International Journal of Scientific Research and Modern Education (IJSRME)
Impact Factor: 7.137, ISSN (Online): 2455 - 5630
(www.rdmodernresearch.com) Volume 7, Issue 2, 2022

CLIMATE DISASTERS AND SUPPLIER SUBSTITUTION IN INTERNATIONAL AGRICULTURAL TRADE NETWORKS

Kannan Vishwanath* & Lloyd Zulu**
* Fellow, Albert Schweitzer International Foundation, Karl-Löwe-Gasse 22/12, A-1120 Wien, Vienna, Austria
** World Christian University, Lusaka, Zambia

Cite This Article: Kannan Vishwanath & Lloyd Zulu, "Climate Disasters and Supplier Substitution in International Agricultural Trade Networks", International Journal of Scientific Research and Modern Education, Volume 7, Issue 2, Page Number 72-83, 2022.

Copy Right: © IJSRME, 2022 (All Rights Reserved). This is an Open Access Article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract:

This study develops a simulation framework for examining how climate disaster frequency, severity, and duration relate to supplier market share losses in international agricultural trade. A synthetic panel covering 2010 to 2021 contains 2,880 bilateral trade observations, with 2,640 entering ordinary least squares estimation after constructing annual supplier share changes. The specification incorporates trading relationship and importer, commodity, and year fixed effects, with standard errors clustered by exporter. Within the simulated scenario, an additional disaster event corresponds to a 0.373 percentage point increase in supplier share loss, while disaster severity and duration exhibit positive conditional associations, all statistically significant at $p < 0.001$. These relationships reflect adverse disaster effects embedded in the data generating process rather than independently identified causal mechanisms. The framework connects multidimensional disaster exposure to sourcing adjustment, refining production network analysis by distinguishing incumbent supplier losses from successful supplier replacement. Its contribution is methodological, providing a structured basis for subsequent analysis of agricultural sourcing vulnerability and procurement continuity using verified disaster and trade records.

Key Words: Climate Disasters; Agricultural Trade; Supplier Substitution; Production Networks; Panel Simulation

1. Introduction:

International agricultural trade can transmit climate disruptions across borders, but a loss of supply from one exporter does not establish that importers can replace it. Maintaining access to agricultural commodities depends on the adjustment of sourcing relationships and the availability of production elsewhere. Importers may redistribute purchases among existing suppliers, establish new relationships, or retain exposed suppliers despite interruptions. These responses have different implications for procurement continuity and dependence on particular exporting countries. Marchand et al. (2016) demonstrate through a food trade simulation that reserves and trade adjustments jointly shape exposure to supply shocks. Their findings explain why international connectivity must be examined alongside the capacity to absorb and redistribute disruption.

Research on climate and trade provides a basis for expecting agricultural sourcing patterns to respond to environmental disturbances. Jones and Olken (2010) find that higher temperatures reduce export growth in poorer countries, with adverse responses concentrated in agriculture and light manufacturing. Their analysis establishes sensitivity in export performance but does not directly identify which alternative suppliers gain when an exposed exporter loses trade. Costinot et al. (2016) examine how geographically differentiated agricultural productivity changes affect production, comparative advantage, and international trade. Their framework explains adjustment to changing production conditions while leaving a distinct question about sourcing responses to discrete disasters. Together, these studies motivate separating changes in an exporter's performance from changes in an importer's allocation of purchases across competing origins.

Production network theory explains why disruption consequences depend on relationships as well as direct exposure. Acemoglu et al. (2012) show that the structure of input and output linkages determines whether localized disturbances generate wider fluctuations. Carvalho et al. (2021) provide evidence that disruption from the Great East Japan earthquake propagated through direct and indirect supplier and customer relationships. These contributions establish the importance of interdependence, but shock transmission and supplier replacement remain different processes. Applied to agricultural trade, this perspective suggests that disruption can alter the relative reliability of exporting countries. Whether this produces sourcing reallocation depends on the ability of alternative exporters to provide suitable commodities within the relevant purchasing period.

Substitution cannot therefore be assumed to follow automatically from disruption. Boehm et al. (2019) identify strong complementarities between imported and domestic inputs following the Tōhoku earthquake, demonstrating how established production relationships can constrain adjustment. Although their setting differs from agricultural commodity trade, their findings indicate why nominally available alternatives may not provide immediate replacements. Commodity requirements, delivery capacity, and established transactions may restrict sourcing adjustments. This creates competing expectations: disasters may increase incentives to reduce reliance

on exposed exporters, while replacement constraints may preserve those relationships despite deteriorating supply conditions. Supplier market share adjustment offers an observable outcome through which these competing pressures can be examined.

The present framework distinguishes disaster frequency, severity, and duration because these dimensions imply different pressures on sourcing continuity. Frequency represents recurring interruptions that may weaken confidence in an incumbent supplier's reliability. Severity represents disruption magnitude and may increase the immediate pressure to redistribute purchases. Duration represents persistence and may influence whether importers accommodate an interruption or seek a sustained sourcing adjustment. These are proposed mechanisms rather than independently established pathways. Separating them avoids treating repeated events as equivalent to a single severe event or assuming that brief and prolonged disruptions produce identical responses. The framework links each exposure dimension to annual losses in an incumbent exporter's share of an importer's agricultural purchases.

Measurement is central to interpreting these relationships. Supplier substitution can involve redistribution among existing exporters, the entry of new suppliers, the exit of established suppliers, or changes in sourcing concentration. These outcomes capture different aspects of network adjustment. The operational outcome in this study is annual supplier market share loss, defined as the previous annual share minus the subsequent annual share within the same importer and commodity market. Positive values indicate declining reliance on the incumbent exporter. This measure represents relative sourcing adjustment but does not independently establish supplier entry, physical replacement, or improved supply continuity. Because expenditure shares reflect both prices and quantities, their interpretation concerns the allocation of import value across origins. This distinction prevents changes in nominal sourcing shares from being treated as equivalent changes in physical deliveries.

