



The inter-industry structure of the USMCA countries analysis: network GMRIO and data science approach

Authors: Bouchain, Méndez, Hernández, and Quiroga
(IIEc-UNAM)



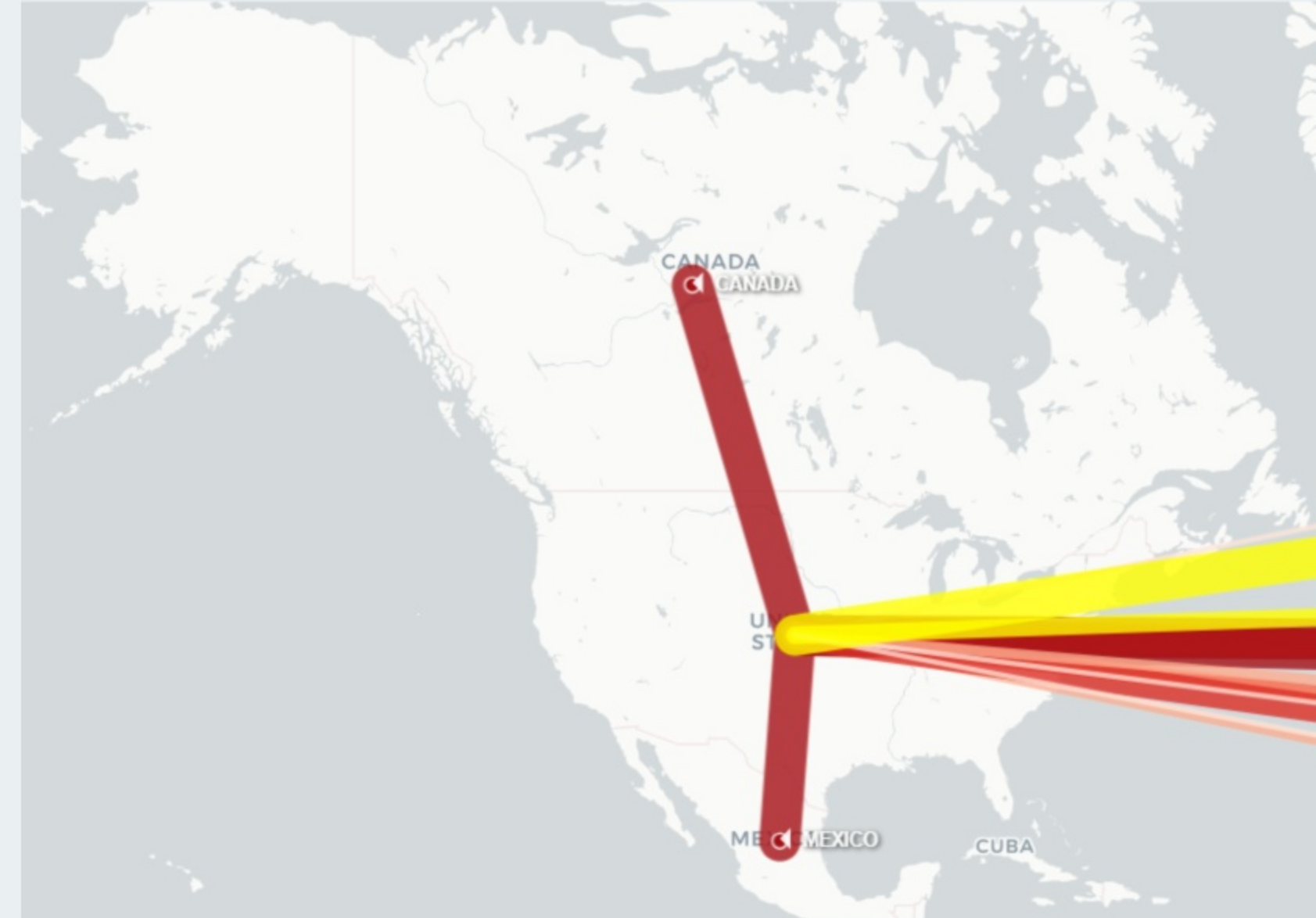
The inter-industry structure of the USMCA countries is analyzed using network Global Multi-Regional Input-Output (GMRIO) data science techniques, illuminating critical industrial relationships.

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Dr. Jorge Méndez Astudillo
Mat. Angel David Hernández Moreno
Lic. Aurora Quiroga Martínez

Motivations.

This presentation focuses on the inter-industry structure of the USMCA countries, analyzing how industries in Mexico, the USA, and Canada are interconnected through network GMRIO and data science approaches.

The COVID-19 pandemic exposed systemic limits (stagnant growth and wealth concentration), forcing a reconsideration of state intervention.ience approaches.



Central Research Question

Core Inquiry: How are the industries of Mexico, the United States, and Canada classified based on their Domestic Value Added (DVA) contained in exports and their orientation towards the international market?

Objective: Unveil the underlying structural dynamics affecting trade integration and global value chain (GVC) participation within North America.

Data Source: OECD Inter-Country Input-Output (ICIO) tables (1995–2022 extended, 2025 edition).



Methodology: Leveraging Data Science Techniques

Algorithms: Implementation of k-means, DBSCAN (density-based), and Hierarchical Clustering via Python's scikit-learn.

Hierarchical Criteria: Ward's method utilized to establish industry segments based on value-added production distances.

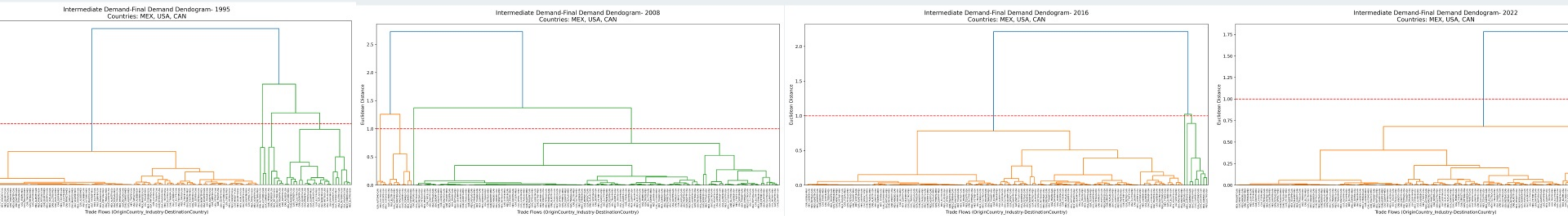
Variables: Mapping multi-dimensional trade attributes without data partitioning.

The dendrogram illustrates the clustering results, showing the relationships between industries according to their trade attributes. This visualization provides insights into how different sectors are interconnected and reflects the degree of dependency among them.

Industry Classification

Activity	Acronym	Activity	Acronym
Forestry and logging	FORLOG	Manufacture of motor vehicles, trailers and semi-trailers	AUTOMO
Fishing and aquaculture	PESCAC	Building of ships and boats	OTRTRA
Extraction of crude petroleum and natural gas	PETGAS	Manufacture of other transport equipment	TRANSP
Manufacture of food products; beverages and tobacco products	ALYBEB	Manufacture of furniture and other manufacturing	OTRMAN
Manufacture of textiles, wearing apparel, leather and related products	TEXTYP	Electricity, gas, steam and air conditioning supply	ELEGAS
Manufacture of wood and of products of wood and cork	MADYPR	Water supply; sewerage, waste management and remediation activities	AGUBAS
Manufacture of paper and paper products; Printing and reproduction of media	PAPYPR	Construction	CONSTR
Manufacture of coke and refined petroleum products	PETREF	Wholesale and retail trade; repair of motor vehicles and motorcycles	COMREV
Manufacture of chemicals and chemical products	QUIMYP	Land transport and transport via pipelines	TRATIE
Manufacture of pharmaceutical products and preparations	FARMED	Water transport	TRAGUA
Manufacture of rubber and plastic products	HUPLAS	Air transport	TRAAIR
Manufacture of other non-metallic mineral products	PRNOMT	Warehousing and support activities for transportation	ALMSTR
Manufacture of basic iron and steel	METBAS	Postal and courier activities	POSTME
Manufacture of basic precious and other non-ferrous metals	NONFER	Accommodation and food service activities	HOTYRE
Manufacture of fabricated metal products	PRMETA	Publishing, Motion picture, video, television production and broadcasting	MMTVRA
Manufacture of computer, electronic and optical products	ELCTRO	Telecommunications	TELECO
Manufacture of electrical equipment	ELCTRI	Computer programming and information service activities	ITSERV
Manufacture of machinery and equipment n.e.c.	MAQYEQ		

INTERMEDIATE DEMAND-FINAL DEMAND DENDOGRAMS



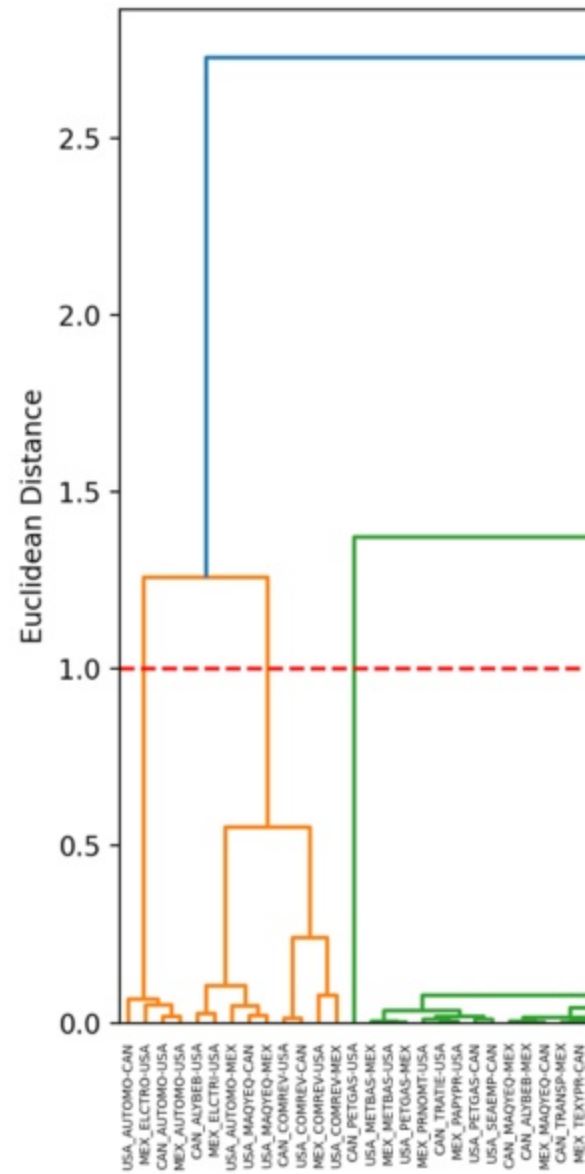
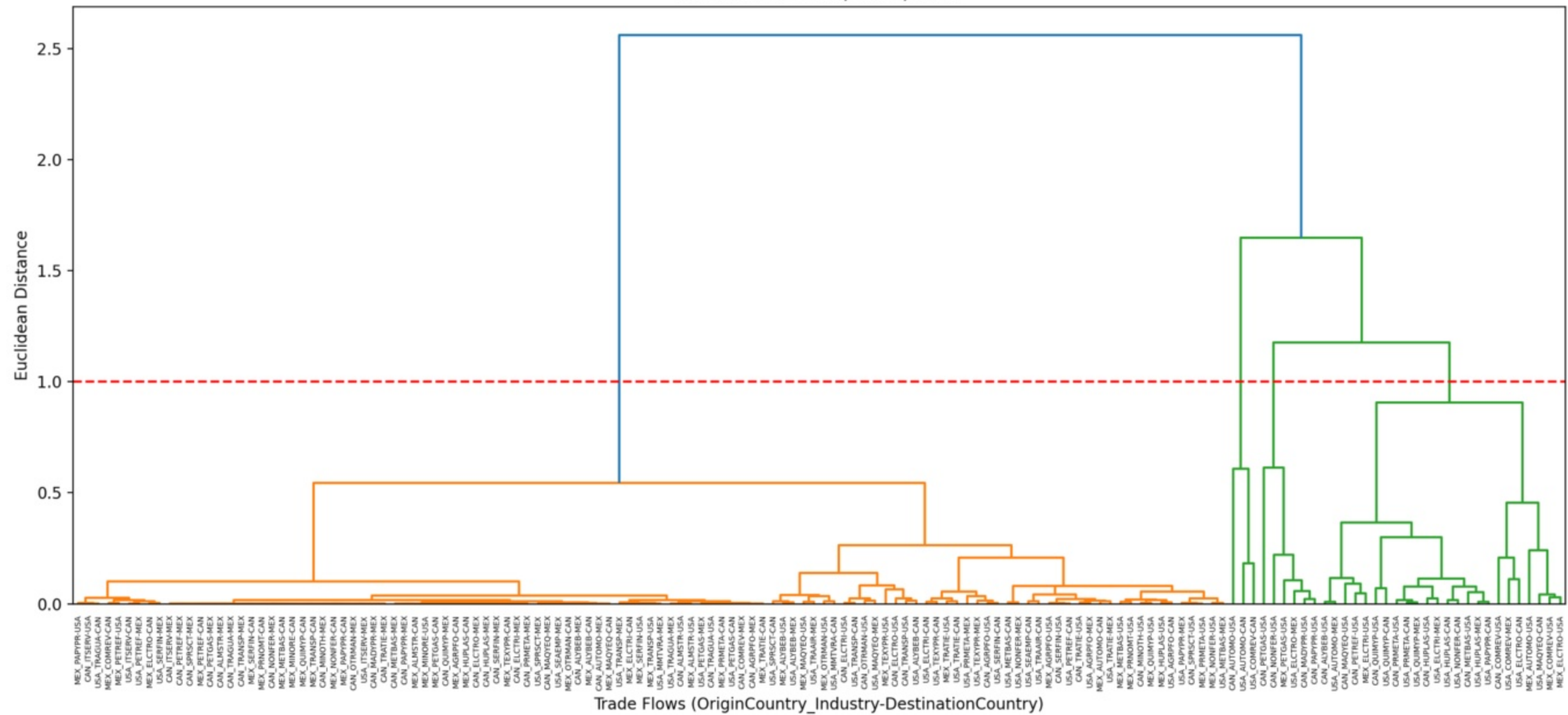
The Ward-linkage algorithm isolates a clear polarization in North American transaction patterns.

Polarized Clusters: Below the 1.0 threshold, the matrix splits into a massive baseline trade group (Orange) and an exclusive high-intensity corridor (Green).

