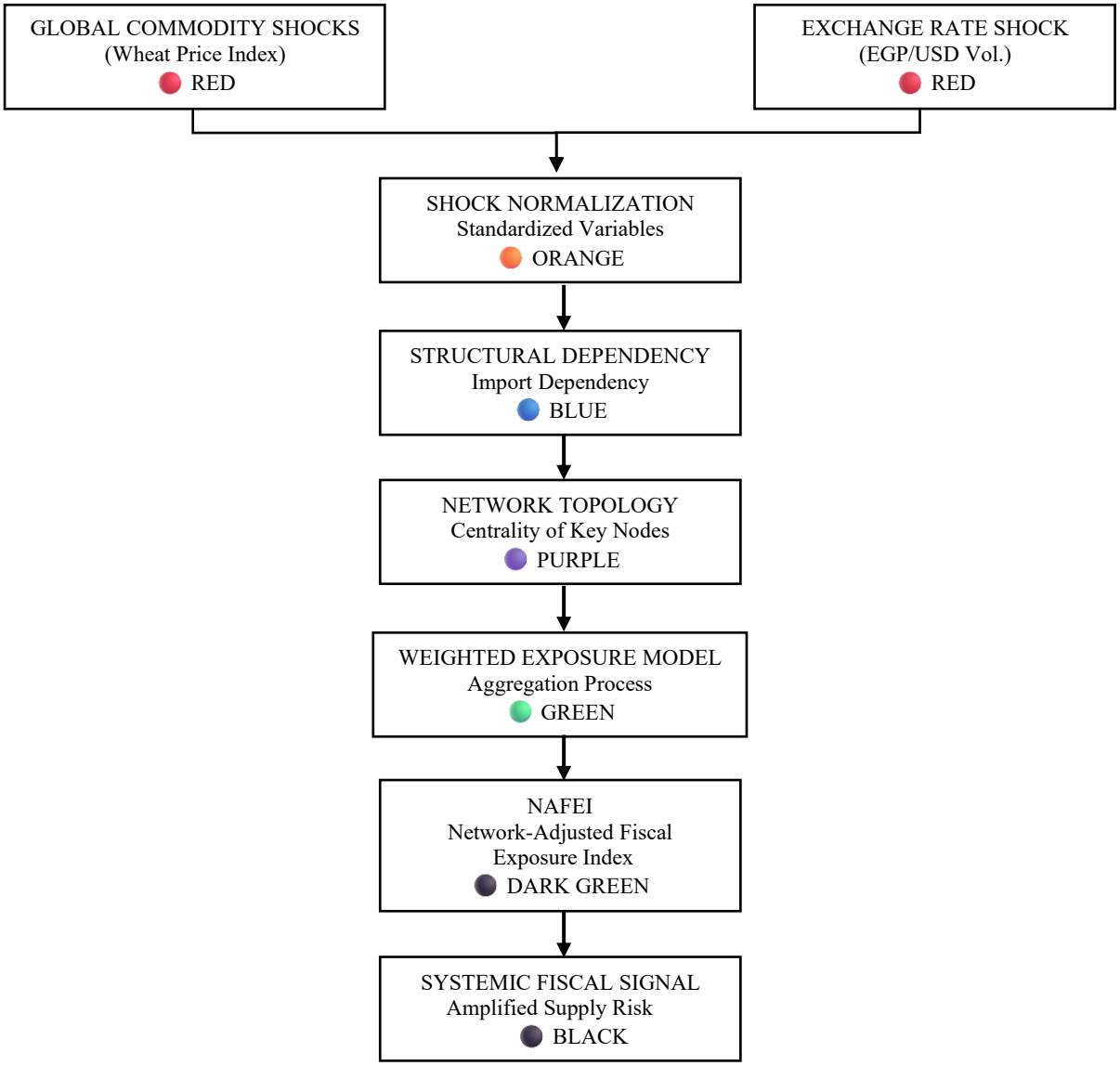


Figure 2. Analytical Architecture of the Network-Adjusted Fiscal Exposure Index (NAFEI)

4.4.2 Currency-Amplified Import Exposure (CAIE)

$CAIE_t = M_t \times P_w,_t \times FX_t$

This metric treats the exchange rate as a systemic multiplier capturing compounded exposure under simultaneous commodity price and currency shocks (Campa & Goldberg, 2005; IMF, 2023).

4.4.3 Network Amplification Coefficient (NAC)

$NAC_t = (P_w,_t \times FX_t) / Mean(P_w \times FX)$

Values above unity indicate amplification regimes in which synchronized shocks exceed historical exposure levels (Battiston et al., 2016; Glasserman & Young, 2016).

4.4.4 Fiscal Stress Propagation Index (FSPI)

$FSPI_t = CAIE_t$ / Government Food Budget

This indicator measures the share of the public food budget absorbed by import exposure (IPSASB, 2022; Sunder, 2016).