The closest literature leaves a bounded question at the intersection of climate exposure and agricultural sourcing adjustment. Existing research establishes weather sensitivity in exports, agricultural adaptation through comparative advantage, disruption propagation through production networks, and the joint role of reserves and trade in absorbing food supply shocks (Carvalho et al., 2021; Costinot et al., 2016; Jones & Olken, 2010; Marchand et al., 2016). The reviewed evidence does not establish whether disaster recurrence, magnitude, and persistence have distinct relationships with subsequent losses in incumbent suppliers' shares within agricultural import markets. The contribution sought here is a specification that separates these exposure dimensions while preserving the importer, exporter, commodity, and annual structure of sourcing relationships. This connects exporter exposure to a clearly defined outcome without equating shock propagation with successful supplier replacement.

This study aims to develop and demonstrate a framework for examining how climate disaster frequency, severity, and duration relate to agricultural supplier market share losses over 2010 to 2021. The research question is: How do these three dimensions of exporter disaster exposure relate to subsequent changes in incumbent suppliers' shares of agricultural import markets? Specifically, the study examines the relationship between disaster frequency and supplier share loss, evaluates the corresponding relationship for disaster severity, and assesses whether longer disaster duration is associated with greater share loss. These objectives follow the three explanatory dimensions in the conceptual framework and distinguish conditional associations from established causal effects.

The analytical demonstration uses a synthetic annual panel organized by importing country, exporting country, agricultural commodity, and year. It applies ordinary least squares with trading relationship fixed effects, importer, commodity, and year fixed effects, and standard errors clustered by exporter. This structure demonstrates how persistent relationship differences and shared market conditions can be represented when estimating the three exposure dimensions together. Because the observations are simulated and the generating process incorporates adverse disaster effects on trade values, the estimates demonstrate model operation rather than independently validate international agricultural trade behavior. The contribution is methodological: the study translates the distinction between disruption exposure and sourcing adjustment into an explicit analytical specification.

The international relevance of this framework lies in a common decision problem across agricultural import markets: whether exposure to disrupted exporters is accompanied by a redistribution of sourcing expenditure. Network research establishes that the consequences of shocks depend on economic interconnections, while agricultural trade research demonstrates that adjustment involves production conditions, trade relationships, and reserves (Acemoglu et al., 2012; Costinot et al., 2016; Marchand et al., 2016). The framework brings these perspectives together around incumbent supplier share loss. Its practical value lies in clarifying the distinctions that procurement and trade risk assessments must preserve when examining disaster exposure and sourcing dependence. The analytical structure can inform research across settings, while substantive conclusions about particular countries and commodities require observed trade and disaster records.

2. Theory, Conceptual Framework and Hypotheses Development:

International agricultural trade operates through interconnected supplier relationships in which importers depend on geographically dispersed producers for commodity availability. Climate disasters can disrupt these relationships by reducing production capacity, interrupting logistics and increasing uncertainty over supply continuity. Network theory suggests that shocks originating in one part of a trading system can influence transactions elsewhere through established interdependencies. This perspective is consistent with the analysis of production networks by Acemoglu et al. (2012) and the evidence on international transmission of supply shocks presented by Carvalho et al. (2021).

The conceptual framework distinguishes climate disaster exposure from agricultural supplier substitution. Climate disaster exposure represents the frequency, severity and characteristics of disruptive events affecting exporting countries. Agricultural supplier substitution represents changes in the distribution and continuity of import sourcing relationships. The central theoretical mechanism is that importers respond to disruptions affecting incumbent suppliers by reallocating purchases toward alternative exporting countries. However, substitution may be constrained by production capacity, commodity compatibility, trade relationships and the availability of alternative suppliers.

The uploaded dataset provides a structure for examining these relationships through annual disaster records and bilateral agricultural trade observations. Nevertheless, its numerical disaster and trade fields have not been populated. Consequently, the proposed relationships remain theoretical expectations rather than empirically validated findings.

2.1 Climate Disaster Frequency and Agricultural Supplier Substitution:

Climate disaster frequency captures the recurrence of disruptive events affecting agricultural exporting countries. Repeated disasters can increase uncertainty over the reliability of incumbent suppliers, particularly when importers depend on established relationships for continuous commodity delivery. Network theory indicates that recurring disturbances may propagate through interconnected transactions and alter the relative attractiveness of alternative suppliers, as established by Acemoglu et al. (2012).

The expected relationship arises through repeated interruptions to supply continuity. As disaster frequency increases, importers may reduce purchases from exposed exporters and expand sourcing from alternative countries. This adjustment can produce declining incumbent supplier shares, increasing alternative supplier shares and the formation of new trade relationships. However, the response depends on whether alternative exporters can supply comparable agricultural products.

Empirical evidence from Carvalho et al. (2021) demonstrates that disasters can propagate through supply relationships and encourage the formation of new transactions. Boehm et al. (2019) provide complementary evidence that rigid production linkages can constrain substitution following external shocks. These findings support a potential relationship between disaster exposure and sourcing adjustment, although neither establishes the specific effect of annual climate disaster frequency on international agricultural supplier substitution.

H1: Higher climate disaster frequency in agricultural exporting countries is associated with greater subsequent substitution away from disaster exposed suppliers, conditional on the availability of alternative suppliers.

2.2 Climate Disaster Severity and Agricultural Supplier Substitution:

Climate disaster severity differs from frequency because it captures the magnitude of disruption rather than the number of events. A single severe disaster may generate greater supply instability than several events with limited consequences. Severity can be represented by affected populations and recorded economic damages, although these indicators measure aggregate disaster impacts rather than agricultural production losses directly.

Greater disaster severity may increase pressure to reallocate imports when physical damage, transport interruptions and economic losses reduce an exporter's capacity to fulfill established supply relationships. Importers may respond by reducing reliance on exposed suppliers and redistributing purchases across alternative countries. However, severe disasters can also restrict substitution when affected exporters supply commodities with limited international alternatives.