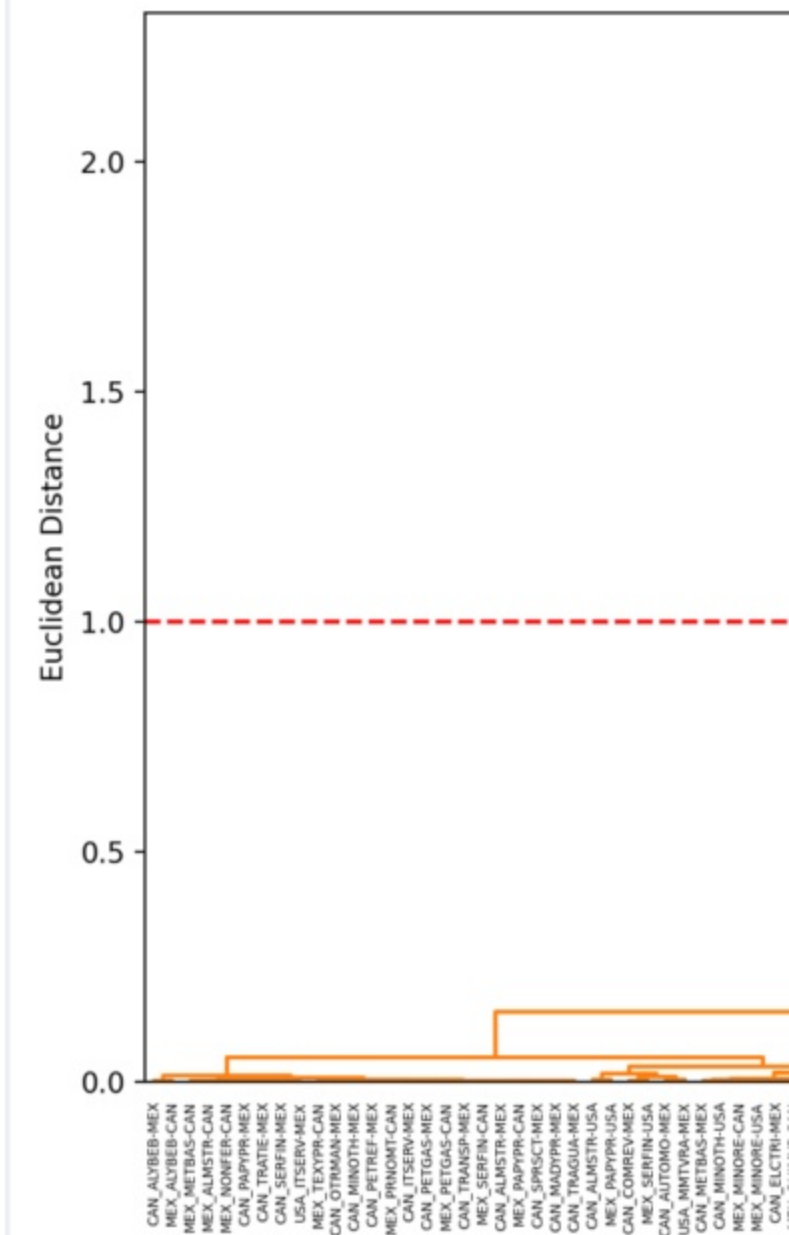
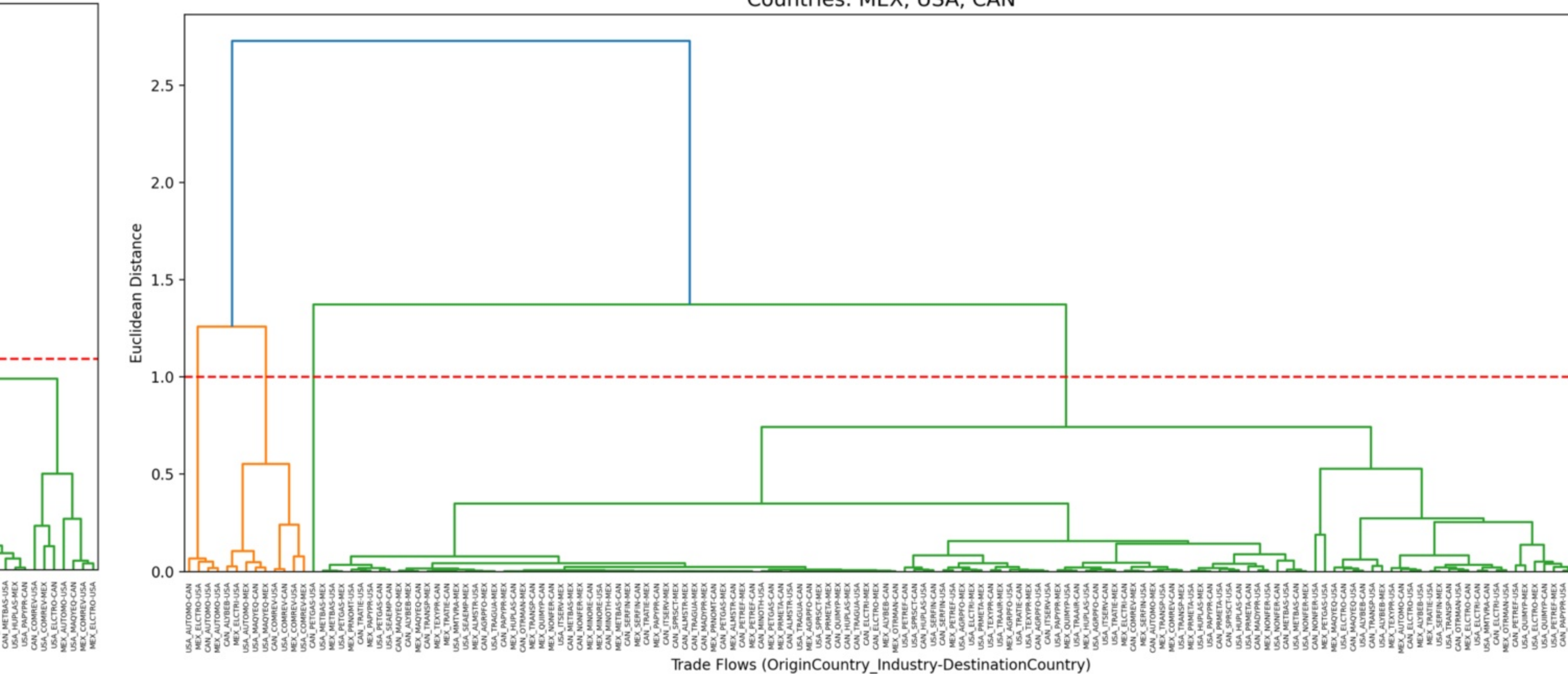
Ecosystem Isolation: The green cluster captures highly concentrated automotive (AUTOMO) and electronic (ELCTRO) transborder flows.

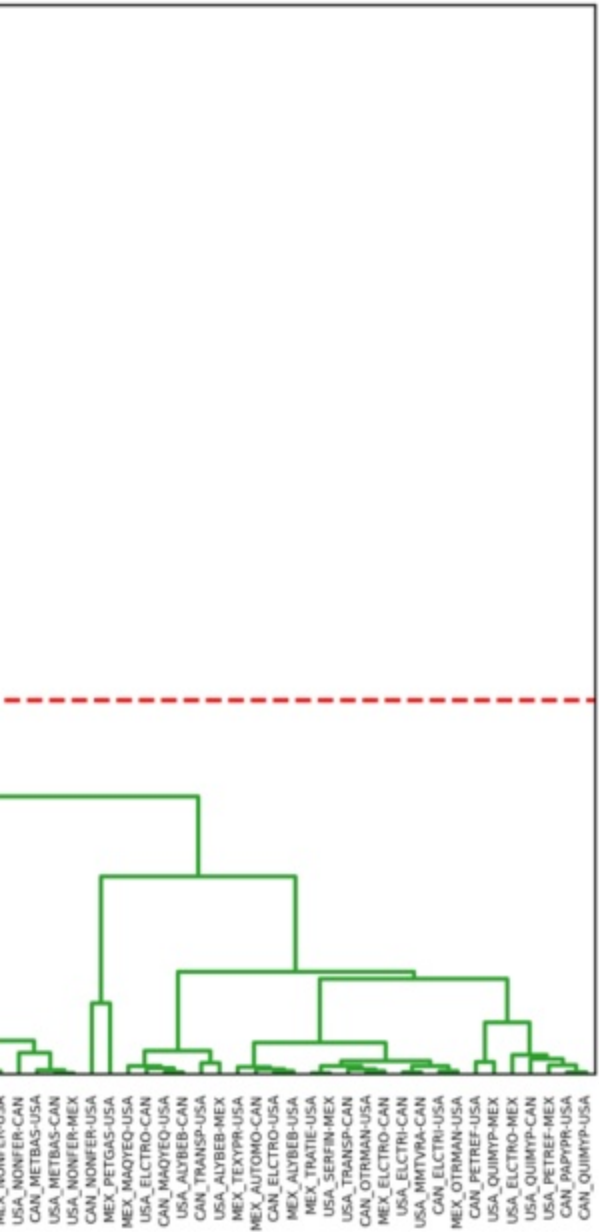
Hyper-Specialization: Over time (1995 -> 2022), the green group becomes visibly tighter, proving that these strategic sectors operate detached from the average regional economy.

Intermediate Demand-Final Demand Dendogram- 1995
Countries: MEX, USA, CAN

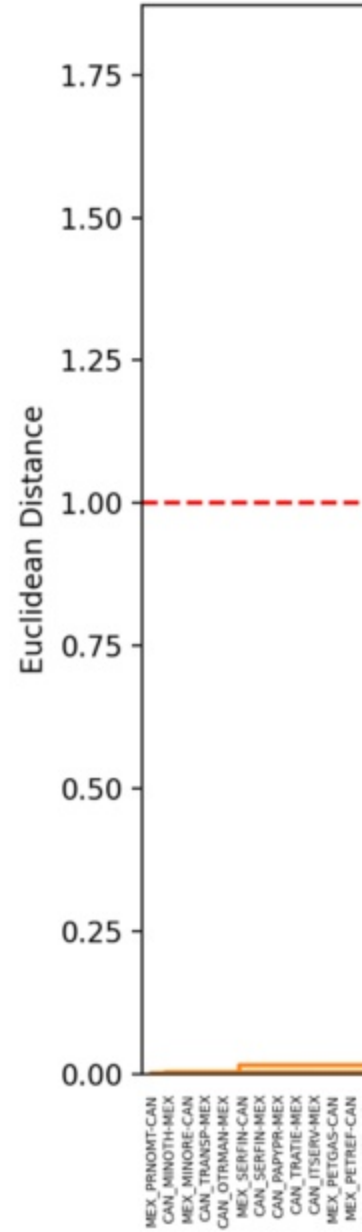
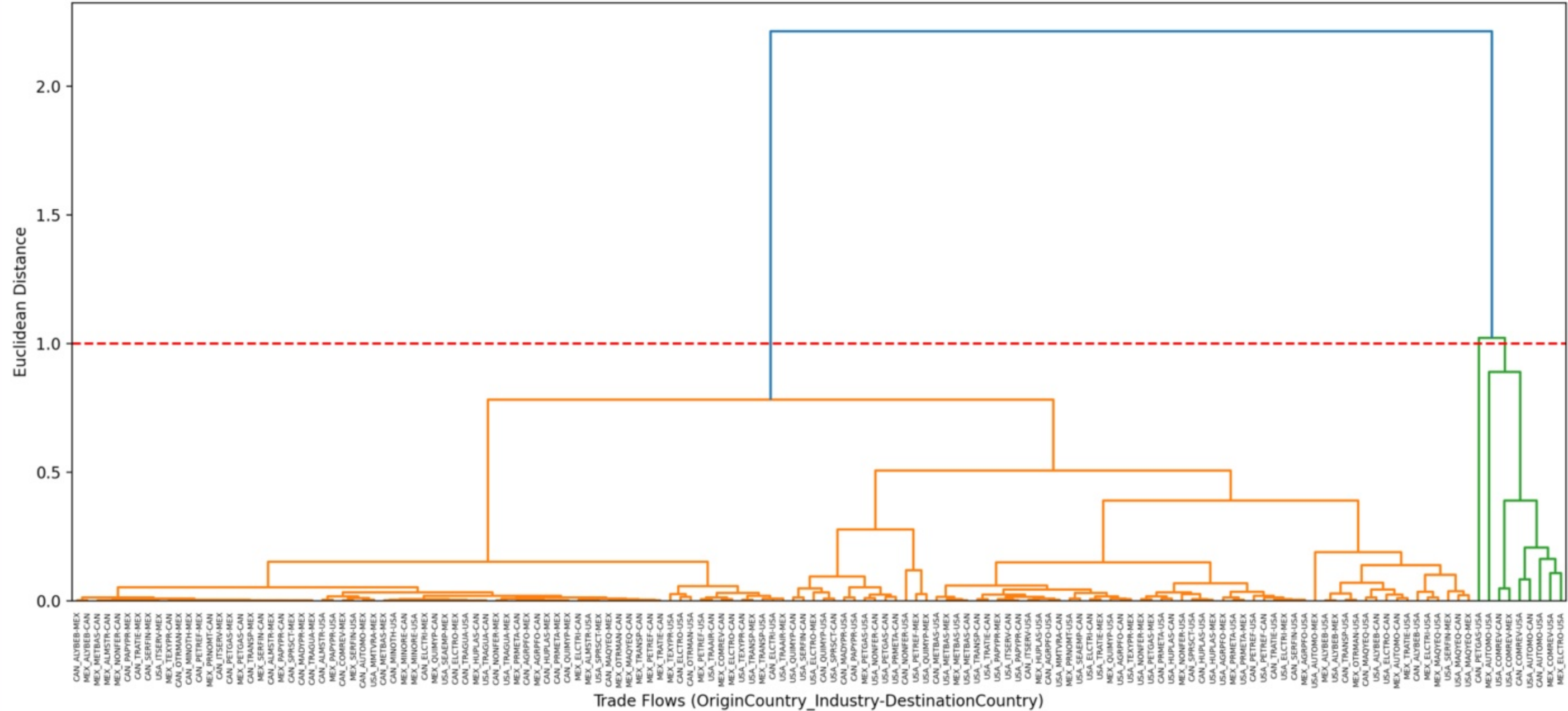