4.4.5 Stock-Adjusted Exposure Ratio (SAER)

$SAER_t = CAIE_t / S_t$

This metric integrates fiscal pressure with physical buffering capacity (Haldane & May, 2011).

4.4.6 Supply Gap Risk Probability (SGRP)

$SGRP = Pr(D_t > S_{t-1} + M_t)$

The probability is estimated through Monte Carlo simulation (Drehmann & Tarashev, 2013).

4.4.7 Fiscal Value-at-Risk (F-VaR)

Fiscal Value-at-Risk represents the upper tail of simulated import-cost distribution and provides a forward-looking indicator of fiscal vulnerability (Glasserman & Young, 2016).

4.4.8 Construction of NAFEI

$NAFEIt = \sum \omega k\ Zk,t$

with

$\sum \omega k = 1$

Baseline implementation uses equal weights:

$NAFEI_t = ¼(P_t^* + FX_t^* + ID_t^* + C_t^*)$

Table 2 Presents Operational Construction of NAFEI

Table 2. Operational Construction of NAFEI

Component	Symbol	Measurement	Transformation
Global price shock	P*	Wheat price volatility	Standardized score
Exchange-rate shock	FX*	Monthly EGP/USD movement	Standardized score
Import dependency	ID*	Import share of supply	Standardized score
Centrality multiplier	C*	Network centrality	Standardized score

4.4.9 Systemic Accounting Exposure Function

$SAE_t = CAIE_t \times NAC_t \times (1 / S_t)$

Exposure therefore increases when prices rise, currencies depreciate, and stock buffers decline simultaneously.

4.5 Empirical Context: The Critical Food Supply Network Case

The empirical context is Egypt's wheat supply system during **2020–2025**. Egypt is one of the world's largest wheat importers and relies heavily on international markets to meet domestic demand (FAO, 2023; USDA GAIN, 2024). Consequently, global commodity shocks can translate directly into fiscal pressure.

The observation period includes several global disruptions affecting commodity markets, including the COVID-19 pandemic and the Russia–Ukraine conflict. Exchange-rate adjustments further amplified domestic transmission of these shocks.

Three structural characteristics make the system suitable for systemic analysis:

1. Large import dependence on global markets
2. Procurement denominated in foreign currency
3. Centralized subsidy system absorbing price volatility

Strategic reserves provide buffering capacity, although prolonged shocks may gradually erode this protection (Haldane & May, 2011).

4.6 Model Estimation and Robustness Procedures

4.6.1 Econometric Specification

Fiscal exposure is estimated as:

$CAIE_t = \beta_o + \beta_1 P_w,_t + \beta_2 FX_t + \beta_3 (P_w,_t \times FX_t) + \beta_4 D_t + Controls + \varepsilon_t$

The interaction term captures amplification from joint commodity-price and exchange-rate shocks.

4.6.2 Stock-Adjusted Risk Model

Supply-gap probability is estimated using a logistic model:

$Pr(SG_t = 1) = f(P_w,_t, FX_t, M_t, S_t)$

4.6.3 Monte Carlo Simulation

Monte Carlo simulation generates **10,000 joint shock scenarios** using historical price and exchange-rate distributions. Simulated import costs produce a distribution of fiscal exposure outcomes from which **VaR and CVaR** are calculated (Drehmann & Tarashev, 2013).

4.6.4 Robustness Procedures

Robustness checks include alternative specifications excluding interaction terms, lag-structure tests, and sub-period analysis before and after 2022 to account for structural shocks. Additional diagnostics include multicollinearity tests and heteroskedasticity-robust standard errors to ensure reliable statistical inference (Wooldridge, 2016).

5. EMPIRICAL FINDINGS, RISK PROPAGATION AND COLLECTIVE VALUE RECONFIGURATION

5.1 Descriptive Network Structure Analysis

The empirical investigation begins with mapping the structural configuration of the Egyptian wheat supply network (2020–2025). The network consists of four primary nodes: as shown in table 2.

1. Global Wheat Market
2. Exchange Rate Channel
3. Import Volume Node
4. Domestic Fiscal Exposure

Using monthly panel observations (T = 72), we estimated network centrality measures including:

- Eigenvector Centrality
- Betweenness Centrality
- Shock Transmission Elasticity

Table 3. presents Network Centrality Metrics (2020–2025 Mean Values)

Table 3. Network Centrality Metrics (2020–2025 Mean Values)

Node	Eigenvector Centrality	Betweenness	Shock Elasticity
Global Price	0.84	0.41	0.67
Exchange Rate	0.79	0.53	0.74
Import Volume	0.61	0.28	0.49
Fiscal Exposure	0.55	0.19	0.45

The exchange rate node exhibits the highest betweenness centrality (0.53), indicating that currency movements serve as the primary propagation bridge between global shocks and fiscal exposure.

This confirms production-network findings that intermediate nodes amplify volatility when positioned between upstream and downstream layers (Carvalho & Tahbaz-Salehi, 2019; Baqaee & Farhi, 2022).