The network transmission mechanism developed by Acemoglu et al. (2012) indicates that the consequences of disturbances depend on the economic importance of affected suppliers. Carvalho et al. (2021) further demonstrate that disaster shocks can spread beyond directly affected firms through existing transaction networks. These findings suggest that disaster severity may influence the magnitude of supplier reallocation, but they do not establish a uniform response across agricultural products or trading partners.

H2: Greater climate disaster severity in agricultural exporting countries is associated with larger subsequent reductions in exposed suppliers' agricultural import market shares.

2.3 Climate Disaster Characteristics and Agricultural Supplier Substitution:

Climate disaster characteristics distinguish events according to their physical nature and duration. Floods and storms may affect agricultural trade through different combinations of production damage,

infrastructure disruption and logistical constraints. Disaster duration can also influence the period during which supply relationships remain exposed to interruption. These distinctions are relevant because importers respond to the expected continuity of supply rather than disaster occurrence alone.

Prolonged disruption may increase incentives to establish alternative sourcing relationships when incumbent suppliers cannot restore reliable deliveries. Conversely, temporary interruptions may encourage importers to preserve established suppliers rather than incur the costs of changing trade relationships. The direction and magnitude of substitution therefore depend on the interaction between disruption persistence and the feasibility of alternative sourcing.

Carvalho et al. (2021) establish that disruption transmission depends on the structure of supplier relationships, while the evidence presented by Boehm et al. (2019) indicates that limited substitutability can magnify the consequences of supply shocks. These findings provide a theoretical basis for distinguishing disaster characteristics, but do not independently establish whether floods or storms produce systematically different substitution responses in agricultural trade.

H3: Longer climate disaster duration in agricultural exporting countries is associated with greater subsequent substitution away from exposed suppliers.

2.4 Conceptual Framework and Empirical Identification:

This analysis conceptualizes climate disaster exposure as the explanatory construct and agricultural supplier substitution as the outcome. The proposed relationships operate through adjustments in bilateral agricultural import values, supplier market shares and the entry or exit of trading partners. The principal unit of analysis is the importer, exporter, agricultural product and year, allowing changes in supplier relationships to be distinguished across commodities and trading countries.

The theoretical framework proposes three directional associations between disaster frequency, severity, duration and subsequent sourcing adjustments. These associations should not be interpreted as established causal effects because annual observational data alone cannot exclude concurrent demand changes, price movements or other disturbances influencing trade relationships.

3. Data:

This analysis establishes the data provenance, sampling structure and measurement requirements for examining climate disasters and supplier substitution in international agricultural trade networks from 2010 to 2021. The available research workbook defines the observation framework and candidate variables, but contains no extracted disaster or bilateral trade observations from which an estimation sample or empirical findings can be established.

3.1 Data Sources, Population, and Sample Construction:

The empirical framework identifies two principal data sources. The United Nations Comtrade Database provides annual bilateral merchandise trade statistics by reporting country, partner country and commodity classification. The Emergency Events Database, EM DAT, maintained by the Centre for Research on the Epidemiology of Disasters, provides information on disaster occurrence, hazard classification, affected populations and reported economic damages. These sources are complementary because they distinguish the geographical exposure of agricultural exporters from subsequent changes in the composition of international import relationships.

The analytical setting covers international agricultural trade during 2010 to 2021. The intended unit of analysis is the importing country, exporting country, agricultural commodity and calendar year. This structure permits examination of changes in supplier market shares within individual importer and commodity markets. Annual import values represent transaction flows rather than accumulated stocks, while disaster event counts and recorded damages represent occurrences and reported impacts within the corresponding observation period.

The target population comprises international agricultural sourcing relationships potentially exposed to climate disasters. The accessible sampling frame has not been established because the workbook does not contain downloaded bilateral trade records or disaster observations. It includes an illustrative index of 21 countries across 12 years, corresponding to 252 country and year combinations. These combinations are structural placeholders rather than verified eligible or observed units. Their inclusion does not establish a representative sample of international agricultural trade.

The distinction between population coverage and actual observations is essential for network analysis. Acemoglu et al. (2012) demonstrate that the economic consequences of disturbances depend on network structure, while Carvalho et al. (2021) identify the propagation of disruptions through supplier relationships. Boehm et al. (2019) further show that production linkages can constrain adjustment following external shocks. These findings justify preserving bilateral supplier identities rather than relying exclusively on aggregate national trade values. They do not, however, establish the coverage or completeness of the present dataset.

Table 1: Sample Construction and Observation Availability

Sample Construction Stage	Units	Observations	Selection Status
Target international agricultural trade population	Not established	Not established	Global agricultural trade relationships

Illustrative country and year index	21 countries	252 combinations	Structural index only
Extracted bilateral agricultural trade records	0	0	No observations supplied
Extracted climate disaster event records	0	0	No observations supplied
Matched disaster and trade records	0	0	Integration not performed
Verified estimation sample	0	0	No analyzable observations

The sample construction record therefore distinguishes a populated indexing structure from empirical observations. The workbook does not document verified inclusion or exclusion decisions, missing record counts, balanced panel coverage or model specific sample losses. Consequently, neither the composition of a retained analytical sample nor its geographical representativeness can be established.

3.2 Data Integration, Cleaning, and Quality Assurance:

The data architecture identifies country codes, calendar years, disaster event identifiers and agricultural commodity codes as the principal fields required for integration. The bilateral trade schema contains importer and exporter identifiers, commodity codes, annual trade values and physical quantities. The disaster schema contains event identifiers, affected country, start and end dates, hazard classification, affected populations and economic damages. These fields provide a basis for associating exporter exposure with changes in sourcing relationships.

The proposed integration requires disaster exposure to be associated with the exporting country rather than automatically attributed to every importer trading with that country. Trade relationships must also retain commodity identities because substitution across suppliers of the same agricultural product differs from changes in the composition of imported products. Country identifiers and commodity classifications must remain consistent across observation periods before supplier market shares can be compared.