Intermediate Demand-Final Demand Dendogram- 2008
Countries: MEX, USA, CAN

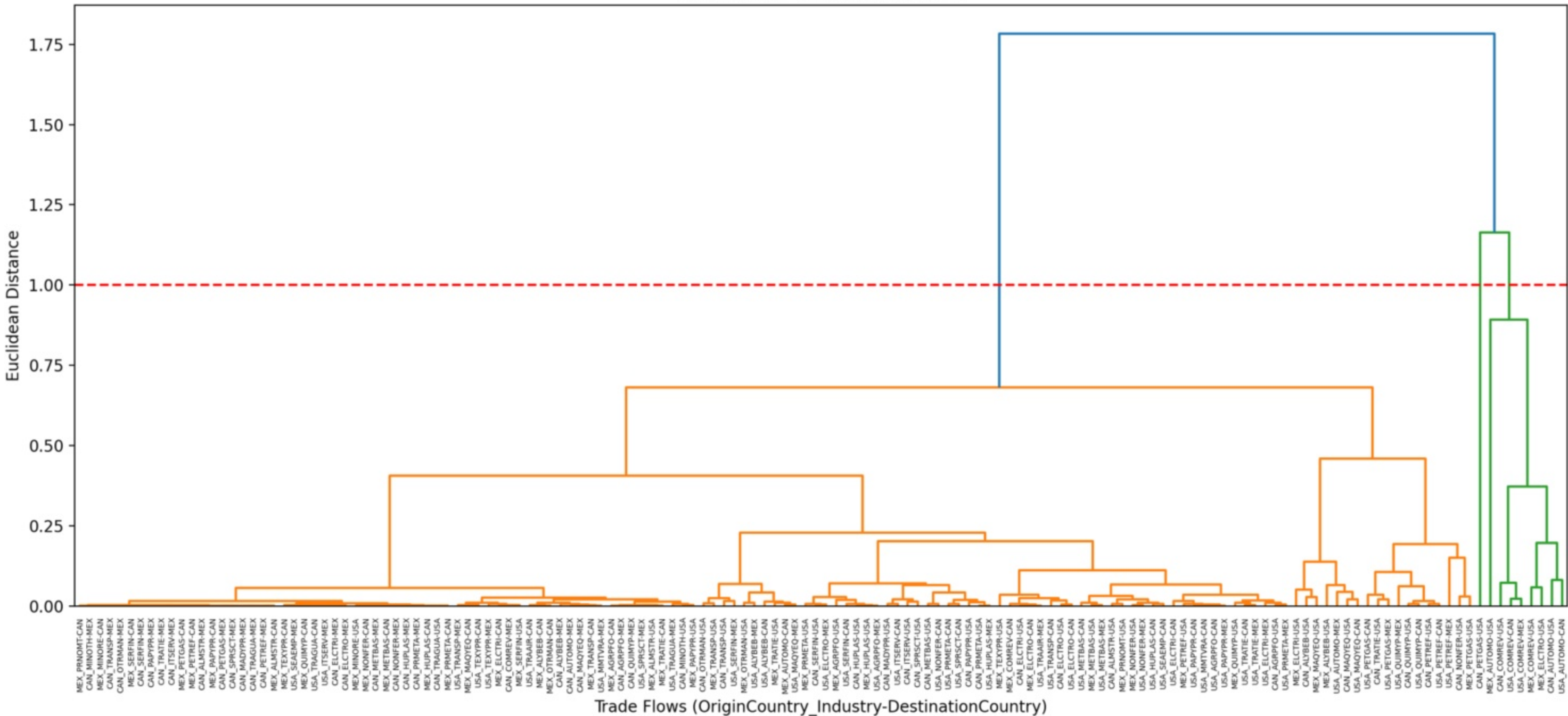
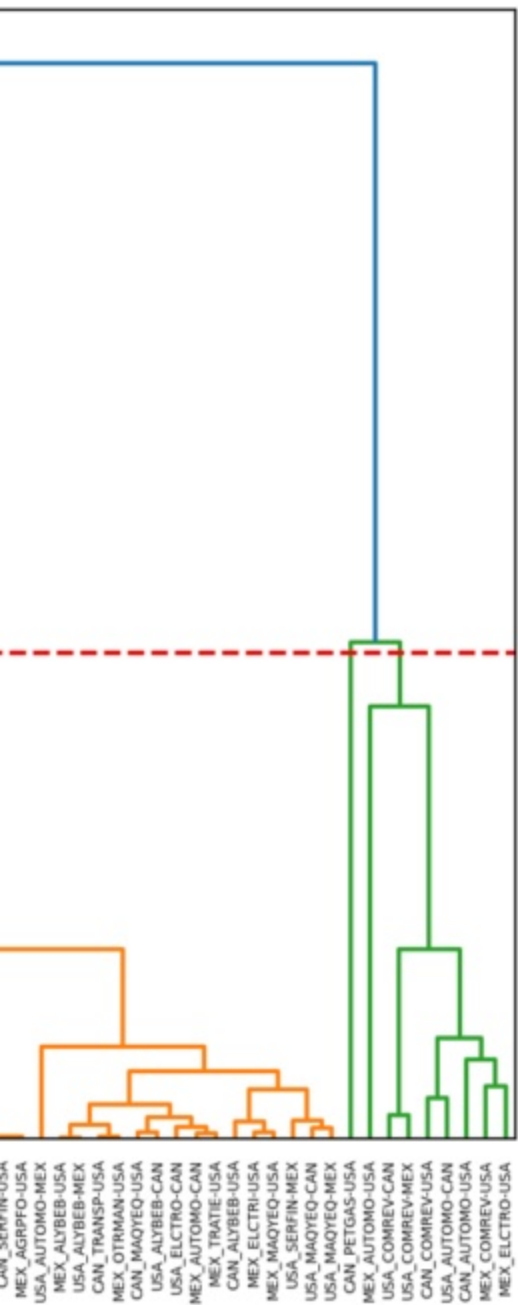




Intermediate Demand-Final Demand Dendrogram- 2016
Countries: MEX, USA, CAN

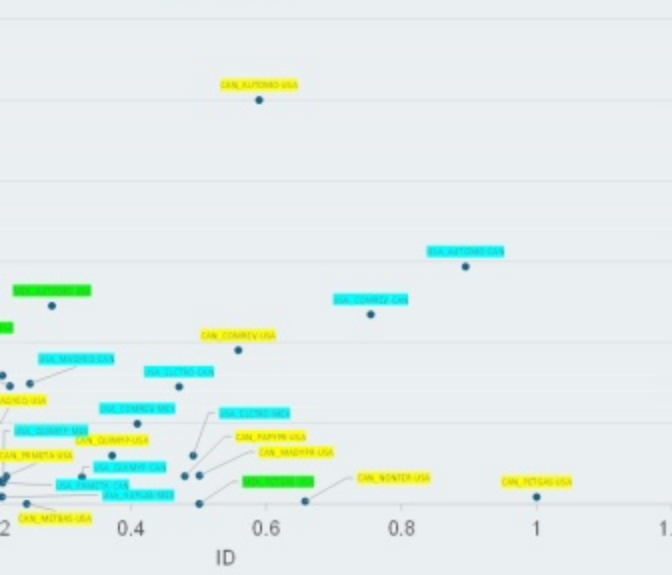


Intermediate Demand-Final Demand Dendrogram- 2022
Countries: MEX, USA, CAN

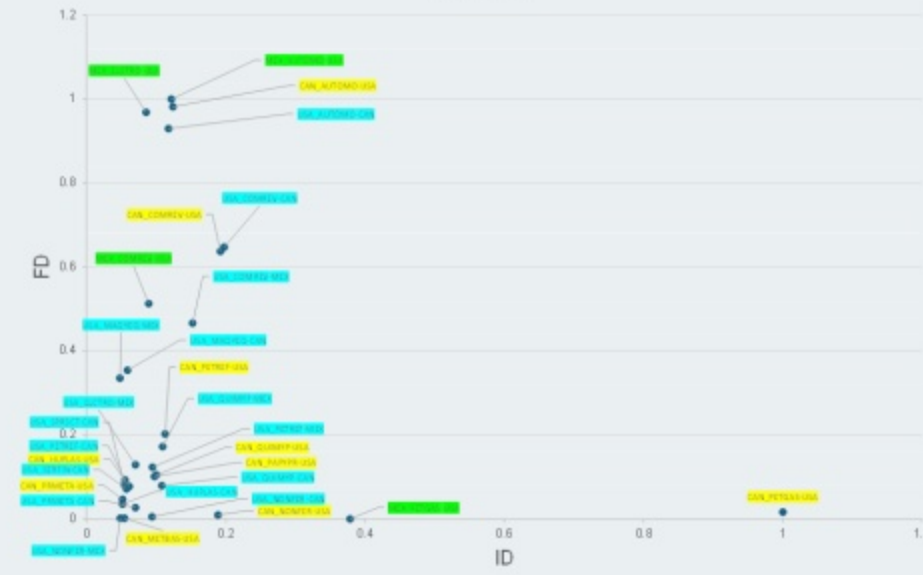


INTERMEDIATE DEMAND-FINAL DEMAND PATTERNS

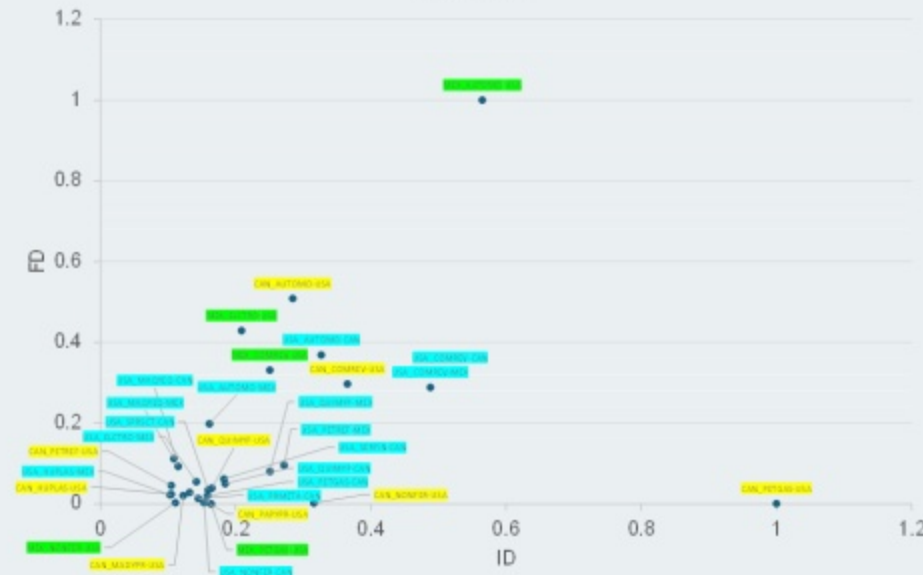
Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 1995.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



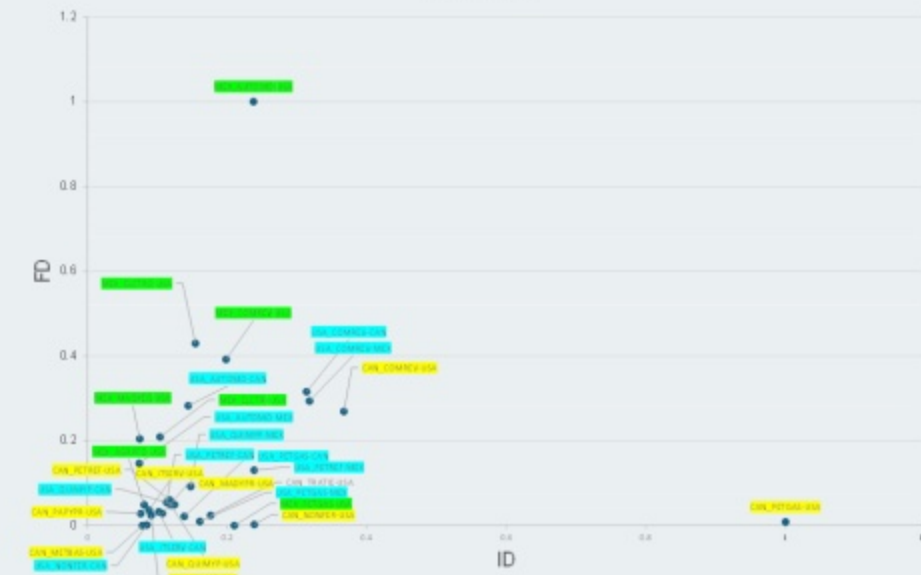
Graph 3: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 2008.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



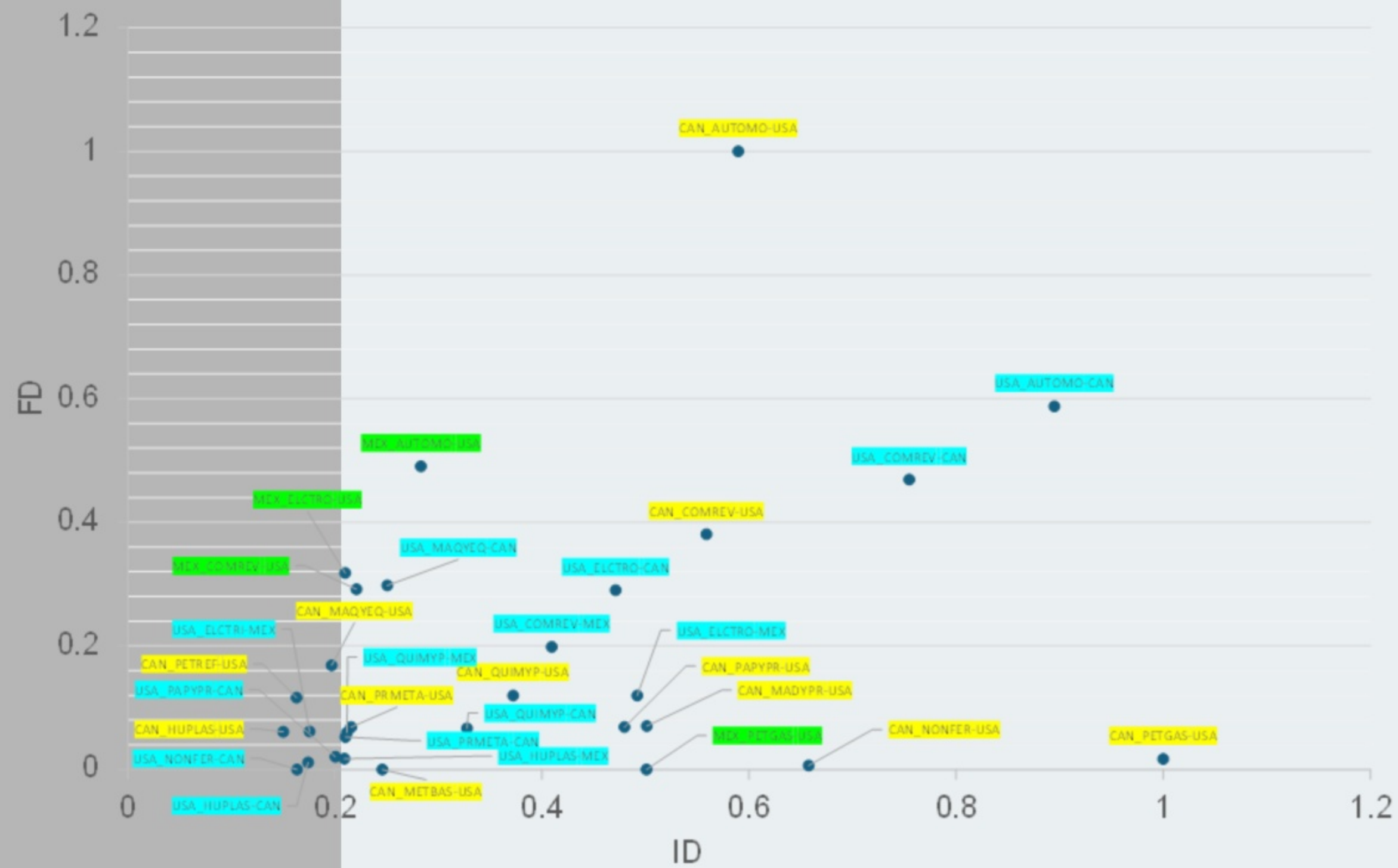
Graph 7: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 2016.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



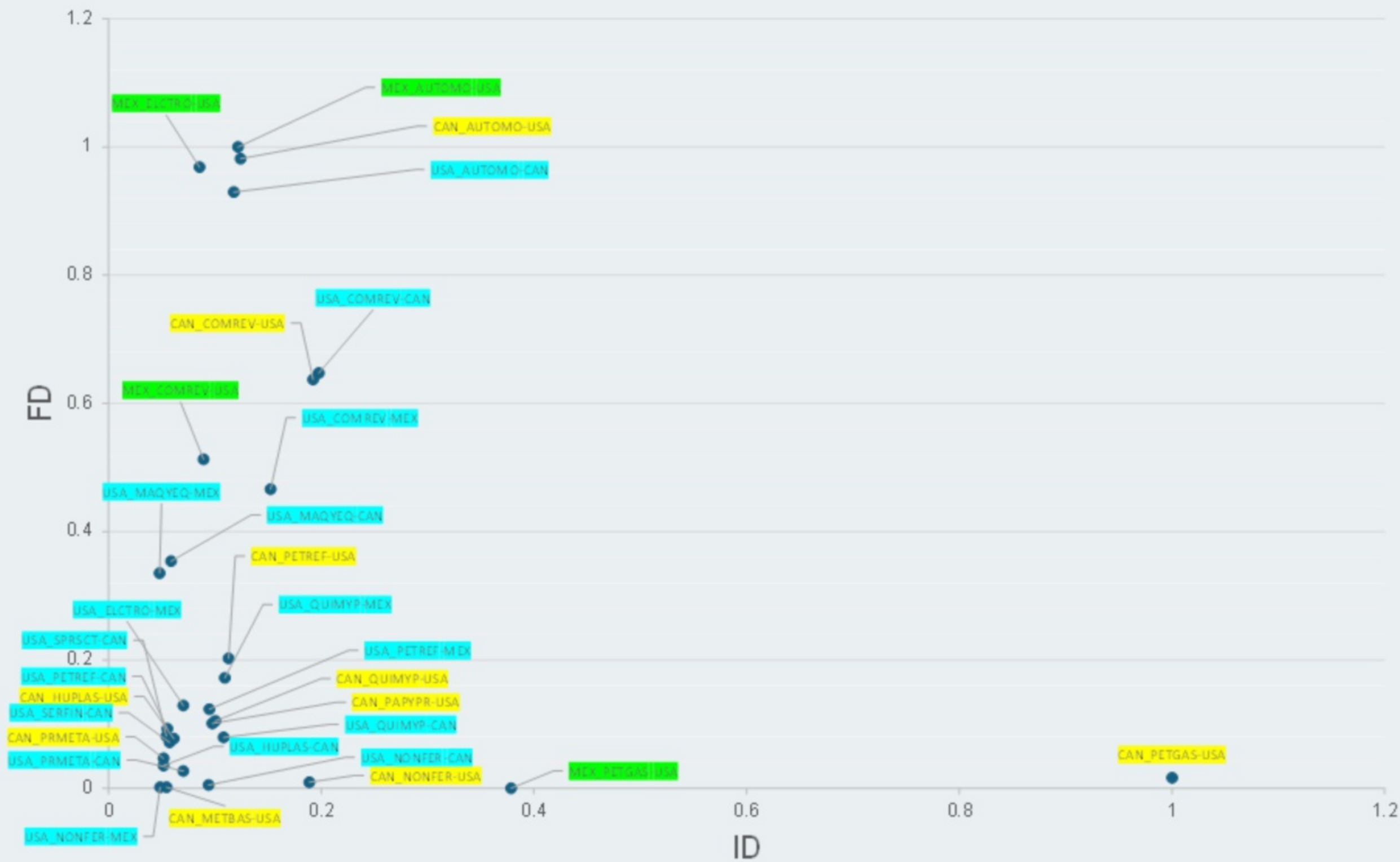
Graph 8: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 2022.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



Graph 5: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 1995.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



Graph 3: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 2008.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.