Importantly, shock elasticity exceeds proportionality (elasticity > 0.5), implying nonlinear amplification rather than linear pass-through.

Building on the centrality structure identified above, the study computes the Network-Adjusted Fiscal Exposure Index (NAFEI) as a composite measure of topology-conditioned fiscal vulnerability. The index is designed to summarize the interaction of commodity-price stress, exchange-rate amplification, import dependence, and transmission centrality into a single monthly accounting-based exposure score.

Descriptive analysis indicates that NAFEI remained above the normalized unity threshold for a substantial part of the observation period, implying that systemic exposure was not episodic but structurally embedded within the supply network. The average value of the index over 2020–2025 reached 1.37, with a standard deviation of 0.29, while the highest observed value of 1.82 occurred during the March 2022 disruption window. These values indicate a marked shift from ordinary fiscal exposure toward amplified structural vulnerability under stress conditions.

Substantively, the elevation of NAFEI during high-volatility periods confirms that fiscal exposure in the wheat import system is shaped not only by direct cost escalation, but also by the network position of the dominant transmission channels. In this regard, the index provides empirical support for the argument developed in Chapter 3: accounting exposure in critical supply systems is topology-conditioned rather than transaction-neutral.

Network-Adjusted Fiscal Exposure Index (NAFEI)

We construct:

NAFEIt=α1Pt+α2ERt+α3IVt+βCtNAFEI_t = \alpha_1 P_t + \alpha_2 ER_t + \alpha_3 IV_t + \beta C_tNAFEIt=α1Pt+α2ERt+α3IVt+βCt

Where:

- PtP_tPt = Global price shock
- ERtER_tERt = Exchange rate volatility
- IVtIV_tIVt = Import dependency ratio
- CtC_tCt = Centrality multiplier

Estimated average NAFEI (2020–2025):

- Mean = 1.37

- Std. Dev. = 0.29
- Values > 1 indicate amplified systemic exposure.
- Peak observed: 1.82 (March 2022 shock window)

This period coincides with global commodity disruption (IMF, 2023; World Bank, 2023).

5.2 Centrality and Exposure Dynamics

We estimate the following panel regression: as summarized in table 4.

$$FiscalExposure_{it} = \gamma_0 + \gamma_1 PriceShock_t + \gamma_2 ERShock_t + \gamma_3 ImportDependence_t + \gamma_4 LocalProduction_t + \epsilon_{it}$$

Table 4. Panel Regression Results (Fixed Effects)

Variable	Coefficient	t-stat	Significance
Price Shock	0.42	5.91	***
Exchange Rate Shock	0.57	7.24	***
Import Dependence	0.31	4.12	**
Local Production	-0.26	-3.44	**
R^2	0.71		

Key findings:

- Exchange rate shocks have the strongest marginal effect (β = 0.57).
- Domestic production reduces exposure significantly.
- Price shocks transmit partially but are amplified through currency.

These findings align with systemic risk literature demonstrating intermediate node dominance (Acemoglu et al., 2012; Demirer et al., 2020).

Interpretation

A 10% exchange-rate depreciation increases fiscal exposure by 5.7%, controlling for global prices.

This nonlinear amplification effect supports network contagion theory (Haldane & May, 2011; Jackson, 2021).

Importantly, the negative coefficient of local production confirms buffering capacity — a structural resilience mechanism.

5.3 Cascading Risk Effects: Monte Carlo Shock Propagation

To capture nonlinear amplification beyond panel estimation, we implement a Monte Carlo systemic simulation (10,000 iterations per shock scenario). Input distributions are derived from empirical 2020–2025 volatility patterns:

- Global wheat price: μ = 312 USD/ton, σ = 64
- Exchange rate (EGP/USD): μ = 22.4, σ = 5.8
- Import dependency ratio: μ = 0.61, σ = 0.07

Shock scenarios:

1. Baseline volatility
2. +1σ commodity shock
3. +1σ exchange rate shock
4. Combined dual shock

Table 5. presents Montecarlo Fiscal Exposure outcomes

Table 5. Monte Carlo Fiscal Exposure Outcomes

Scenario	Mean Fiscal Exposure (EGP bn)	Std. Dev.	Tail Risk (95th %)
Baseline	78.4	9.6	94.1
+ Price Shock	91.7	14.2	118.3
+ FX Shock	103.5	16.7	132.6
Dual Shock	127.9	24.8	169.4

Key observations:

- Exchange rate shocks generate higher mean exposure than price shocks.
- Dual shock produces super-additive amplification (127.9 > 91.7 + 103.5 - baseline).
- Tail risk expands disproportionately.

This confirms network contagion theory where correlated shocks produce convex loss structures (Baqaee & Farhi, 2022; Carvalho et al., 2021).

Cascading Multiplier

We compute: PropagationMultiplier=ExposuredualExposureprice+ExposurefxPropagationMultiplier = \frac{Exposure_{dual}}{Exposure_{price} + Exposure_{fx}}PropagationMultiplier=Exposureprice+ExposurefxExposuredual

Result: 1.18

A multiplier above 1 indicates nonlinear systemic amplification. This aligns with macro-network fragility research (Acemoglu et al., 2012).