The workbook records annual trade values in current United States dollars. It does not document exchange rate conversion, price deflation or harmonization across different commodity classification revisions. Consequently, observed changes in nominal trade values cannot automatically be interpreted as changes in physical supply. Quantity based measures would require compatible units and sufficient reporting coverage.

The distinction between physical disruption and trade value adjustment is supported by Boehm et al. (2019), who demonstrate the importance of input relationships in transmitting shocks. Carvalho et al. (2021) also establish that network responses may involve the formation of new supplier relationships rather than only changes in existing transactions. These findings support separate identification of incumbent suppliers, new suppliers and discontinued relationships when the underlying records become available.

The available workbook does not document completed record matching, duplicate identification, missing value treatment, outlier screening or cross source validation. Empty numerical fields indicate that observations have not been extracted; they do not represent zero disaster occurrence, zero economic damage or zero agricultural trade. No interpolation, imputation, winsorization or deletion procedure can therefore be reported as implemented.

The absence of verified integration results prevents assessment of unmatched records, inconsistent identifiers, observation duplication and changes in sample composition. It also prevents evaluation of whether differences in disaster reporting and trade coverage could introduce systematic selection into the analytical sample.

3.3 Variable Measurement, Construction, and Validation:

The conceptual framework distinguishes climate disaster exposure as the independent construct and agricultural supplier substitution as the dependent construct. Climate disaster exposure comprises disaster frequency, severity and characteristics. Supplier substitution concerns changes in established sourcing relationships, including supplier market shares, entry, exit and import concentration.

Disaster frequency is represented by annual event counts, including floods and storms. Disaster severity is represented by the number of affected people and reported economic damages. Disaster characteristics include event duration and hazard classification. These are observed or potentially calculated measures rather than indicators of a validated latent scale. Their empirical interpretation depends on the completeness and consistency of disaster records.

Agricultural supplier substitution requires bilateral import observations for consecutive years. The outcome dimensions include changes in incumbent supplier shares, changes in alternative supplier shares, newly active suppliers, discontinued suppliers and import sourcing concentration. These measures are not interchangeable. Market share changes capture redistribution among suppliers, entry and exit capture changes in relationship continuity, and concentration captures the distribution of sourcing across available exporters.

Table 2: Variable Dictionary and Measurement Availability

Variable or Indicator	Analytical Role	Definition and Construction	Source and Identifier	Unit and Frequency	Direction and Transformation	Missing Value Rule	Coverage and Limitation
Total disaster frequency	Independent, dimension 1	Number of recorded climate disaster events in an exporter country and year	EM DAT, disaster ID and country	Events per year	Higher values indicate more events	Unextracted values remain missing	No observed counts
Flood frequency	Independent, dimension 1	Annual count of recorded flood events	EM DAT, hazard type	Events per year	Higher values indicate greater flood frequency	Unextracted values remain missing	No observed counts
Storm frequency	Independent, dimension 1	Annual count of recorded storm events	EM DAT, hazard type	Events per year	Higher values indicate greater storm frequency	Unextracted values remain missing	No observed counts
People affected	Independent, dimension 2	Reported number of people affected by disaster events	EM DAT, affected people	Persons per event or year	Higher values indicate greater reported impact	Missing remains missing	No observed values
Economic damages	Independent, dimension 2	Reported economic damage attributable to disaster events	EM DAT, damages	USD per event or year	Higher values indicate greater reported damage	Missing remains missing	No observed values
Average damages per event	Independent, dimension 2	Annual recorded damages divided by the number of events with usable damage information	EM DAT, damages and event ID	USD per event	Higher values indicate greater average recorded damage	Undefined denominators remain missing	Not calculated
Disaster duration	Independent, dimension 3	Elapsed time between recorded disaster start and end dates	EM DAT, start and end dates	Days per event	Higher values indicate longer disruption periods	Missing dates remain missing	Not calculated
Flood occurrence	Independent, dimension 3	Indicator identifying whether a recorded event is classified as a flood	EM DAT, hazard type	Binary event indicator	One identifies flood classification	Unclassified events remain missing	No event records
Storm occurrence	Independent, dimension 3	Indicator identifying whether a recorded event is classified as a storm	EM DAT, hazard type	Binary event indicator	One identifies storm classification	Unclassified events remain missing	No event records
Incumbent supplier share change	Dependent	Difference between current and previous annual supplier shares	UN Comtrade, importer, exporter, commodity and year	Percentage points annually	Negative values indicate declining supplier share	Missing trade records remain missing	Not calculated
Alternative supplier share change	Dependent	Annual change in the market share of an identified alternative exporter	UN Comtrade, bilateral imports	Percentage points annually	Positive values indicate increasing alternative sourcing	Missing shares remain missing	Not calculated
New supplier entry	Dependent	Supplier becoming active after having no recorded imports in the preceding comparable period	UN Comtrade, bilateral imports	Supplier count annually	Higher values indicate additional supplier relationships	Unobserved trade is not assumed zero	Not calculated
Supplier exit	Dependent	Previously active supplier with no recorded imports in the subsequent comparable period	UN Comtrade, bilateral imports	Supplier count annually	Higher values indicate relationship discontinuation	Missing reporting is not treated as exit	Not calculated
Import sourcing concentration	Dependent	Sum of squared supplier market shares within an importer, commodity and year	UN Comtrade, bilateral imports	Index annually	Higher values indicate greater concentration	Undefined shares remain missing	Not calculated

Supplier market shares require annual imports from an individual exporting country to be divided by total imports of the same agricultural commodity by the same importing country. Market share changes are measured in percentage points when shares are expressed as percentages. Import concentration requires consistent supplier coverage within each importer and commodity market. The resulting index cannot establish substitution direction independently because concentration can increase or decrease following supplier replacement.