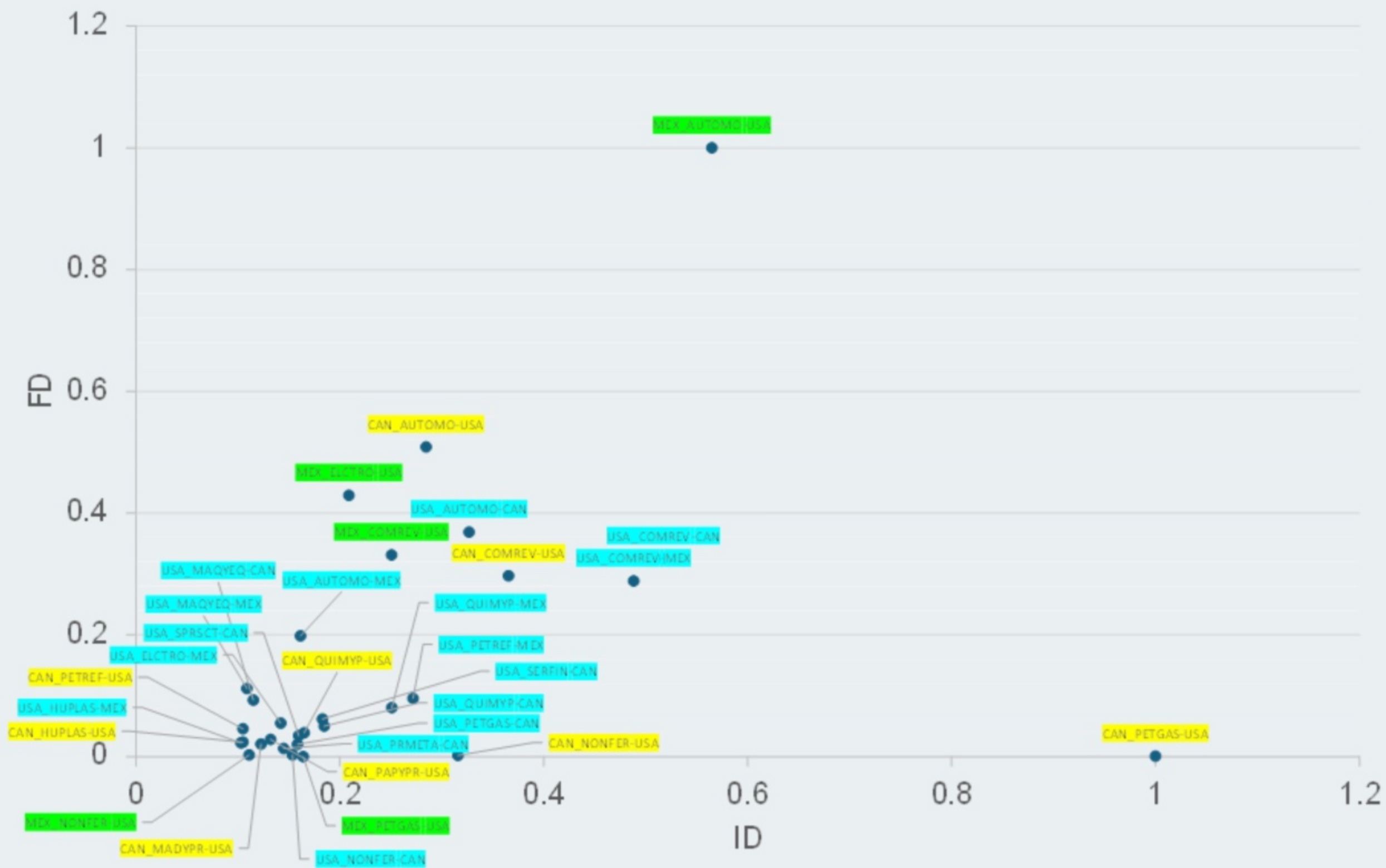


Graph 7: Hierarchical
Intermediate Demand



2008.
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Graph 7: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 2016.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



Graph 8: H
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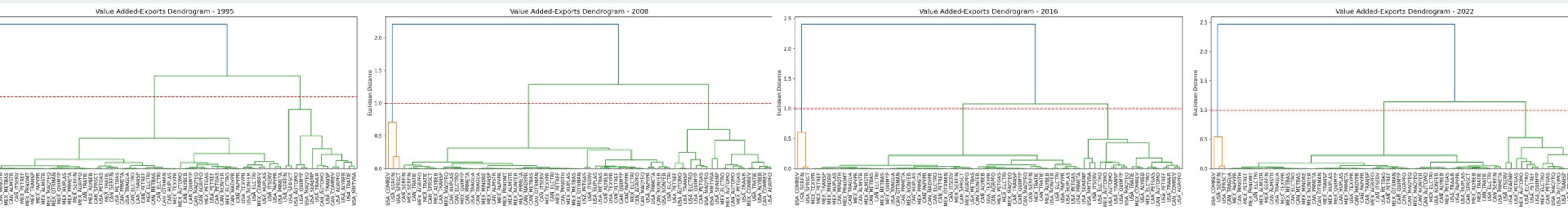


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Graph 8: Hierarchical cluster (Ward). UMSCA: USA, México y Canadá, 2022.
Intermediate Demand vs. Final Demand. Country of origin-Sector-Country of destination.



VALUE ADDED-EXPORTATIONS DENDOGRAMS

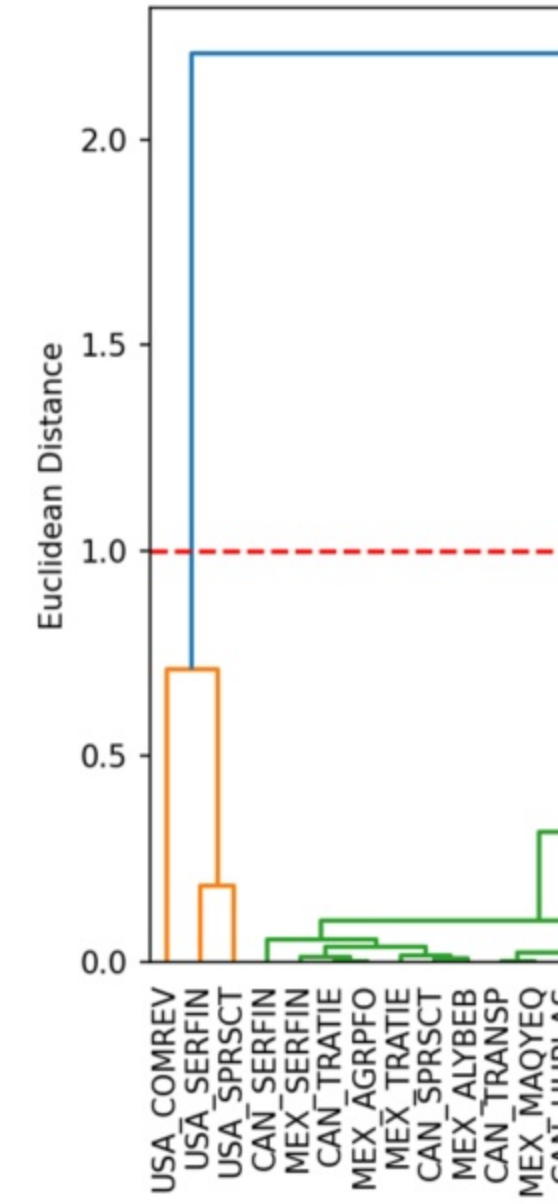
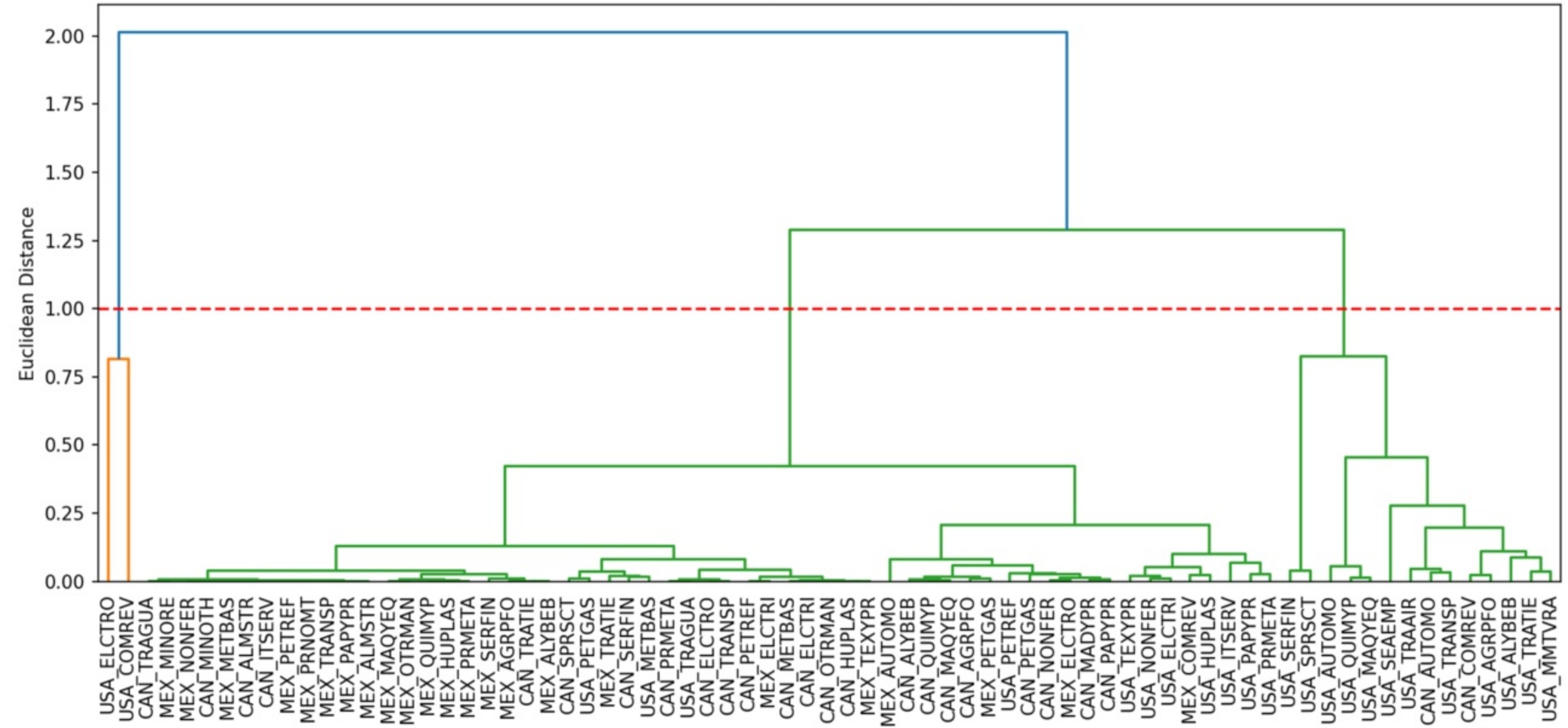


Classifying sectors by gross trade vs. real local retention exposes the underlying hierarchy of the bloc. US Service Hegemony: High-DVA domestic sectors (USA_COMREV, USA_SERFIN, USA_SPRSCT}) isolate at a massive Euclidean distance (≈ 2.0), driven by massive internal value capture.