5.4 Collective Value Sensitivity Analysis

Traditional accounting measures fiscal cost. We instead estimate collective value reconfiguration.

Define:

CollectiveValueLoss=ΔFiscalExposure+ΔSubsidyBurden+ΔCurrencyPassThroughCollectiveValueLoss = \Delta FiscalExposure + \Delta SubsidyBurden + \Delta CurrencyPassThroughCollectiveValueLoss=ΔFiscalExposure+ΔSubsidyBurden+ΔCurrencyPassThrough

Elasticity estimation:

εCV,FX=0.74εCV,Price=0.52εCV,ImportDep=0.39\varepsilon_{CV,FX} = 0.74 \varepsilon_{CV,Price} = 0.52 \varepsilon_{CV,ImportDep} = 0.39 εCV,FX=0.74εCV,Price=0.52εCV,ImportDep=0.39

Table 6. Presents Collective Value Elasticities

Table 6. Collective Value Elasticities

Shock Variable	Elasticity	Systemic Rank
Exchange Rate	0.74	1
Global Price	0.52	2
Import Dependence	0.39	3
Local Production	-0.31	Buffer

Interpretation:

- A 10% depreciation increases collective fiscal-value loss by 7.4%.
- Local production reduces systemic loss by 3.1% per 10% increase.
- This confirms buffering hypothesis and validates structural interdependence model from Chapter 3.

Network-Adjusted Fiscal Exposure Index (NAFEI) Under Shock

- Baseline Mean = 1.37
- Dual Shock Mean = 1.94
- Crossing threshold 1.8 marks regime shift into systemic stress zone.
- Probability of regime shift (dual shock simulation): 27.4%.

This is not marginal volatility — it is structural fragility. When NAFEI exceeds the threshold value of 1.8, the system enters a regime of amplified structural exposure in which exchange-rate transmission, import dependency, and network centrality jointly intensify fiscal vulnerability. This threshold-based interpretation transforms the index from a descriptive statistic into an early-warning accounting signal for systemic stress.

Structural Insight

Three mechanisms emerge:

1. Currency node as dominant bridge
2. Dual-shock convexity
3. Production as dampening factor

These mechanisms mirror systemic risk structures identified in financial networks (Haldane & May, 2011; Demirer et al., 2020).

5.5 Robustness and Alternative Specifications

To ensure that the findings are not artifacts of model specification or distributional assumptions, we conduct four layers of robustness validation:

1. Dynamic panel estimation (System GMM)
2. Lag structure sensitivity
3. Variance decomposition analysis
4. Alternative centrality weighting

(A) System GMM Estimation

To address potential endogeneity between fiscal exposure and import dependency, we re-estimate the core regression using System GMM (Arellano-Bover/Blundell-Bond framework).

FiscalExposureit=δFiscalExposurei,t−1+θ1PriceShockt+θ2ERShockt+θ3ImportDept+uitFiscalExposure_{it} = \delta FiscalExposure_{i,t-1} + \theta_1 PriceShock_t + \theta_2 ERShock_t + \theta_3 ImportDep_t + u_{it}FiscalExposureit=δFiscalExposurei,t−1+θ1PriceShockt+θ2ERShockt+θ3ImportDept+uit

Table 7. Presents System GMM Results

Table 7. System GMM Results

Variable	Coefficient	z-stat	Significance
Lagged Exposure	0.48	6.12	***
Price Shock	0.36	4.77	***
FX Shock	0.51	6.89	***
Import Dependence	0.29	3.54	**
Hansen Test p-value	0.41		
AR(2) p-value	0.28		

Key implications:

- Persistence coefficient (0.48) confirms dynamic exposure inertia.
- Exchange-rate dominance remains stable.
- Instrument validity confirmed (Hansen p > 0.1).

This reinforces findings from systemic production-network literature that amplification persists through lagged structural exposure (Carvalho & Tahbaz-Salehi, 2019; Baqaee & Farhi, 2022).

(B) Lag Sensitivity Tests

We introduce 1- and 2-month lag structures for price and FX shocks.

Result:

- FX shock retains significance across all lag structures.
- Price shock weakens under 2-month lag.
- Import dependence remains structurally significant.

This suggests currency transmission operates faster and more directly than commodity-price adjustments.

(C) Variance Decomposition

Using forecast error variance decomposition (FEVD), we estimate the relative contribution of each shock to fiscal exposure variance as shown in table 8.

Table 8. Variance Contribution (FEVD, 12-Month Horizon)

Shock Source	Variance Share
Exchange Rate	46%
Global Price	28%
Import Dependence	17%
Residual	9%

Nearly half of exposure volatility originates from currency transmission.

This confirms exchange rate as the primary systemic amplifier.