Disaster severity also requires careful interpretation. Aggregate economic damages are not equivalent to agricultural production losses, and the number of affected people does not directly measure lost export

capacity. These indicators can represent exposure severity but cannot independently establish the mechanism through which a disaster influences agricultural trade.

Acemoglu et al. (2012) establish the importance of network positions in understanding the transmission of shocks. Boehm et al. (2019) provide evidence that supply relationships influence adjustment following disruptions. Carvalho et al. (2021) demonstrate that the reorganization of supplier relationships can accompany shock propagation. Together, these studies support the distinction between exposure indicators and observed trade network adjustments without validating the specific measurements in the present workbook.

No descriptive statistics can be reported for the substantive variables because the numerical observations are unavailable. Valid counts, means, standard deviations, medians, minimum values and maximum values therefore remain undetermined. No empirical measurement validation, cross source agreement test or sensitivity assessment has been completed.

3.4 Analytical Framework, Identification, and Reproducibility:

The research question concerns whether climate disaster exposure is associated with subsequent changes in international agricultural supplier relationships. The appropriate analytical orientation is associational unless a credible identification strategy can distinguish disaster effects from concurrent changes in demand, prices, trade policy and supplier capacity. The annual bilateral structure provides a potential basis for examining temporal relationships, but the available workbook does not contain the observations required to estimate those relationships.

The three hypothesized exposure dimensions correspond to disaster frequency, severity and duration. The proposed outcomes represent different manifestations of supplier substitution rather than a single validated composite measure. This distinction is important because a decline in an exposed supplier's market share does not necessarily establish that another supplier entered the market, while changes in concentration do not uniquely identify which relationships changed.

Network theory establishes why the effects of disturbances may extend beyond directly affected producers. Acemoglu et al. (2012) show that network structure shapes the aggregate consequences of microeconomic disturbances. Carvalho et al. (2021) provide evidence of disruption propagation through supplier relationships, while Boehm et al. (2019) identify constraints arising from input linkages. These contributions justify evaluating supplier level responses, but they do not substitute for empirical identification within the agricultural trade dataset.

No baseline model has been estimated. Consequently, there are no verified regression coefficients, standard errors, confidence intervals, statistical significance results or model diagnostics. Fixed effects, clustering procedures, lag structures and robustness estimators cannot be described as implemented. The data structure alone does not establish that exporter disaster exposure is exogenous to all other determinants of bilateral agricultural trade.

The research workbook provides an explicit variable dictionary, source inventory and extraction protocol. Its documentation identifies UN Comtrade and EM DAT as the principal sources and records FAOSTAT, World Development Indicators and United Nations country classifications as potential supplementary resources. The workbook does not provide completed source downloads, extraction timestamps, processing code, verified dataset versions or reproducible estimation outputs.

The analytical framework therefore establishes the intended alignment between disaster exposure, supplier identities, commodity markets and annual sourcing changes. The principal limitation is the absence of empirical observations, which prevents the construction of a validated estimation sample and the resolution of the proposed hypotheses. Reporting this limitation preserves the distinction between the measurement framework and evidence actually established by the available data.

4. Methods:

4.1 Research Design and Analytical Scope:

The study uses a simulation-based panel design to demonstrate the estimation of relationships between climate disaster exposure and agricultural supplier substitution over 2010 to 2021. The unit of analysis is the importer-exporter-commodity-year relationship. The outcome is the annual loss in an incumbent exporter’s share of an importer’s agricultural purchases. Disaster frequency, severity, and duration constitute the three explanatory dimensions.

The analytical target is the conditional association between each simulated exposure dimension and supplier market share loss, holding the other dimensions and specified fixed effects constant. The design demonstrates an estimation procedure rather than identifying causal effects in observed international trade. The generating process incorporates adverse disaster effects into simulated trade values. Estimated relationships therefore reflect the specified scenario and cannot independently validate the substantive hypotheses. This distinction follows the separation of simulation assumptions, analytical targets, and performance assessment described by Morris et al. (2019). The specification estimates the three exposure dimensions jointly. It does not estimate interaction effects or identify production losses, transport disruption, and switching costs as separate transmission pathways.

4.2 Measurement and Model Specification:

The sample construction table and variable dictionary describe the intended observational framework. The numerical demonstration uses synthetic observations. Supplier market shares are calculated within each importer, commodity, and year:

$$s_{ijpt} = 100 \frac{V_{ijpt}}{\sum_k V_{ikpt}}.$$

Here, s_{ijpt} is exporter j's percentage share of importer i's purchases of commodity pin year t; V_{ijpt} is the corresponding simulated bilateral import value; and \(k\) indexes exporters included in the market denominator. Shares describe expenditure allocation across the suppliers represented in the synthetic market. Annual supplier market share loss is calculated as:

$$L_{ijpt} = s_{ijp,t-1} - s_{ijpt}.$$

Here, L_{ijpt} is measured in percentage points. Positive values indicate declining incumbent supplier shares, while negative values indicate increasing shares. Construction requires comparable observations in consecutive years. The outcome captures relative expenditure reallocation rather than physical supplier replacement. The reported fixed-effects model is expressed as:

$$L_{ijpt} = \beta_1 F_{jt} + \beta_2 S_{jt} + \beta_3 D_{jt} + \alpha_{ijp} + \lambda_{ipt} + \varepsilon_{ijpt}.$$

Here, F_{jt} represents simulated disaster frequency for exporter jin year t, S_{jt} represents the synthetic severity index; and D_{jt} represents simulated disaster duration in days. The coefficients β_1, β_2 and β_3 measure their respective conditional associations with supplier share loss. The term α_{ijp} represents trading relationship fixed effects, λ_{ipt} represents importer commodity year fixed effects, and ε_{ijpt} is the residual.

Trading relationship fixed effects absorb persistent differences across sourcing relationships. Importer-commodity-year fixed effects absorb conditions shared by suppliers competing within the same annual import market. The coefficients depend on exposure variation remaining after these adjustments. Exposure in year \(t\) is associated with the share change ending in that year, so the model does not establish transaction-level temporal ordering.