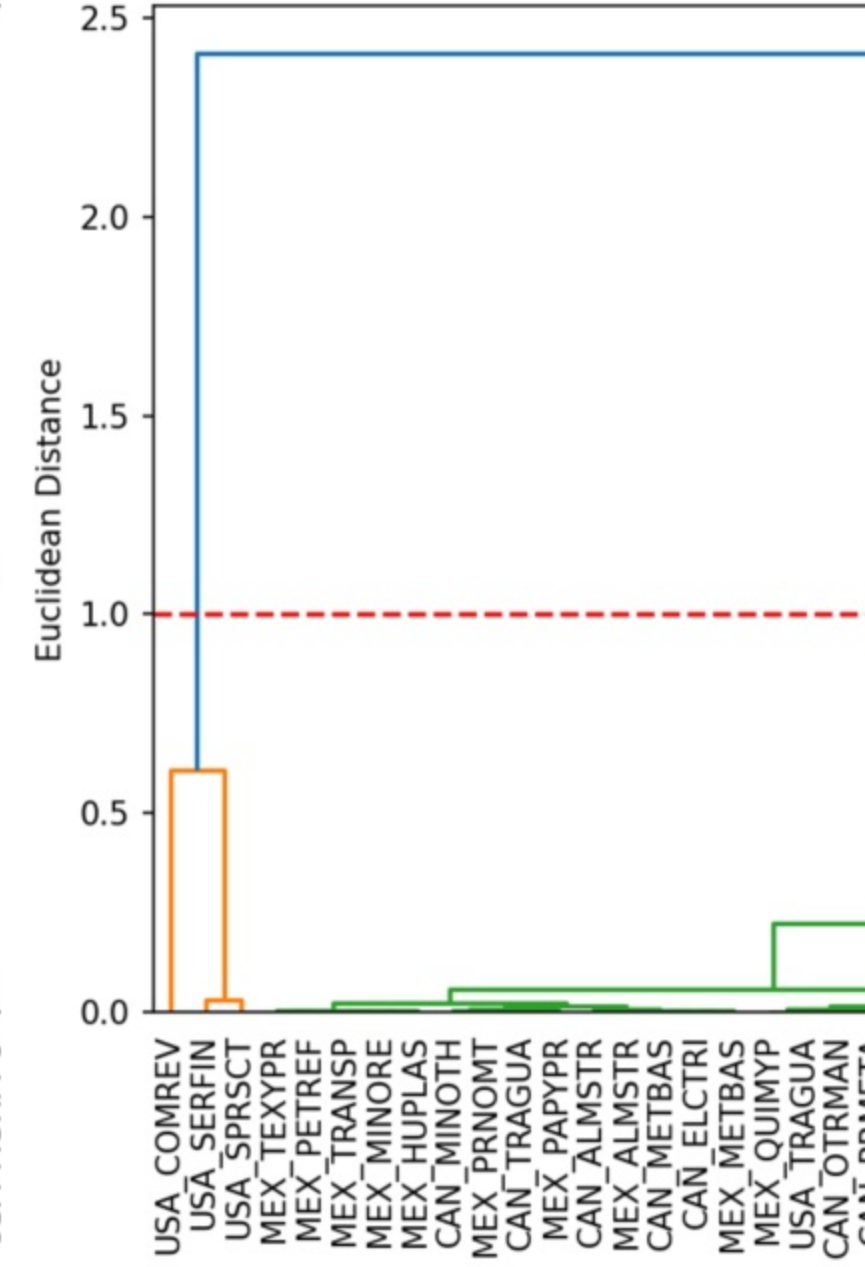
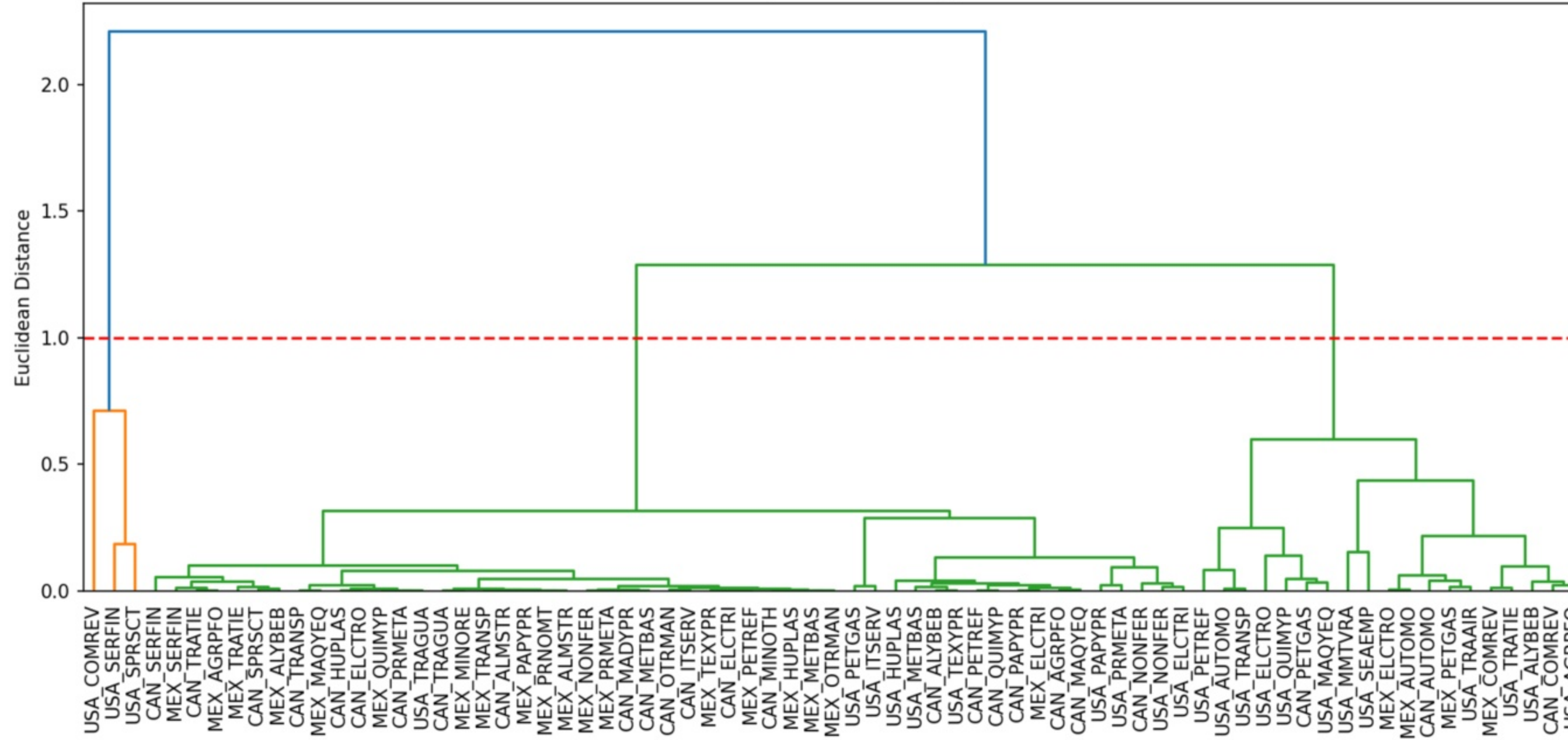
The Assembly Trap: Core Mexican exporting industries (MEX_AUTOMO, MEX_ELCTRO) fail to break away, merging instead into the general baseline pool (Green).

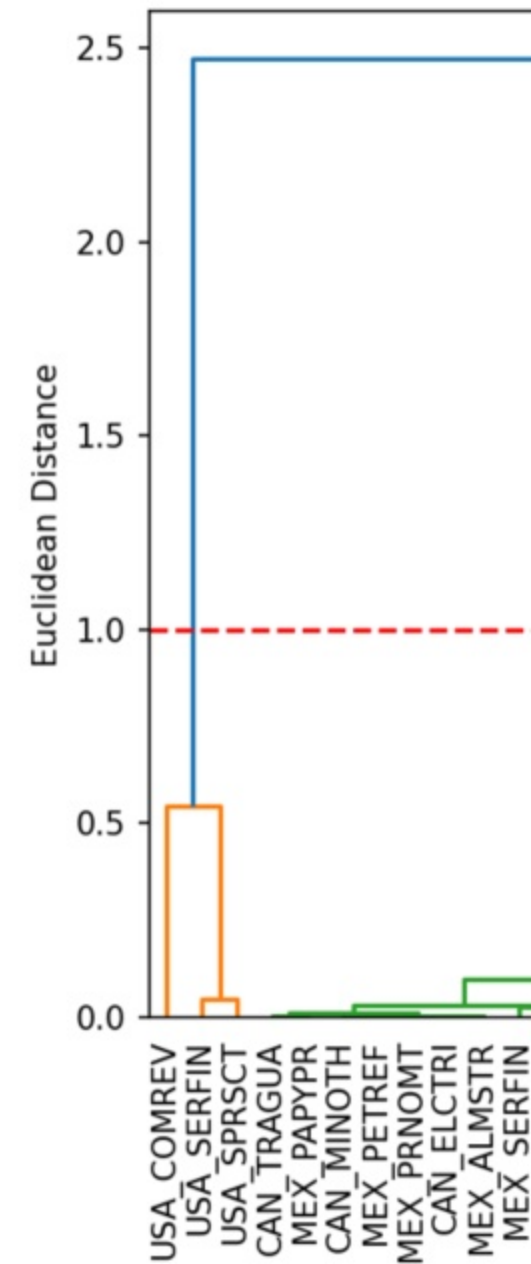
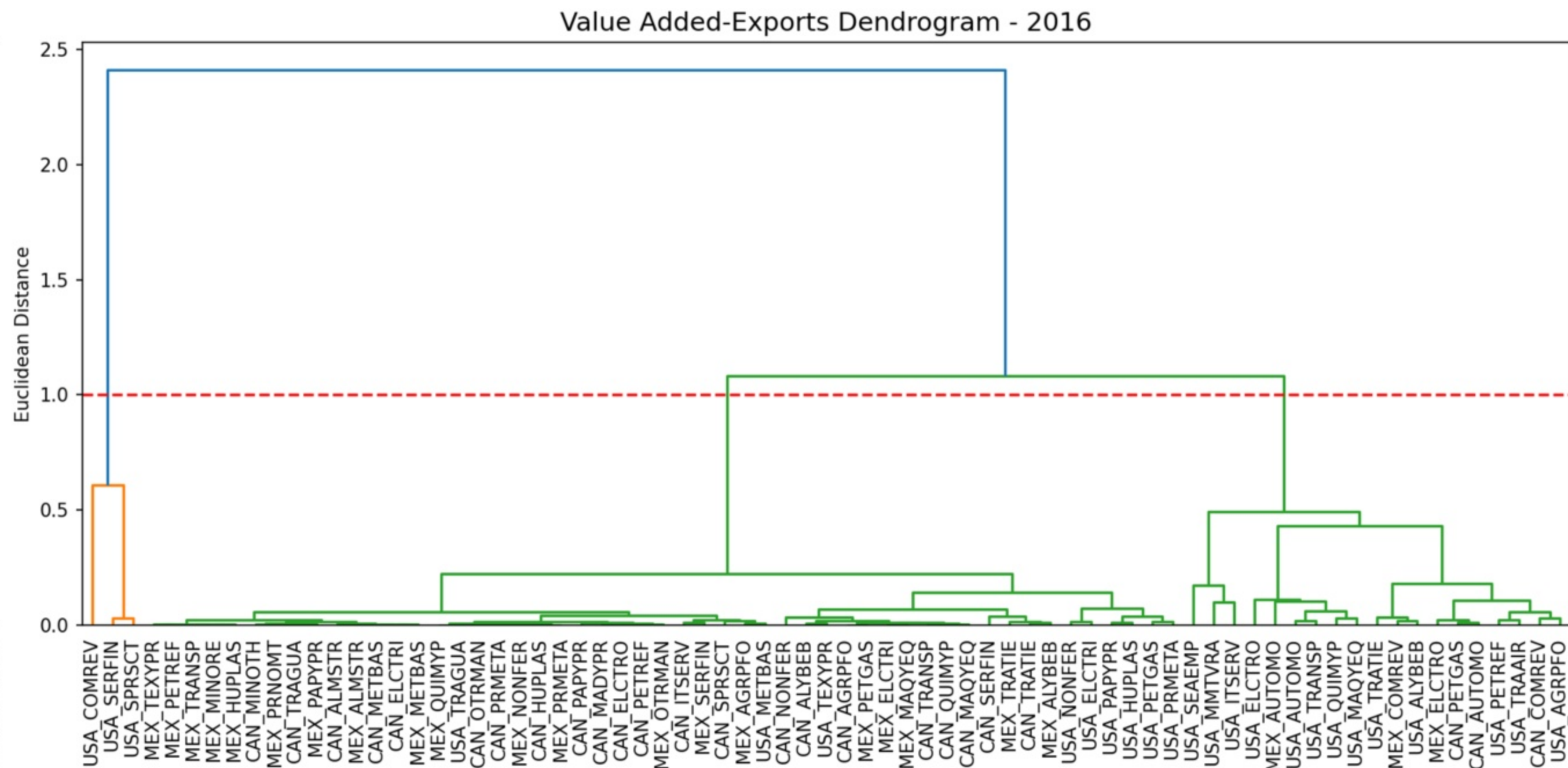
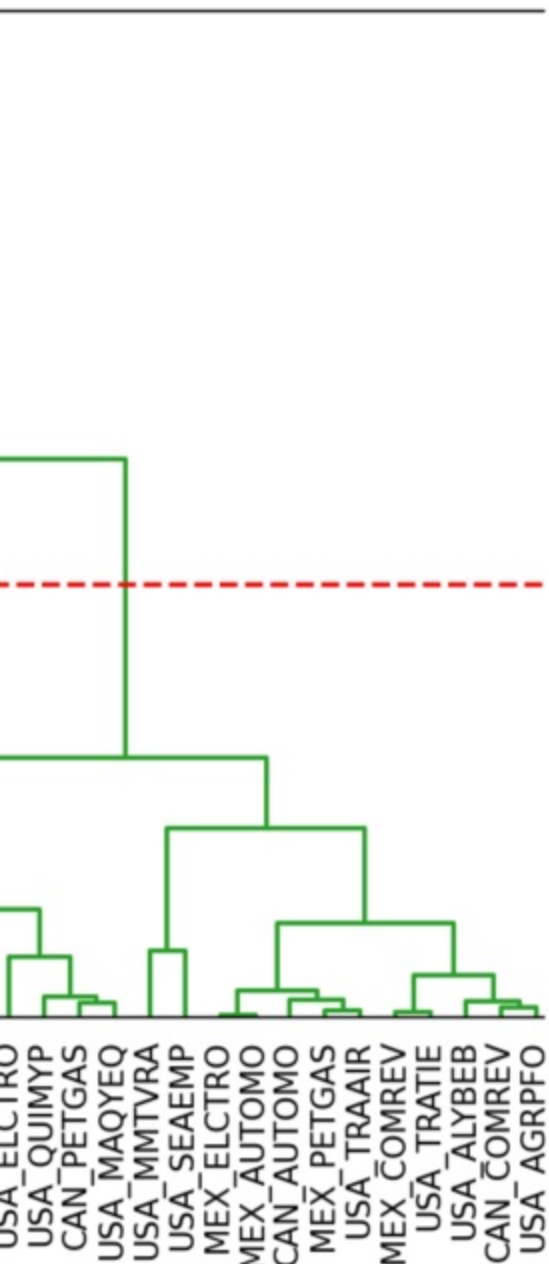
Profile Resemblance: Unsupervised clustering groups Mexico's star industries with traditional sectors because high import-content dilutes their ability to retain domestic value.