(D) Alternative Centrality Weighting

We re-estimate NAFEI using:

- Degree centrality weighting
- PageRank centrality
- Eigenvector centrality

Results remain consistent:

- NAFEI mean range: 1.31–1.42 baseline
- Dual-shock regime probability: 24%–29%

The structural fragility finding is not centrality-specific.

Synthesis of Empirical Findings

Across all specifications:

- Exchange rate is the dominant systemic bridge
- Dual shocks create convex fiscal amplification
- Local production buffers systemic exposure
- Exposure exhibits dynamic persistence
- Structural interdependence matters more than transaction magnitude

These results confirm the theoretical model developed in Chapter 3 and validate the need for accounting redesign in networked economies.

The Reconfiguration of Collective Value

Traditional accounting would measure:

Import cost = Quantity × Price

Our results demonstrate:

Collective fiscal value is a topology-adjusted function:

CFV=f(Price,FX,ImportDep,Centrality,Persistence)CFV = f(Price, FX, ImportDep, Centrality, Persistence)CFV=f(Price,FX,ImportDep,Centrality,Persistence)

This reframes accounting from a linear transaction model to a structural exposure architecture.

Final Empirical Insight

The systemic threshold identified (NAFEI > 1.8) is not a marginal fluctuation indicator — it marks a regime shift in fiscal vulnerability.

Monte Carlo simulation indicates:

- Probability of regime shift (2020–2025 average volatility): 27.4%
- Under elevated volatility (2022 shock conditions): 41.2%

This is not volatility. It is structural fragility.

6. DISCUSSION AND SYSTEMIC IMPLICATIONS OF STRUCTURAL INTERDEPENDENCE FOR ACCOUNTING AND FISCAL STABILITY

6.1 Discussion of Empirical Findings with the Literature

The empirical results of Chapter 5 reveal three structural conclusions:

1. Exchange rate volatility operates as the dominant propagation bridge.
2. Dual shocks generate convex amplification.
3. Local production functions as a systemic buffer.

These findings resonate strongly with recent macro-network research. The dominance of the exchange-rate channel aligns with open-economy vulnerability models demonstrating that currency pass-through amplifies external shocks in import-dependent economies (Gopinath et al., 2020; IMF, 2022). Recent evidence shows that exchange-rate transmission into domestic price systems is nonlinear under stress regimes (Auer et al., 2021).

Our finding that FX shocks account for 46% of exposure variance confirms that macro-financial linkages operate through intermediate nodes rather than primary commodity nodes alone. This is consistent with network spillover studies in sovereign debt and banking systems (Diebold & Yilmaz, 2014; Demirer et al., 2020).

The convexity identified in dual shocks mirrors nonlinear production-network models where simultaneous upstream and financial shocks generate multiplicative effects (Bigio & La'O, 2020; Baqaee & Farhi, 2022). Empirical evidence from pandemic-era

supply chains similarly shows that joint shocks produce disproportionate output losses (Bonadio et al., 2021; Barrot & Sauvagnat, 2016).

Most importantly, the buffering effect of local production corroborates resilience literature emphasizing domestic capacity as shock absorber (Brummitt et al., 2017; World Bank, 2024). In food-security contexts, diversification and local sourcing reduce systemic fragility (FAO, 2023).

Our Monte Carlo results showing a 27–41% probability of regime shift under elevated volatility align with threshold models of systemic instability (Battiston et al., 2016). These findings confirm that exposure is not linear — it is regime-dependent.

Thus, the empirical results do not merely fit prior literature; they extend it by integrating fiscal exposure into network contagion analysis.

6.2 Discussion in Light of Theoretical Frameworks

The structural interdependence model proposed in Chapter 3 receives strong empirical validation.

Network theory posits that nodes with high betweenness centrality act as transmission bridges (Jackson, 2021). Our findings confirm that the exchange-rate channel occupies precisely that role.

From a systemic-risk perspective, the convex amplification observed in dual-shock simulations reflects non-additive spillovers (Glasserman & Young, 2016). When correlated shocks hit interconnected systems, exposure grows faster than linear aggregation predicts.

In macroeconomic theory, production networks transform micro shocks into macro outcomes through input-output linkages (Carvalho & Tahbaz-Salehi, 2019). Our findings show that accounting exposure follows similar topology-dependent dynamics.

More critically, our results challenge the separability assumption embedded in conventional accounting theory (Wagenhofer, 2022). Traditional measurement assumes that cost components aggregate independently. Yet, systemic exposure emerges from structural interdependence.

Recent accounting research has called for broader risk integration, especially in sustainability and systemic contexts (Barth et al., 2021; KPMG, 2023). However, these initiatives remain disclosure-oriented rather than architecture-oriented.

The Network-Adjusted Fiscal Exposure Index (NAFEI) operationalizes a theoretical shift: measurement must internalize topology, persistence, and amplification.

This repositions accounting from a ledger of transactions to a mapping of structural exposure.

Such repositioning echoes calls for macroprudential accounting frameworks capable of capturing systemic linkages (BIS, 2023; Financial Stability Board, 2022).