The severity measure is an artificial index rather than an observed measure of damages or affected populations. Its coefficient is interpreted per index unit. Direct comparisons of coefficient magnitudes across the three predictors are inappropriate because their measurement scales differ.

4.3 Analytical Procedures, Estimation, and Inference:

The manuscript reports 2,880 generated bilateral observations and 2,640 estimation observations after constructing annual supplier share changes. These are synthetic record counts rather than a probability sample of agricultural trading relationships. They do not establish geographical representativeness.

Processing proceeds from simulated bilateral import values to annual market totals, supplier shares, and consecutive share differences. The resulting outcome is associated with exporter year exposure measures and estimated using ordinary least squares with the fixed effects specified in Equation 3. Observations without the consecutive shares needed to construct the outcome cannot contribute to estimation.

Ordinary least squares accommodate the continuous outcome, including both positive and negative share changes. The fixed effects account for the specified persistent relationship differences and shared market conditions. Their inclusion does not establish causal identification.

Reported standard errors are clustered by exporter to accommodate residual dependence across observations sharing an exporting country. This includes repeated observations over time and transactions involving multiple destination markets. Cameron and Miller (2015) explain that cluster-robust inference permits within-cluster dependence but relies on adequate independent cluster information. Exporter clustering does not automatically address dependence between different exporters, including dependence arising from their shared market-share denominator.

The effective number of estimation clusters, finite-sample correction, and reference distribution are not documented in the supplied manuscript. Reported confidence intervals and significance tests therefore remain conditional on implementation settings that are not fully specified.

4.4 Validation, Replicability, and Interpretive Scope:

The analysis demonstrates coefficient estimation and hypothesis testing within a constructed panel. It does not document repeated simulation replications or assessments of estimator bias, confidence interval coverage, and rejection rates. The exercise is therefore an illustrative application rather than a validated comparison of statistical procedures. Morris et al. (2019) emphasize that evaluating statistical performance requires explicit generating mechanisms and repeated simulation designs.

Model fit and statistical significance describe the constructed scenario. They do not demonstrate external validity or establish that the estimated relationships characterize observed agricultural trade. No unperformed diagnostic, sensitivity analysis, or robustness check is treated as completed.

Independent numerical replication requires the generating equations, parameter values, random seed, synthetic observations, software requirements, and estimation scripts. Although the manuscript states that a

fixed random seed was used, it does not provide the seed value or complete generating procedure. Exact regeneration of the numerical results cannot therefore be established from the manuscript alone.

The design aligns three dimensions of disruption exposure with a defined measure of annual sourcing adjustment. Its contribution lies in applying established analytical tools to demonstrate this relationship. Interpretation remains confined to the synthetic scenario, while substantive conclusions about agricultural trade require independently observed records.

5. Findings:

This analysis evaluates three hypotheses linking climate disaster frequency, severity and duration to agricultural supplier substitution during 2010 to 2021. A synthetic panel was constructed to demonstrate the proposed empirical framework, estimate the hypothesized relationships and assess statistical inference. All numerical findings in this section are simulated and do not constitute empirical evidence about actual international agricultural trade.

5.1 Sample Characteristics and Analytical Results:

The simulation covers 21 exporting countries, six importing countries and two agricultural commodity categories. The generated panel contains 2,880 bilateral trade observations, of which 2,640 enter the regression analysis after constructing annual changes in supplier market shares. Supplier substitution is measured as the previous year's supplier market share minus the current year's share, expressed in percentage points. Positive values therefore indicate a reduction in the exposed exporter's market share. The analysis uses ordinary least squares with trading relationship fixed effects and importer, commodity and year fixed effects. Standard errors are clustered by exporting country. The estimated model has an R^2 of 0.2015.

5.2 Hypothesis Testing Results:

Dependent variable: annual supplier market share loss, in percentage points

Hypothesis	Coefficient	Standard Error	95% Confidence Interval	p Value
H1	0.37284	0.08366	0.20887 to 0.53681	< 0.001
H2	0.08283	0.01485	0.05373 to 0.11193	< 0.001
H3	0.12301	0.02772	0.06868 to 0.17735	< 0.001

Computed synthetic panel using a fixed random seed. The generating process explicitly includes negative disaster effects on simulated trade values.

5.3 Climate Disaster Frequency and Supplier Substitution:

The simulated coefficient for disaster frequency is positive at 0.37284, with a 95% confidence interval from 0.20887 to 0.53681. Holding the other model variables constant, one additional simulated disaster event is associated with a 0.373 percentage point increase in supplier market share loss. The result is statistically distinguishable from zero within the simulation and agrees with the predicted direction of H1. This outcome is consistent with the theoretical network transmission mechanisms discussed by Acemoglu et al. (2012) and Carvalho et al. (2021), although it cannot establish that the same relationship exists in observed agricultural trade.

5.4 Climate Disaster Severity and Supplier Substitution:

The simulated disaster severity coefficient is 0.08283, with a 95% confidence interval from 0.05373 to 0.11193. A one unit increase in the synthetic severity index is associated with a 0.083 percentage point increase in supplier market share loss. The positive estimate agrees with the predicted direction of H2. However, the severity measure is an artificial index, not an observed measure of economic damages or affected populations. The coefficient therefore illustrates model behavior rather than an empirically established economic effect.

5.5 Climate Disaster Duration and Supplier Substitution:

The simulated coefficient for disaster duration is 0.12301, with a 95% confidence interval from 0.06868 to 0.17735. One additional simulated disaster day is associated with a 0.123 percentage point increase in supplier market share loss, conditional on the other predictors and fixed effects. This positive relationship agrees with the predicted direction of H3. The result illustrates how persistent disruption can be represented within the model, consistent with the broader literature on supply chain linkages and adjustment constraints presented by Boehm et al. (2019).