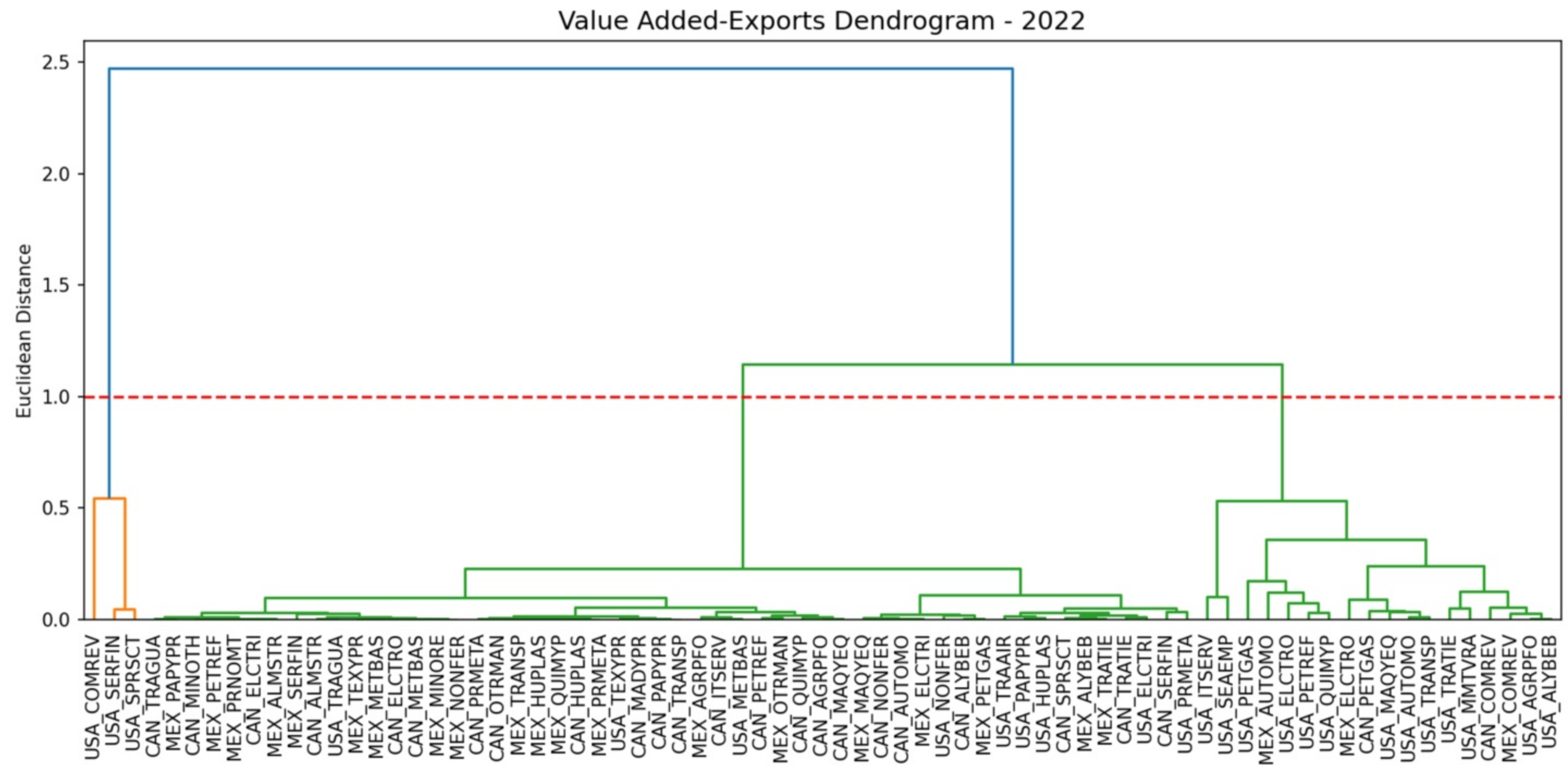
Value Added-Exports Dendrogram - 1995



Value Added-Exports Dendrogram - 2008





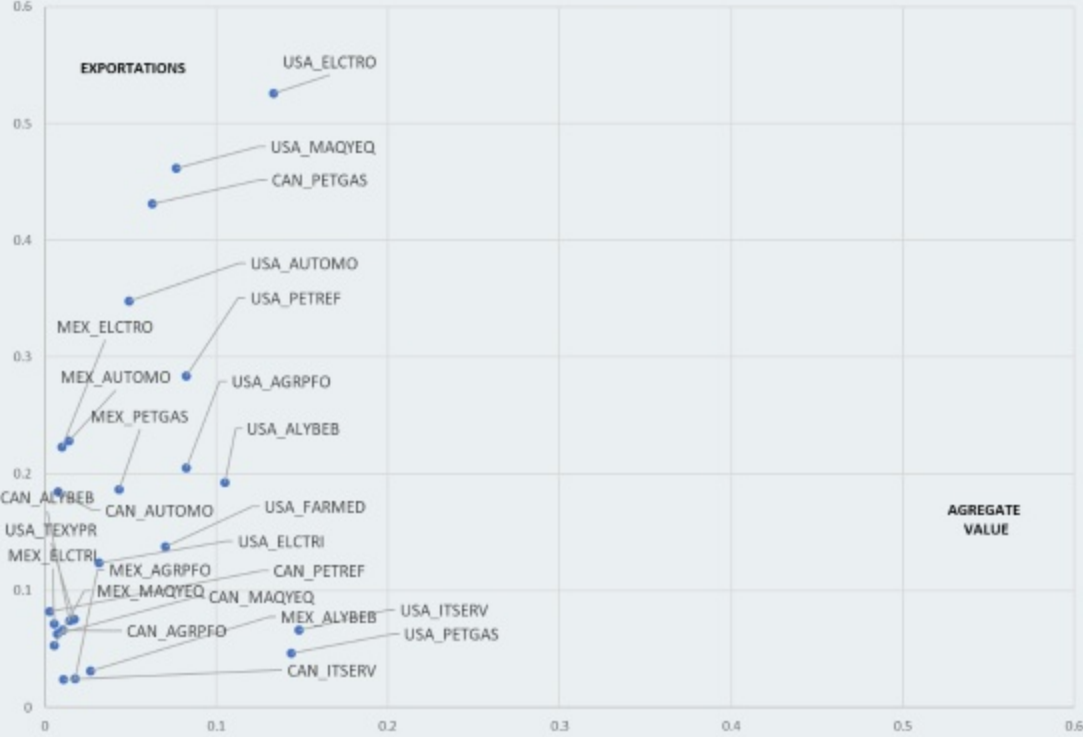


VALUE ADDED-EXPORTATIONS DENDOGRAMS

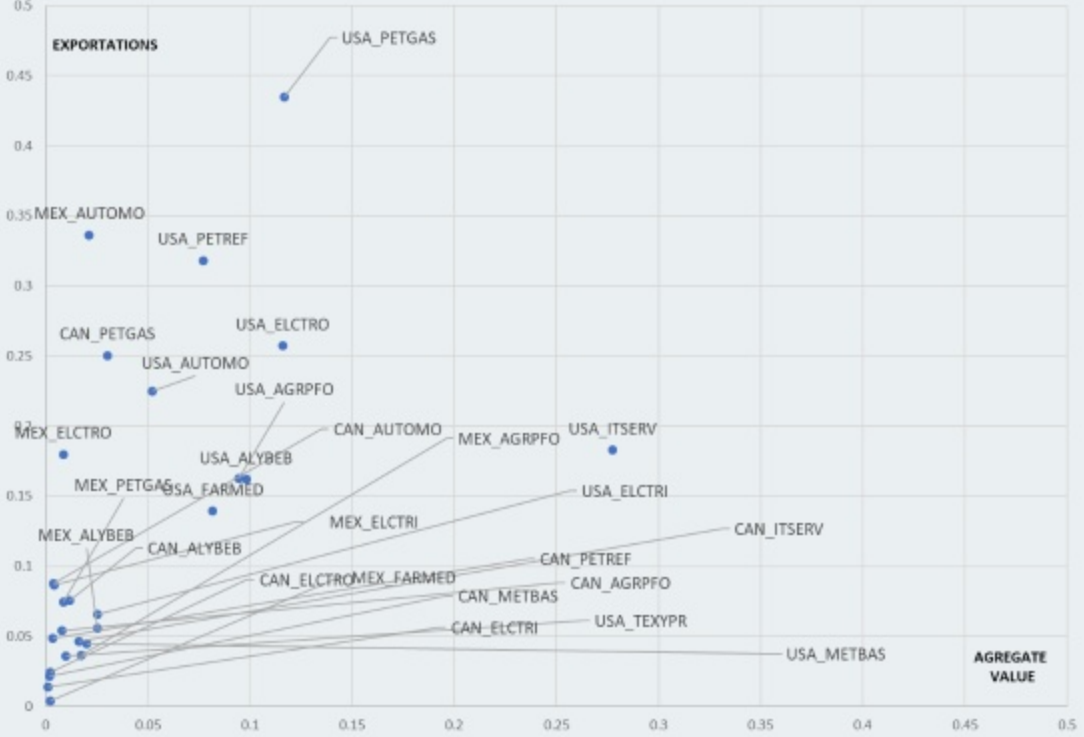
USMCA: EXPORTATIONS VS. AGREGATE VALUE, 2008.



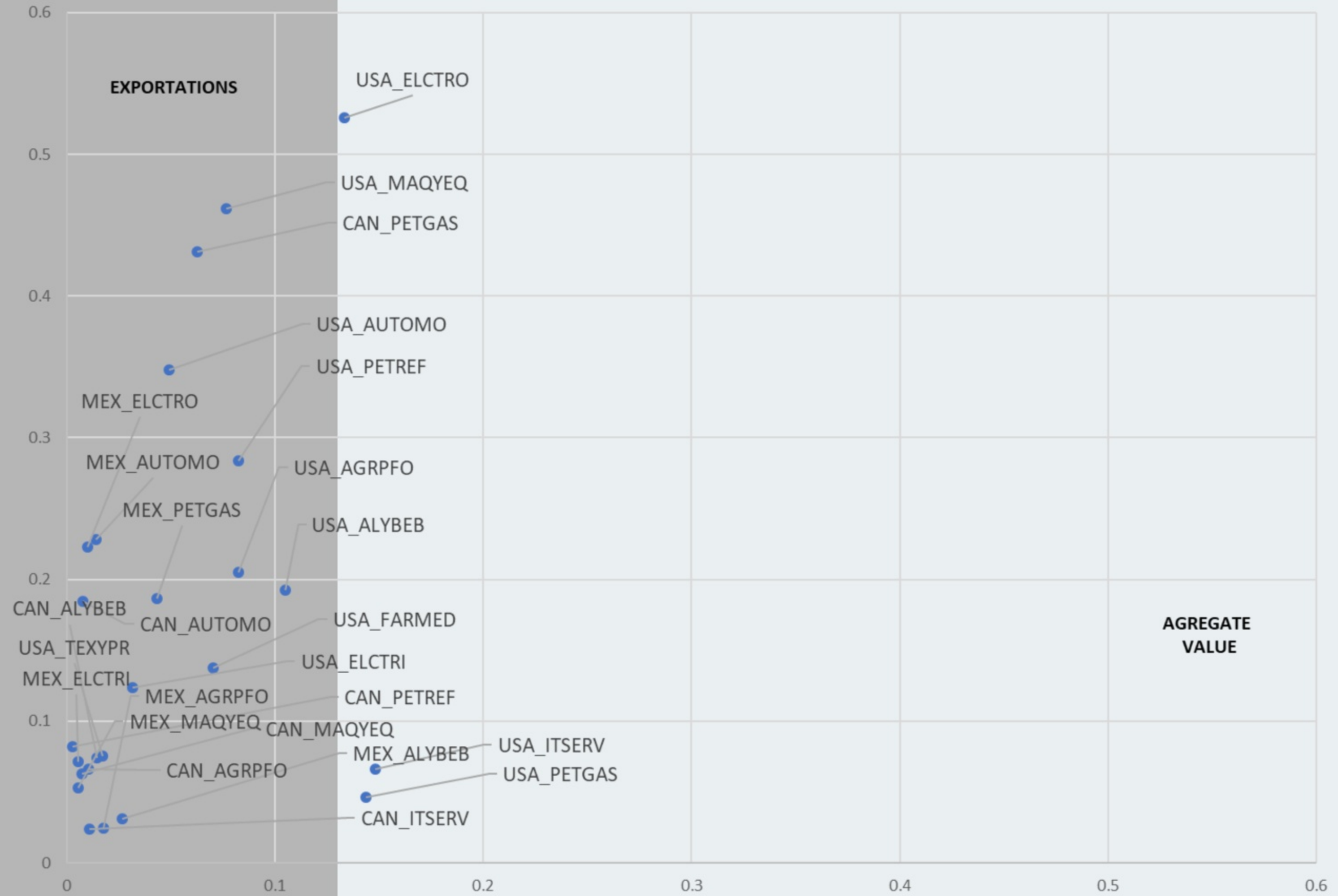
USMCA: EXPORTATIONS VS. AGREGATE VALUE, 2008.



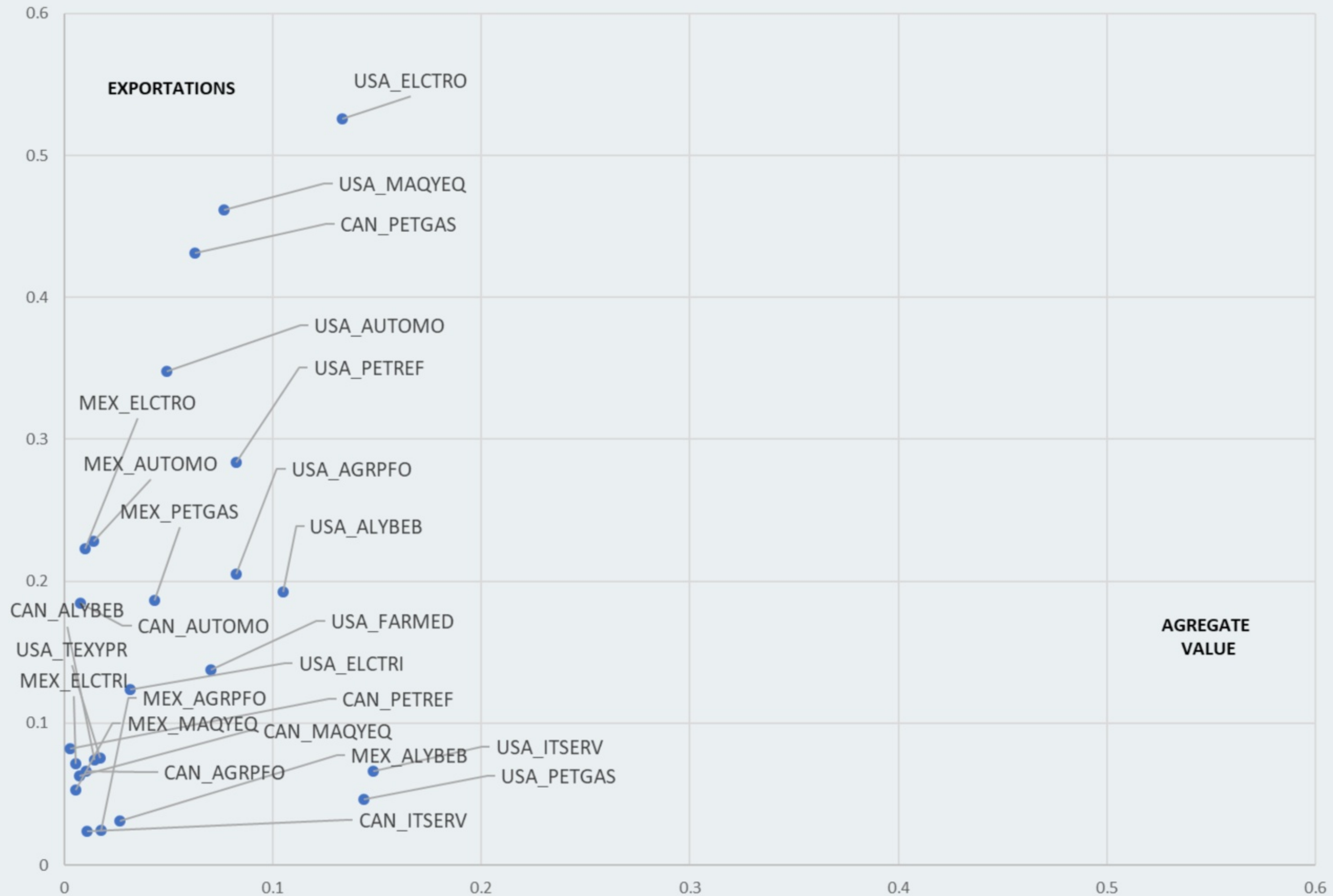
USMCA: EXPORTATIONS VS. AGREGATE VALUE, 2022.