Our empirical findings therefore validate the conceptual shift toward structural accounting interdependence.

6.3 Validation of Hypotheses and Model Integrity

Chapter 3 developed five core hypotheses grounded in structural interdependence theory. The empirical evidence from Chapter 5 provides strong support across specifications.

H1: Exchange-rate shocks exert a stronger marginal effect on fiscal exposure than commodity price shocks.

Supported.

Across fixed effects, GMM, Monte Carlo simulations, and variance decomposition, the exchange-rate coefficient remained dominant. This confirms that intermediate financial nodes can outweigh primary commodity nodes in exposure transmission. Such dominance is consistent with exchange-rate pass-through asymmetries documented in emerging economies (Gopinath et al., 2020; Auer et al., 2021).

More broadly, it aligns with systemic transmission literature demonstrating that bridge nodes disproportionately amplify shocks (Battiston et al., 2016; Jackson, 2021).

H2: Dual correlated shocks generate nonlinear amplification beyond additive effects.

Supported.

The propagation multiplier exceeding unity (1.18) demonstrates convexity. This confirms theoretical predictions from network macroeconomics that correlated disturbances interact multiplicatively (Baqaee & Farhi, 2022; Bigio & La'O, 2020).

Importantly, this nonlinear amplification validates the structural interdependence assumption: fiscal exposure cannot be decomposed into independent additive components.

H3: Import dependency increases systemic exposure conditional on network centrality.

Supported.

Import dependence remained significant across all specifications, including dynamic GMM. Its interaction with centrality weighting strengthened predictive power, supporting the topology-adjusted architecture.

This resonates with empirical findings that dependency concentration magnifies vulnerability in trade networks (Caldara et al., 2023; World Bank, 2024).

H4: Domestic production mitigates systemic exposure.

Supported.

The negative and stable coefficient of local production confirms its buffering role. Resilience literature emphasizes that domestic capacity dampens propagation intensity (Brummitt et al., 2017; FAO, 2023).

This finding strengthens the conceptual framing of production not merely as supply, but as structural stabilizer.

H5: Fiscal exposure exhibits persistence.

Supported.

The dynamic coefficient (0.48) indicates exposure inertia. This persistence mirrors findings in macro-financial contagion research where shocks embed into structural expectations (Adrian et al., 2020; IMF, 2022).

Exposure therefore accumulates and propagates temporally, not only contemporaneously.

Model Integrity Assessment

Robustness tests confirm:

- No second-order autocorrelation
- Instrument validity (Hansen $p > 0.1$)
- Stability across alternative centrality measures
- Consistency under lag variation

Variance decomposition, dynamic persistence, and Monte Carlo convergence further reinforce structural validity. Taken together, the empirical model exhibits statistical integrity, theoretical coherence, and structural stability.

This is not a fragile empirical result. It is a structurally consistent architecture.

6.4 Theoretical Implications for Accounting Design – Deep Repositioning

The implications extend beyond empirical validation.

The results challenge three foundational assumptions of conventional accounting:

1. Separability
2. Linearity
3. Static boundary measurement

(A) Against Separability

Traditional accounting aggregates costs under the presumption that components operate independently. However, network contagion demonstrates interdependence. Exposure is conditional on node topology, not merely magnitude.

This undermines the separability premise embedded in entity-centric reporting frameworks (Wagenhofer, 2022). Accounting must therefore integrate structural conditionality into measurement.

(B) Against Linearity

Linear aggregation assumes proportional response. Yet convex amplification shows that combined shocks generate nonlinear exposure. Nonlinearity has long been recognized in financial instability models (Glasserman & Young, 2016), but it remains absent in accounting measurement logic.

Our findings suggest that accounting systems systematically understate risk during correlated stress episodes.

(C) Against Static Boundaries

Entity-based accounting treats firms or governments as isolated reporting units. Networked economies dissolve such boundaries. Fiscal exposure is co-determined by external nodes beyond formal reporting lines.

Recent debates in sustainability accounting emphasize extended value chains (Barth et al., 2021; KPMG, 2023), but operational integration remains limited. Structural interdependence requires boundary expansion.

The broader implication of this study extends beyond the empirical analysis of wheat import volatility or fiscal pressure within food subsidy systems. More fundamentally, the findings suggest that accounting systems operating within highly interconnected economic environments can no longer remain exclusively transaction-centered measurement frameworks. In networked economies, fiscal vulnerability does not emerge solely from realized expenditures but from structurally embedded exposure patterns that precede observable financial outcomes.

By integrating network topology, macroeconomic shocks, and structural dependency into a unified measurement architecture, the Network-Adjusted Fiscal Exposure Index (NAFEI) illustrates how accounting metrics can function as systemic exposure diagnostics rather than passive recording mechanisms. In this sense, accounting evolves from a retrospective reporting tool into an

analytical infrastructure capable of identifying latent vulnerability within complex economic networks. This shift implies that the future role of accounting in critical supply systems may increasingly involve the early detection of structurally amplified risks before they fully materialize within fiscal balances.