6. Discussion:

The central insight from the simulated analysis is that climate disaster exposure can be represented as a multidimensional pressure on international agricultural supplier relationships rather than as a single disruption event. The positive coefficients for disaster frequency, severity and duration in Table 2 illustrate how repeated shocks, increasing damage and prolonged interruptions may jointly influence supplier market share losses. The simulated frequency coefficient of 0.373 indicates that an additional disaster event corresponds to a 0.373 percentage point increase in supplier share loss under the specified data generating process. This result is consistent with the network propagation framework developed by Acemoglu et al. (2012), but the simulation extends the analytical representation from shock transmission to observable supplier reallocation. The distinction matters because declining incumbent market shares and increasing alternative sourcing are separate

dimensions of network adjustment. Carvalho and Tahbaz-Salehi (2019) establish the importance of production network structures, while Boehm et al. (2019) demonstrate how rigid supply relationships influence the transmission of external disturbances. The present simulation illustrates how these theoretical insights can be translated into testable agricultural trade outcomes. Its contribution is methodological rather than empirical: it demonstrates the feasibility of jointly estimating disaster exposure dimensions and supplier substitution, without establishing that the simulated coefficients describe actual international trade behavior.

The interpretation of transmission mechanisms requires distinguishing associations incorporated into the simulation from independently identified causal pathways. Table 2 reports positive conditional relationships between the three disaster exposure variables and supplier market share losses, but no mediation model was estimated. Consequently, the analysis cannot establish whether production losses, transport disruptions, inventory adjustments or supplier switching costs transmit the effects of climate disasters. These channels remain theoretically plausible. Barrot and Sauvagnat (2016) show that firm level production networks transmit idiosyncratic shocks, particularly when inputs are difficult to substitute. Carvalho et al. (2021) demonstrate that supplier relationships can transmit disaster disturbances across connected firms. In agricultural trade, comparable mechanisms could operate through export capacity, transport reliability and sourcing decisions. However, the simulated estimates cannot distinguish these pathways or establish partial or complete mediation. This distinction refines the interpretation of the model by identifying the specific evidence needed to move from an observed association to a credible explanation of supplier substitution. The next empirical requirement is therefore to measure intermediate adjustments rather than infer them from changes in supplier market shares alone.

The relative importance of disaster frequency, severity and duration cannot be established by directly comparing their coefficients because the explanatory variables use different measurement scales. The coefficients in Table 2 represent changes associated with one additional event, one unit of the synthetic severity index and one additional disaster day, respectively. Their numerical ordering does not constitute a decomposition of total disaster effects. No standardized effect decomposition, indirect effect estimation or channel contribution analysis was performed. This limitation is theoretically important because disaster recurrence, intensity and persistence may influence supplier decisions through different mechanisms. Antràs and Chor (2013) demonstrate that organizational decisions within international production systems depend on the structure of relationships and incentives, while Costinot et al. (2012) show that comparative advantage in agriculture varies with climatic conditions. These contributions suggest that supplier substitution may depend not only on the magnitude of disaster exposure but also on the availability and economic attractiveness of alternative exporting countries. The simulation provides a framework for examining these competing explanations, but does not establish which mechanism dominates. A credible decomposition would require observed supplier responses, comparable exposure scales and explicit identification of intermediate transmission channels.

A deeper challenge concerns the interpretation of supplier substitution when agricultural trade values reflect both quantities and prices. A decline in an exposed exporter's import market share may arise from reduced physical deliveries, changing commodity prices, altered importer demand or changes in competing suppliers' performance. The simulated model does not independently identify these processes. This distinction matters because agricultural markets are characterized by geographically uneven production risks and imperfect substitution across origins. Jones and Olken (2010) demonstrate that temperature shocks can influence export performance, while Dell et al. (2012) identify broader economic responses to temperature variation. These findings imply that climate disturbances may affect trade through multiple economic margins rather than a single supply channel. The simulated framework therefore highlights a measurement problem central to interpreting agricultural trade networks: changes in nominal sourcing shares are not equivalent to physical supplier replacement. Resolving this problem requires observed trade quantities, consistent commodity definitions and information on the continuity of supplier relationships. Without these measurements, market share adjustment should be interpreted as a sourcing outcome rather than definitive evidence of operational supplier switching.

The international relevance of the framework lies in its capacity to connect climate exposure with adjustments in bilateral agricultural trade relationships across exporting and importing countries. Previous research has established that climate conditions influence agricultural production and international trade patterns. Costinot et al. (2016) examine how climate change affects agricultural markets through production and trade adjustments, while Dallmann (2019) documents relationships between weather variation and international trade. These studies provide a basis for distinguishing long term changes in comparative advantage from shorter term adjustments following discrete disasters. The present simulation illustrates a specification designed to examine the latter mechanism through supplier market share changes. However, it does not establish whether the simulated relationships differ between advanced and emerging economies, whether geographic diversification reduces exposure or whether agricultural commodities exhibit different substitution responses. Such claims require observed cross country variation and appropriate comparative estimation. The potential

international contribution is therefore a testable distinction between climate driven changes in production competitiveness and disaster induced changes in sourcing relationships, rather than a demonstrated difference between national or regional trading systems.

The practical implication is that climate risk assessment should distinguish disaster frequency, severity and duration when evaluating the vulnerability of agricultural sourcing relationships. Table 2 illustrates how each dimension can enter a common analytical specification, but the simulated results do not establish their relative policy importance or justify allocating resources according to their estimated coefficients. Decision makers could use the framework to examine whether sourcing diversification, alternative supplier availability and relationship continuity influence exposure to climate disruptions once verified observations become available. Theoretically, the framework extends the network perspective by treating supplier substitution as a measurable adjustment outcome rather than assuming that trade relationships remain unchanged following shocks. This approach is consistent with the emphasis on interconnected economic structures in Acemoglu et al. (2012) and the evidence on supplier network reorganization presented by Carvalho et al. (2021). Future empirical analysis should determine whether disaster exposure predicts supplier entry and exit, whether physical trade quantities respond differently from nominal market shares, and whether substitution is concentrated among particular commodities or trading relationships. These questions would establish whether supplier reallocation acts as an adjustment mechanism that limits disruption or creates additional concentration risks. The present results demonstrate the analytical procedure needed to investigate these questions, but substantive conclusions about international agricultural trade require independently observed data.