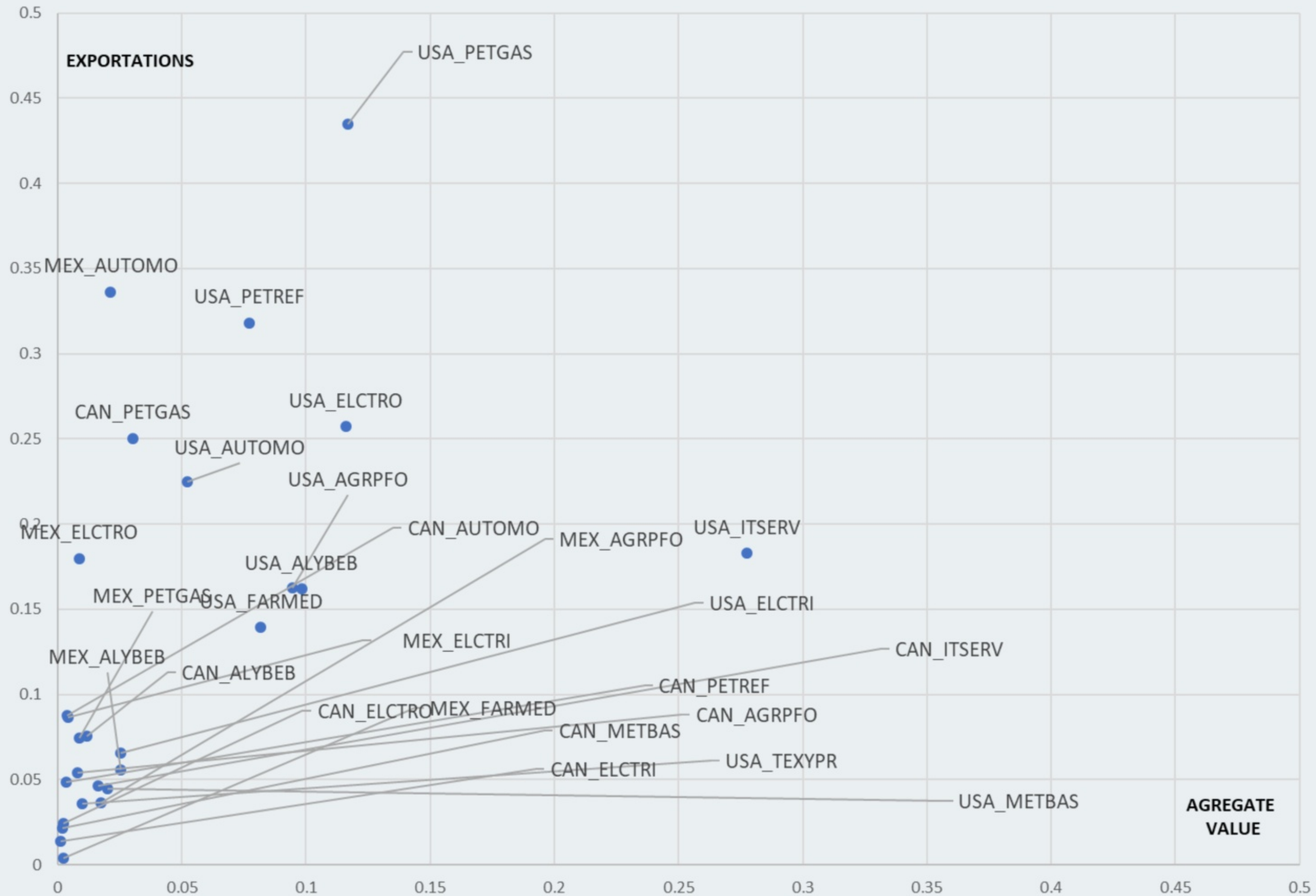


USMCA: EXPORTATIONS VS. AGREGATE VALUE, 2008.



USMCA: EXPORTATIONS VS. AGREGATE VALUE, 2008.





Mathematical Framework

Understanding the mathematical foundations allows for the accurate representation of inter-industry dynamics in value chains, revealing crucial insights into domestic and foreign contributions.

Mathematical Model

Reference

The analysis utilizes the model from Wang et al. (2017), which decomposes inter-industry transactions into domestic and foreign components. This framework enables the examination of how industries interact within the Global Value Chains (GVCs) and the broader economic structure of the USMCA countries.

Following the GMRIO framework partitioned into Domestic (D) and Foreign (F) components based on Wang et al. (2017):

$$X = A^D X + Y^D + A^F X + Y^F \quad (1)$$

Using the domestic Leontief inverse (L^D), gross output is solved as:

$$X = L^D Y^D + L^D Y^F + L^D A^F B Y \quad (2)$$

Simple and Complex Chains

Global Value Chains can be categorized into simple and complex chains. Simple chains represent transactions crossing one border, while complex chains involve multiple cross-border transactions, reflecting a higher intricacy in trade relationships and production processes in the USMCA context.

Decomposing into Simple and Complex Global Value Chains:

$$X = L^D Y^D + L^D Y^F + \underbrace{L^D A^F L^D Y^D}_{\text{Simple GVC}} + \underbrace{[L^D A^F B Y - L^D A^F L^D Y^D]}_{\text{Complex GVC}} \quad (3)$$

The accounting system for value-added trade yields:

$$VBY = VL^D Y^D + VL^D Y^F + VL^D A^F L^D Y^D + VL^D A^F B Y - VL^D A^F L^D Y^D \quad (4)$$

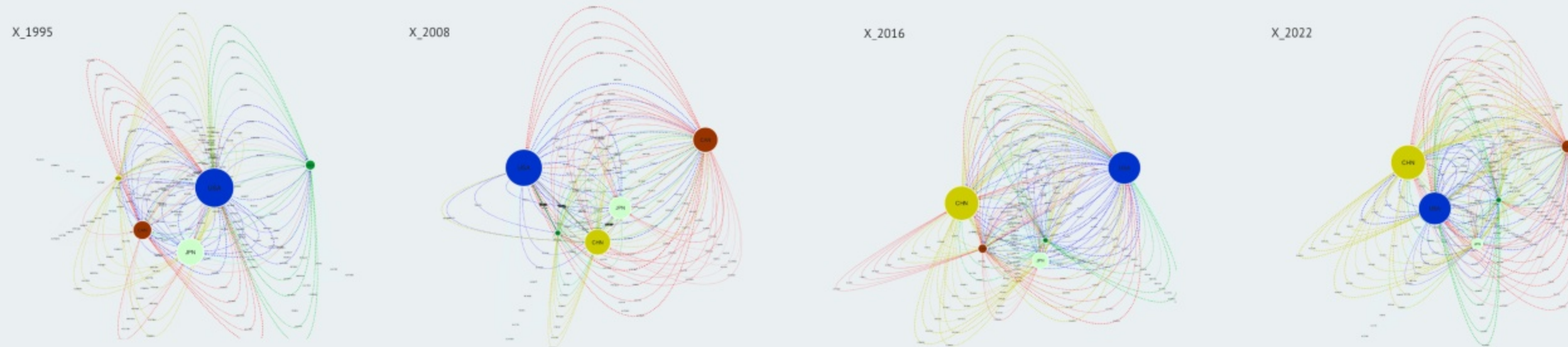
Network and GMRIO Approach

This section delves into the utilization of OECD databases and GMRIO methodology to conduct a thorough input-output mapping, revealing intricate relationships within global value chains.

OECD Databases for Input-Output Mapping

The OECD's Inter-Country Input-Output (ICIO) tables offer a comprehensive dataset from 1995 to 2022, critical for analyzing trade relationships among USMCA countries. This data enables the visualization of input-output flows and preparations for global value chain assessments, highlighting dependencies and economic interconnections. We chose the years 1995, 2008, 2016 and 2022 for this network analysis.

Gross Production X



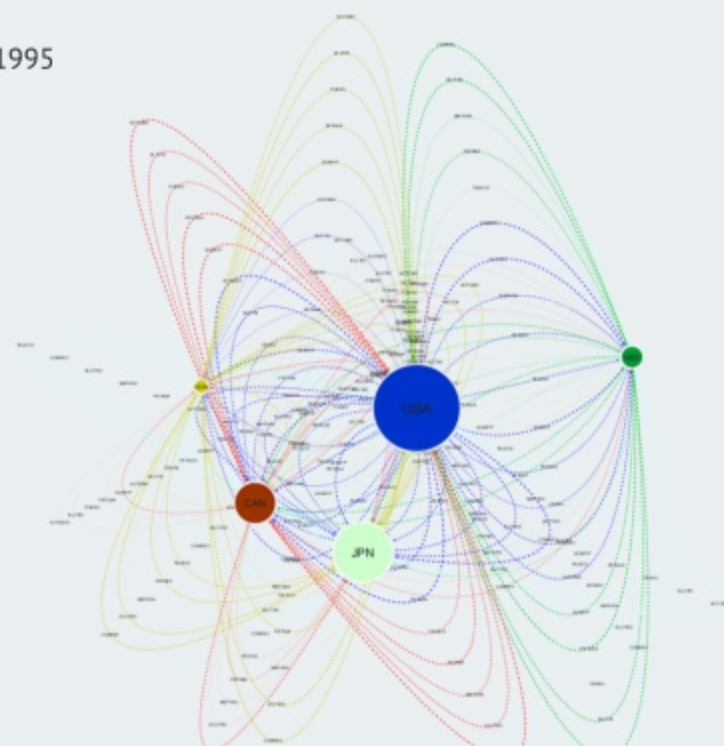
1995 (The Origin of NAFTA): The US (blue node) acts as the absolute center of gravity of the region. Mexico (green node) and Canada (brown node) operate as commercial satellites with a linear dependence on the US market. China (yellow node) is peripheral and irrelevant within the bloc.

2008--2016 (The Asian Irruption): Following China's entry into the WTO (2001), its node expands rapidly across the network, beginning to displace traditional supplier links within the North American region.

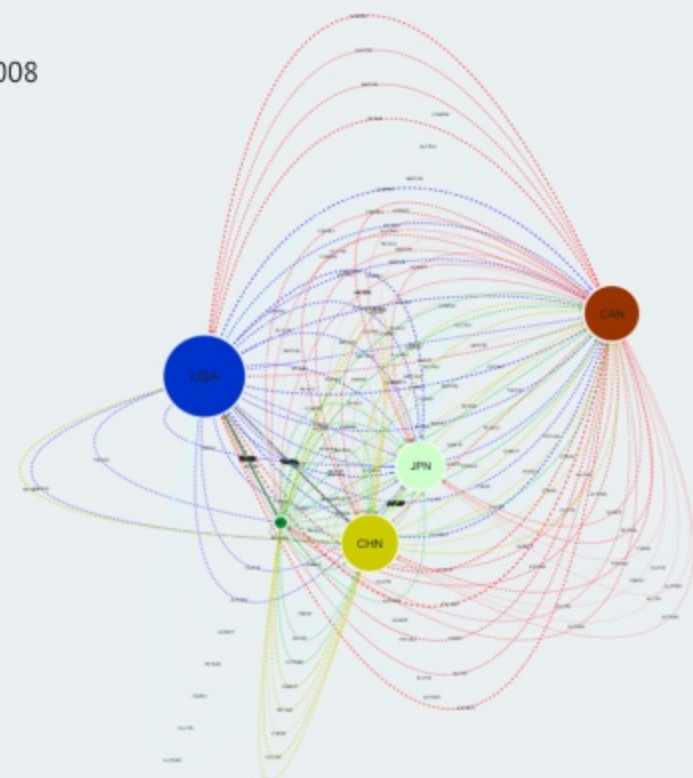
2022 (The Current Asymmetry): China's node (CHN) reaches a critical size that directly rivals the US. Conversely, despite Mexico's (MEX) enormous export volume, its node structurally remains small, demonstrating that exporting higher volumes has not translated into retaining more value.