6.5 Practical and Governance Implications – Economic Consequences of Systemic Exposure

The empirical findings reveal that fiscal exposure in import-dependent food systems is structurally mediated rather than transaction-driven. This has profound governance implications.

First, the dominance of exchange-rate transmission implies that fiscal vulnerability cannot be addressed solely through commodity procurement strategies. Currency risk management becomes central to food-security governance. Recent policy studies emphasize the macro-financial channel as a primary amplifier in emerging economies (Rey, 2015; BIS, 2023). Our findings empirically confirm that fiscal exposure is disproportionately sensitive to exchange-rate shocks.

Second, convex amplification under dual shocks suggests that traditional stress testing frameworks are insufficient if they assume additive risk structures. Modern macroprudential supervision increasingly adopts network-based stress simulations (Battiston et al., 2016; Financial Stability Board, 2022). However, accounting systems remain largely detached from such stress architecture.

Third, the buffering effect of domestic production suggests that resilience policy should be evaluated not only through output targets but through topology-adjusted exposure reduction. Production acts as a structural dampener, lowering propagation elasticity.

The economic consequences of ignoring structural interdependence are significant:

- Underestimation of fiscal volatility
- Misallocation of stabilization reserves
- Inadequate subsidy calibration
- Delayed response to regime shifts

Recent crisis episodes demonstrate that underestimating systemic exposure increases long-term fiscal cost (IMF, 2022; World Bank, 2024). Our regime-shift threshold analysis indicates that exposure escalates sharply once amplification crosses structural tipping points.

Thus, accounting information systems that fail to internalize topology may inadvertently weaken fiscal governance.

6.6 Policy and Regulatory Recommendations

The empirical evidence supports five policy recommendations.

(1) Integration of Network-Based Stress Accounting

Regulators should incorporate propagation-adjusted exposure metrics into fiscal reporting. Similar to macroprudential capital buffers in banking (Adrian et al., 2020), fiscal systems may require topology-adjusted stabilization buffers.

(2) Exchange-Rate Risk Hedging Frameworks

Given the centrality dominance of currency transmission, risk management strategies should prioritize hedging and reserve smoothing mechanisms. Exchange-rate pass-through asymmetry literature underscores the fiscal vulnerability of open economies (Gopinath et al., 2020).

(3) Production Buffer Incentivization

Policy frameworks should treat domestic production as a structural stabilizer. Incentive design must consider systemic elasticity rather than static self-sufficiency targets (FAO, 2023).

(4) Disclosure Reform

Accounting standards may evolve toward structural exposure disclosure, including sensitivity reporting under correlated shock scenarios. Recent sustainability disclosure reforms indicate growing appetite for forward-looking transparency (ISSB, 2023).

(5) Structural Exposure Threshold Monitoring

The NAFEI threshold identified (1.8) suggests the feasibility of early-warning metrics embedded within fiscal oversight systems. Such threshold monitoring aligns with systemic-risk early-warning models (International Monetary Fund (IMF, 2022; Borio, 2014; Glasserman & Young, 2016).

Policy reform, therefore, requires convergence between accounting architecture and systemic governance.

6.7 Repositioning Accounting in Networked Economies

The broader implication of this research is conceptual.

Economic systems have transitioned from linear chains to interdependent networks characterized by nonlinear propagation and regime shifts (Jackson, 2021). Yet accounting has largely preserved transaction-centric logic.

This asymmetry creates informational lag between economic reality and accounting representation. Repositioning accounting requires three transformations:

1. From entity-centered reporting to topology-aware mapping
2. From linear aggregation to nonlinear exposure modeling
3. From historical recognition to structural anticipation

Recent interdisciplinary scholarship calls for accounting frameworks capable of addressing systemic risk and sustainability interdependence (Barth et al., 2021; Wagenhofer, 2022). However, operational integration remains limited.

The empirical findings of this study demonstrate that fiscal exposure behaves structurally. Accounting must therefore evolve structurally.

1. In networked economies, value is co-determined.
2. Risk is co-propagated.
3. Stability is co-produced.
4. Accounting cannot remain isolated from these dynamics.

By embedding network topology, persistence, and amplification into fiscal measurement, accounting transforms from record-keeping mechanism into systemic architecture.

This repositioning does not abandon traditional principles; rather, it extends them to reflect contemporary economic structure.

The future of accounting lies not in expanding disclosure alone, but in redesigning measurement logic to internalize structural interdependence.

7. CONCLUSION: ACCOUNTING FOR SYSTEMIC FISCAL EXPOSURE IN NETWORKED SUPPLY SYSTEMS

7.1 Summary of Theoretical Advancements

This study set out to examine how systemic fiscal exposure emerges within structurally interconnected supply systems and how accounting measurement can be extended to capture these dynamics. By integrating network topology, macroeconomic shocks, and structural dependency within a unified analytical framework, the research demonstrates that fiscal vulnerability in critical food supply systems is not merely a consequence of individual price fluctuations but the outcome of structurally amplified transmission processes operating within interconnected economic networks.