7. Conclusion and Implications:

Global agricultural supply security depends on whether disrupted sourcing relationships can be reorganized. Within the simulation, recurring interruptions, greater disruption, and prolonged disturbance jointly correspond to declining incumbent supplier shares, illustrating how multiple pressures can be represented within one sourcing framework. The study contributes a methodological bridge between network disruption and supplier reallocation by distinguishing exposure to shocks from adjustments in purchasing relationships. Its theoretical value lies in treating network connections as potentially adjustable rather than assuming that disruption merely travels through unchanged relationships. However, the simulation demonstrates specified relationships rather than discovering causal mechanisms or validating conditional effects. For managers, the framework offers a structure for assessing sourcing dependence alongside different dimensions of disruption, supporting clearer procurement risk assessments. Operationally, it directs attention toward consistent supplier records, commodity comparability, and separate monitoring of expenditure shares and physical deliveries. For policymakers, it provides an analytical basis for investigating whether access to alternative exporters supports agricultural supply continuity. These applications require validation with observed records before informing resource allocation or intervention priorities. The broader social relevance concerns the reliability of agricultural availability across interconnected markets: understanding sourcing adjustment can support better decisions about exposure and continuity without assuming that diversification automatically prevents shortages.

The synthetic design creates a clear pathway toward empirical validation using matched disaster records and bilateral agricultural trade observations. Future research should compare expenditure shares with physical quantities and distinguish redistribution among established suppliers from supplier entry and exit. More frequent observations could identify adjustment timing, while credible identification strategies could separate disruption responses from concurrent price, demand, and policy changes. Cross-country and commodity comparisons could assess transferability. Explicit interaction models incorporating alternative supply capacity, reserves, or trade restrictions would test when sourcing adjustment becomes feasible, extending the framework from methodological demonstration toward evidence on agricultural resilience.

References:

1. Acemoglu, D., Carvalho, V. M., Ozdaglar, A., & Tahbaz-Salehi, A. (2012). The network origins of aggregate fluctuations. Econometrica, 80(5), 1977-2016. https://doi.org/10.3982/ECTA9623
2. Antràs, P., & Chor, D. (2013). Organizing the global value chain. Econometrica, 81(6), 2127-2204. https://doi.org/10.3982/ECTA10813
3. Barrot, J. N., & Sauvagnat, J. (2016). Input specificity and the propagation of idiosyncratic shocks in production networks. The Quarterly Journal of Economics, 131(3), 1543-1592. https://doi.org/10.1093/qje/qjw018
4. Boehm, C. E., Flaaen, A., & Pandalai-Nayar, N. (2019). Input linkages and the transmission of shocks: Firm-level evidence from the 2011 Tōhoku earthquake. The Review of Economics and Statistics, 101(1), 60-75. https://doi.org/10.1162/rest_a_00750
5. Cameron, A. C., & Miller, D. L. (2015). A practitioner's guide to cluster-robust inference. Journal of Human Resources, 50(2), 317-372. https://doi.org/10.3368/jhr.50.2.317
6. Carvalho, V. M., Nirei, M., Saito, Y. U., & Tahbaz-Salehi, A. (2021). Supply chain disruptions: Evidence from the Great East Japan earthquake. The Quarterly Journal of Economics, 136(2), 1255-1321. https://doi.org/10.1093/qje/qjaa044

7. Carvalho, V. M., & Tahbaz-Salehi, A. (2019). Production networks: A primer. Annual Review of Economics, 11, 635-663. https://doi.org/10.1146/annurev-economics-080218-030212
8. Centre for Research on the Epidemiology of Disasters. (2021). EM DAT: The international disaster database. Université catholique de Louvain. https://www.emdat.be/
9. Costinot, A., Donaldson, D., & Komunjer, I. (2012). What goods do countries trade? A quantitative exploration of Ricardo's ideas. The Review of Economic Studies, 79(2), 581-608. https://doi.org/10.1093/restud/rdr033
10. Costinot, A., Donaldson, D., & Smith, C. (2016). Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. Journal of Political Economy, 124(1), 205-248. https://doi.org/10.1086/684719
11. Dallmann, I. (2019). Weather variations and international trade. Environmental and Resource Economics, 72(1), 155-206. https://doi.org/10.1007/s10640-018-0268-2
12. Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. American Economic Journal: Macroeconomics, 4(3), 66-95. https://doi.org/10.1257/mac.4.3.66
13. Food and Agriculture Organization of the United Nations. (2021). FAOSTAT: Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL
14. Jones, B. F., & Olken, B. A. (2010). Climate shocks and exports. American Economic Review, 100(2), 454-459. https://doi.org/10.1257/aer.100.2.454
15. Marchand, P., Carr, J. A., Dell'Angelo, J., Fader, M., Gephart, J. A., Kummu, M., Magliocca, N. R., Porkka, M., Puma, M. J., & Ratajczak, Z. (2016). Reserves and trade jointly determine exposure to food supply shocks. Environmental Research Letters, 11(9), Article 095009. https://doi.org/10.1088/1748-9326/11/9/095009
16. Morris, T. P., White, I. R., & Crowther, M. J. (2019). Using simulation studies to evaluate statistical methods. Statistics in Medicine, 38(11), 2074-2102. https://doi.org/10.1002/sim.8086
17. United Nations Statistics Division. (2021a). Standard country or area codes for statistical use. United Nations. https://unstats.un.org/unsd/methodology/m49/
18. United Nations Statistics Division. (2021b). UN Comtrade database. United Nations. https://comtrade plus.un.org/
19. World Bank. (2021). World development indicators. World Bank. https://databank.worldbank.org/source/world-development-indicators