Through the development and empirical validation of a structural interdependence framework, this research advances accounting theory along three dimensions.

First, it demonstrates that fiscal exposure in import-dependent supply systems is topology-conditioned rather than additive. Exchange-rate centrality, dual-shock convexity, and exposure persistence confirm that risk propagates through structural architecture, not merely through transaction magnitude. This finding extends network macroeconomics (Acemoglu et al., 2017) into the domain of fiscal accounting and supports nonlinear amplification theory in interconnected systems (Glasserman & Young, 2016).

Second, the introduction of the Network-Adjusted Fiscal Exposure Index (NAFEI) formalizes exposure as a topology-weighted function. This represents a conceptual shift from entity-based recognition to structural mapping, aligning accounting with systemic risk frameworks increasingly adopted in macroprudential regulation (BIS, 2023).

Third, the study integrates resilience theory with accounting measurement by empirically demonstrating the buffering role of domestic production. This bridges food-security research (FAO, 2023) with fiscal governance and redefines production capacity as a structural stabilizer rather than a static output metric.

Together, these advancements reposition accounting within the architecture of networked economies.

7.2 Methodological Contributions

The study contributes to accounting research by proposing a network-adjusted analytical framework capable of identifying systemic exposure patterns that remain largely invisible within conventional transaction-centered accounting systems. Through the introduction of the Network-Adjusted Fiscal Exposure Index (NAFEI), the research provides an operational mechanism for translating structural interdependence into measurable accounting signals of fiscal vulnerability.

This integrated empirical architecture moves beyond conventional accounting research methods, incorporating tools traditionally used in macro-financial contagion analysis (Diebold & Yilmaz, 2014; Battiston et al., 2016).

The identification of regime thresholds (NAFEI > 1.8) and nonlinear propagation multipliers illustrates how accounting metrics can embed stress-testing logic similar to systemic banking supervision (Adrian et al., 2019).

By integrating network theory, stochastic modeling, and fiscal exposure estimation, the research offers a replicable methodological blueprint for structural accounting analysis.

7.3 Systemic Accounting as a Future Research Agenda

The findings suggest that accounting must evolve toward what may be termed systemic accounting - an approach that internalizes interdependence, propagation, and amplification.

Future research may explore:

- Topology-adjusted reporting standards in sovereign accounting
- Dynamic exposure dashboards for fiscal early-warning systems
- Integration of sustainability interdependencies into systemic exposure models
- Real-time monitoring of network centrality shifts

Recent debates on sustainability and systemic disclosure (ISSB, 2023; Wagenhofer, 2022) indicate growing institutional appetite for forward-looking reporting. However, these initiatives remain disclosure-based rather than architecture-based.

Systemic accounting research should therefore address measurement redesign rather than disclosure expansion alone.

Moreover, linking structural exposure metrics to public budgeting and stabilization policy could bridge accounting and macroeconomic governance more directly (IMF, 2022; World Bank, 2024).

7.4 Expanding the Model to Other Critical Networks

Although this study focused on a critical food-import network, the structural framework is transferable to other interdependent systems.

Potential applications include:

- Energy-import networks
- Pharmaceutical supply systems
- Strategic mineral value chains
- Sovereign debt exposure networks

In each case, fiscal exposure may be conditioned by centrality, dependency concentration, and correlated shock propagation.

Recent global disruptions have underscored the vulnerability of critical supply systems (OECD, 2023; UNCTAD, 2023). Applying structural accounting interdependence models to these sectors may enhance resilience mapping and policy calibration.

Future research could also incorporate multilayer networks combining trade, finance, and currency channels simultaneously — extending recent advances in multilayer contagion modeling (Brummitt et al., 2017).

Final Reflection

This research argues that accounting cannot remain structurally neutral in an interdependent world. In networked economies: **1** Exposure is conditional. **2** Risk is propagated. **3** Value is collectively reconfigured.

Accounting must therefore evolve from transaction recording to structural exposure mapping.

From a policy perspective, this transformation is particularly relevant for import-dependent economies in the Arab region, where food security, fiscal stability, and exchange-rate volatility are tightly intertwined. Structural exposure metrics such as NAFEI provide policymakers with forward-looking indicators capable of identifying amplification regimes before fiscal stress materializes. Embedding such metrics within public financial management systems could support early-warning mechanisms for commodity shocks and improve the resilience of national food-security strategies.

More broadly, the findings suggest that the future evolution of accounting systems in highly interconnected economic environments may require moving beyond traditional cost-recognition models toward analytical architectures capable of diagnosing structurally embedded economic risk. In such contexts, accounting can play a critical role not only in recording financial outcomes but also in identifying systemic exposure within complex supply networks.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this paper. The author has no financial, personal, or professional relationships that could have appeared to influence the work reported in this study.

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