Gross Production X

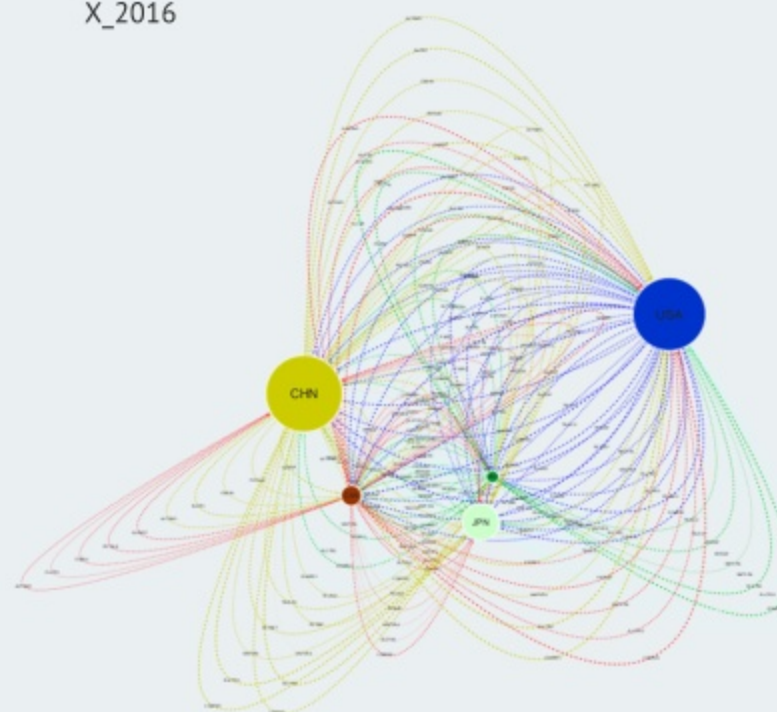
X_1995



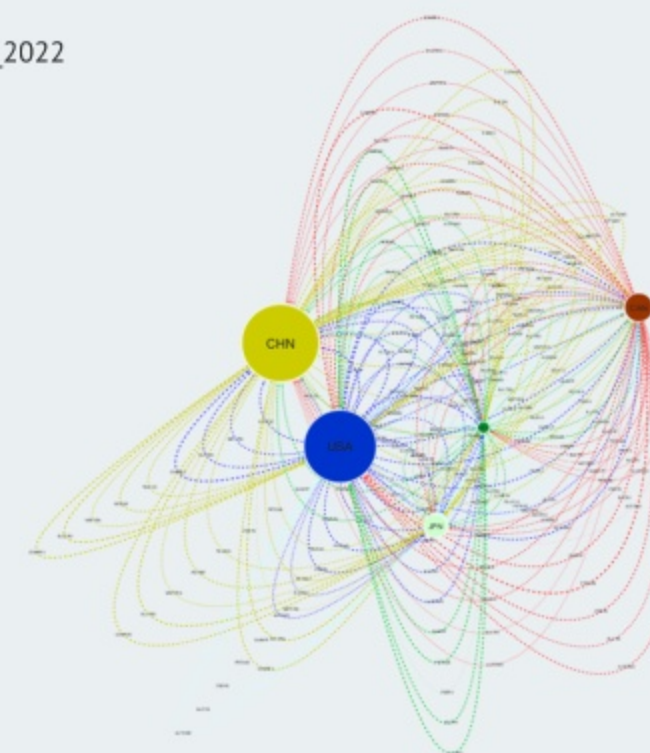
X_2008



X_2016



X_2022



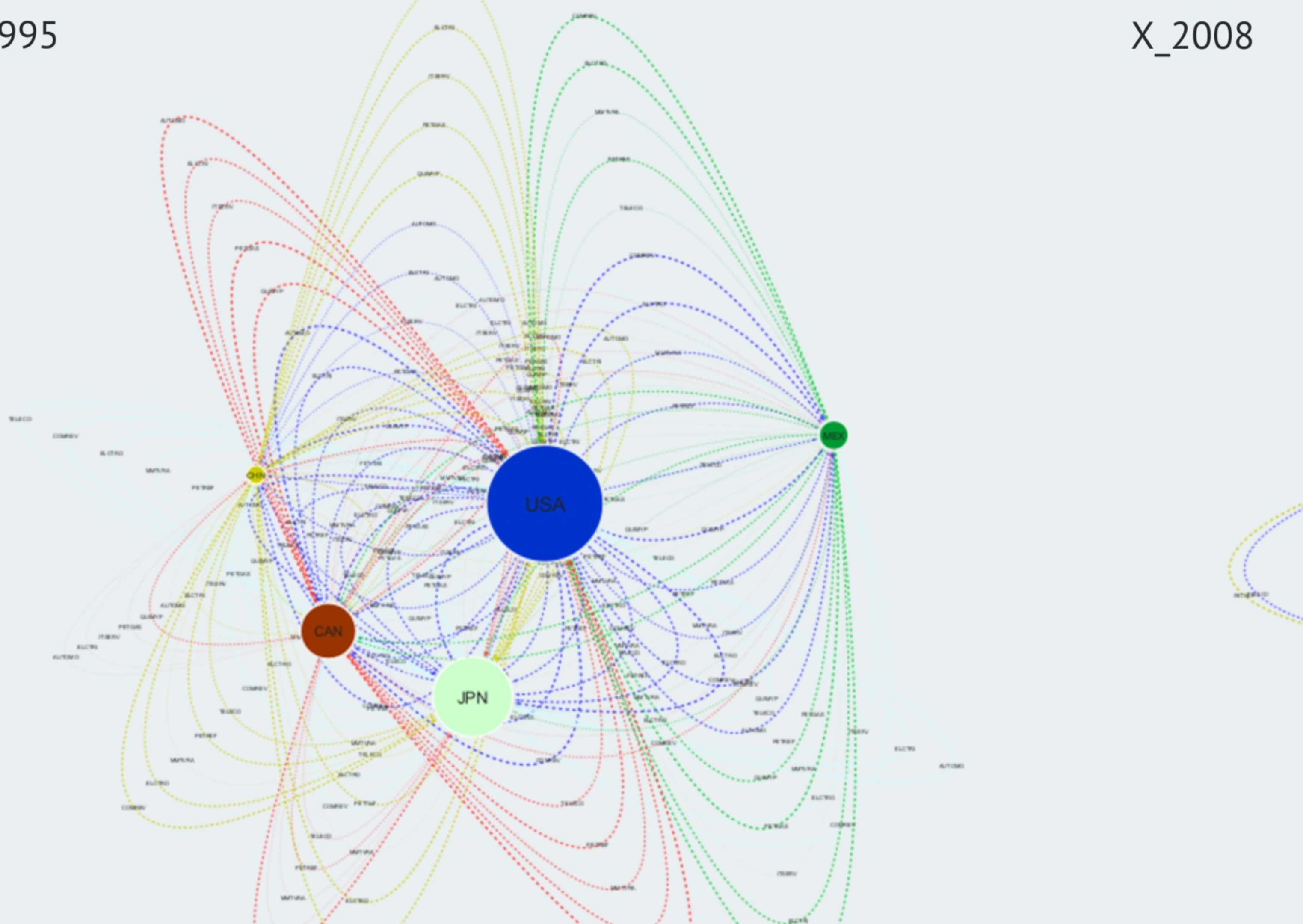
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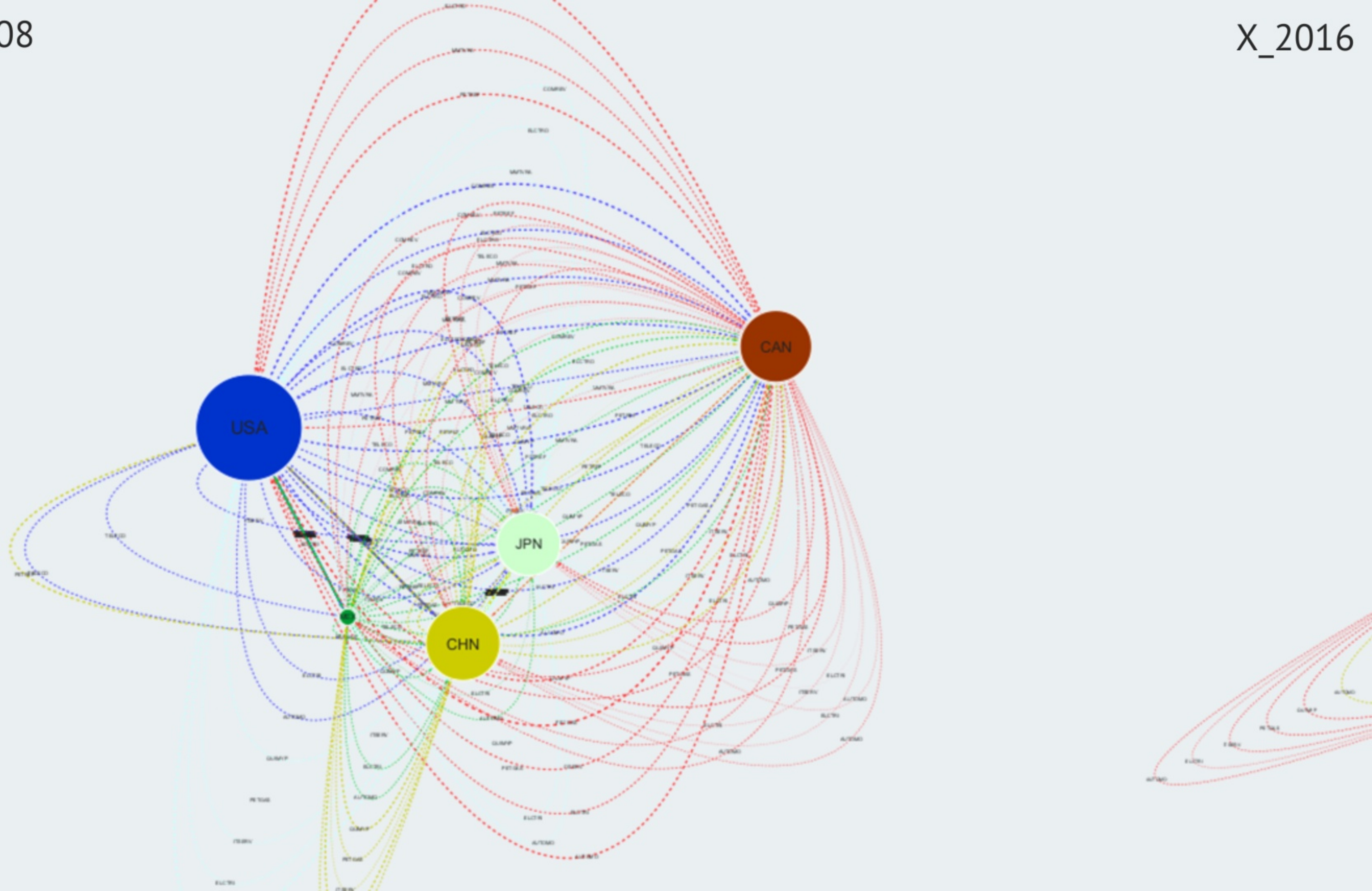
X_1995

X_2008

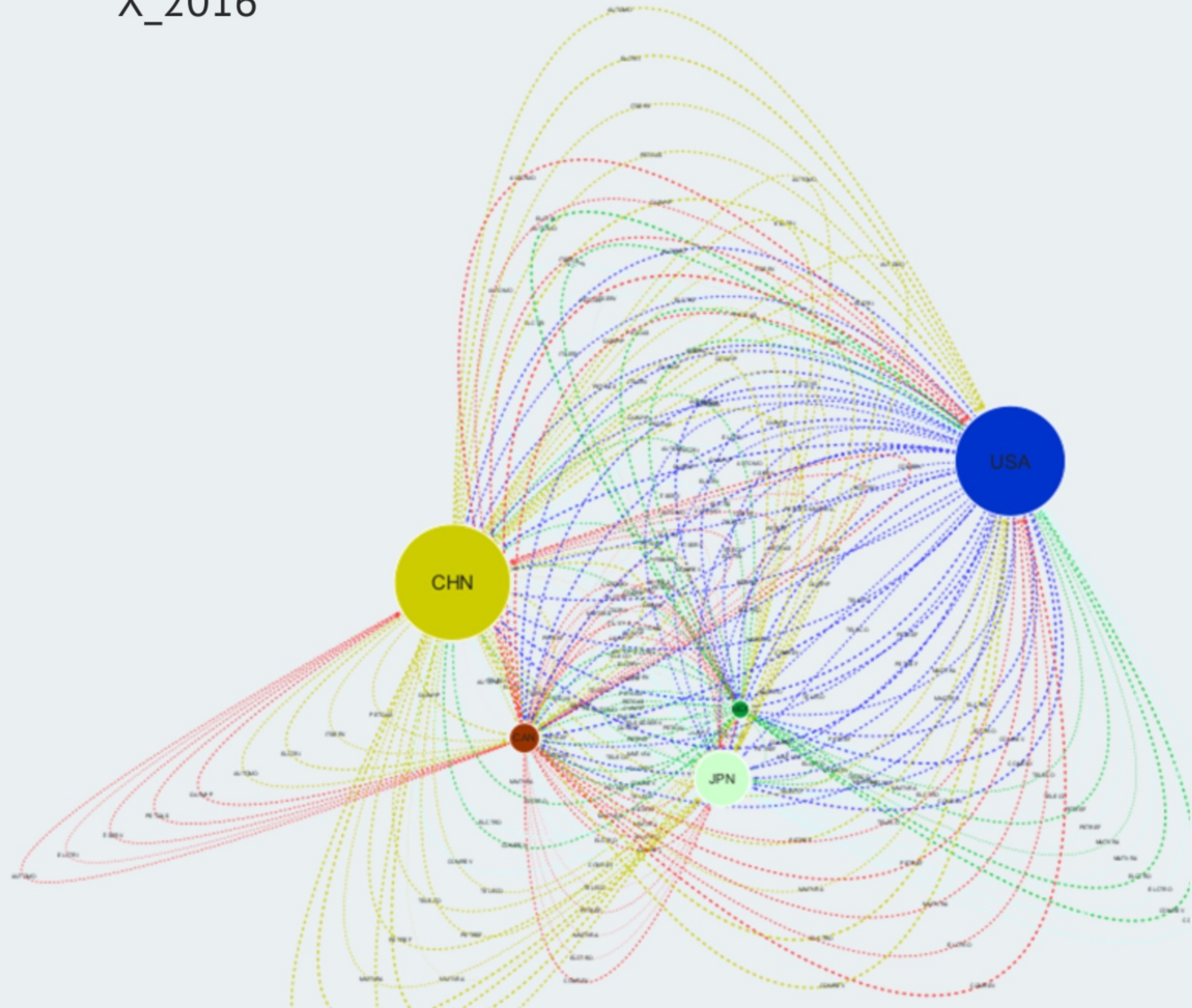


X_2008

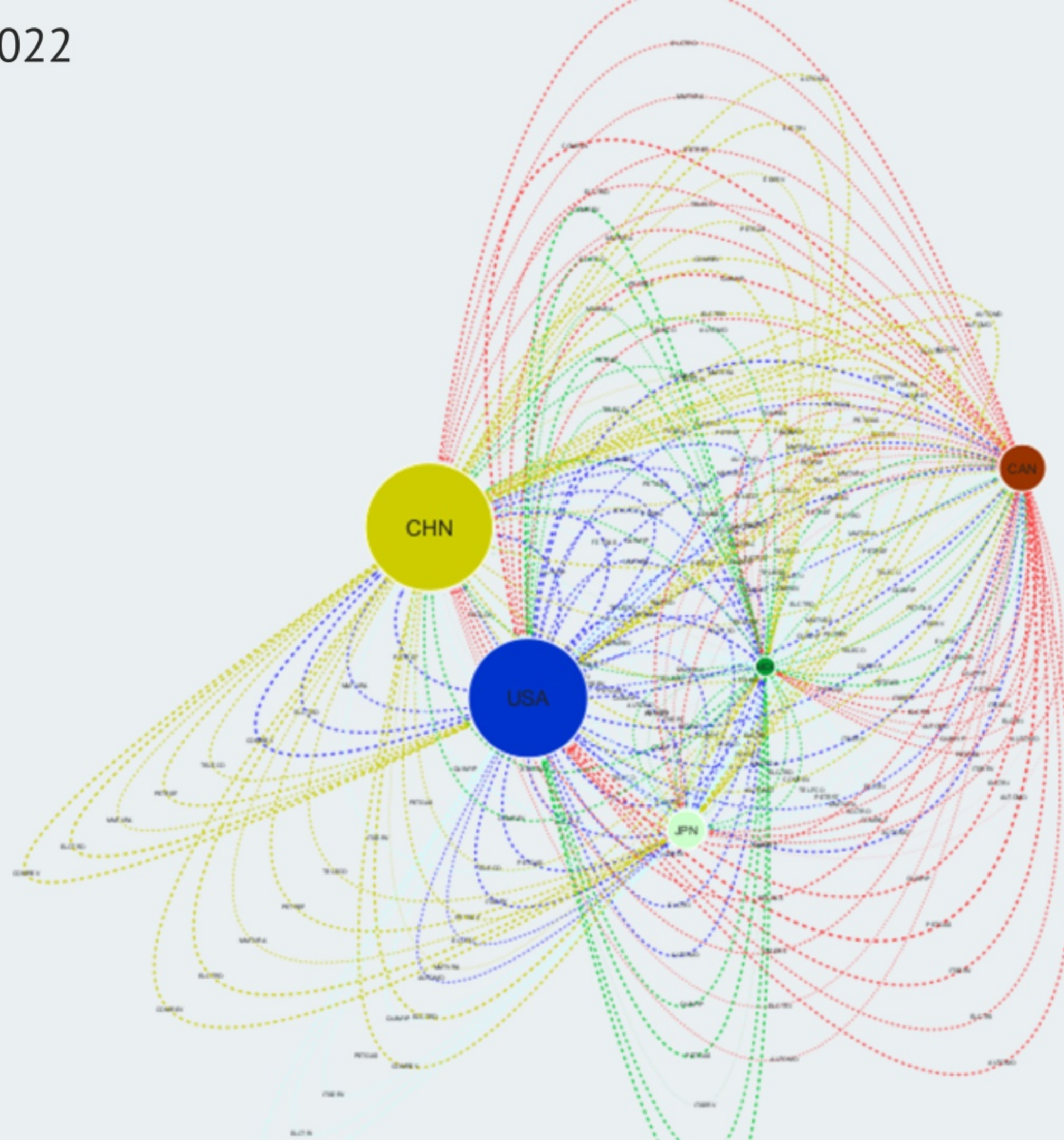
X_2016



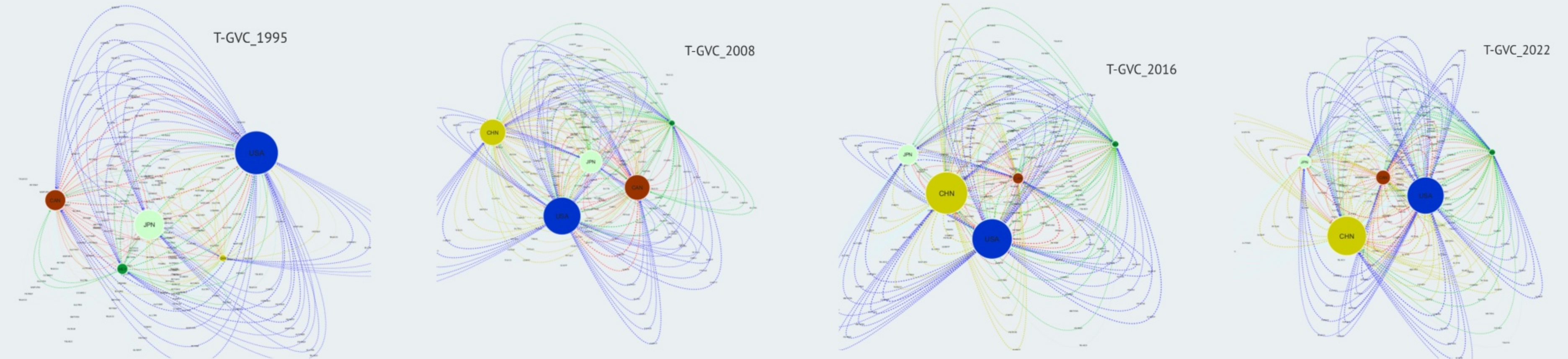
X_2016



X_2022



T-GVC

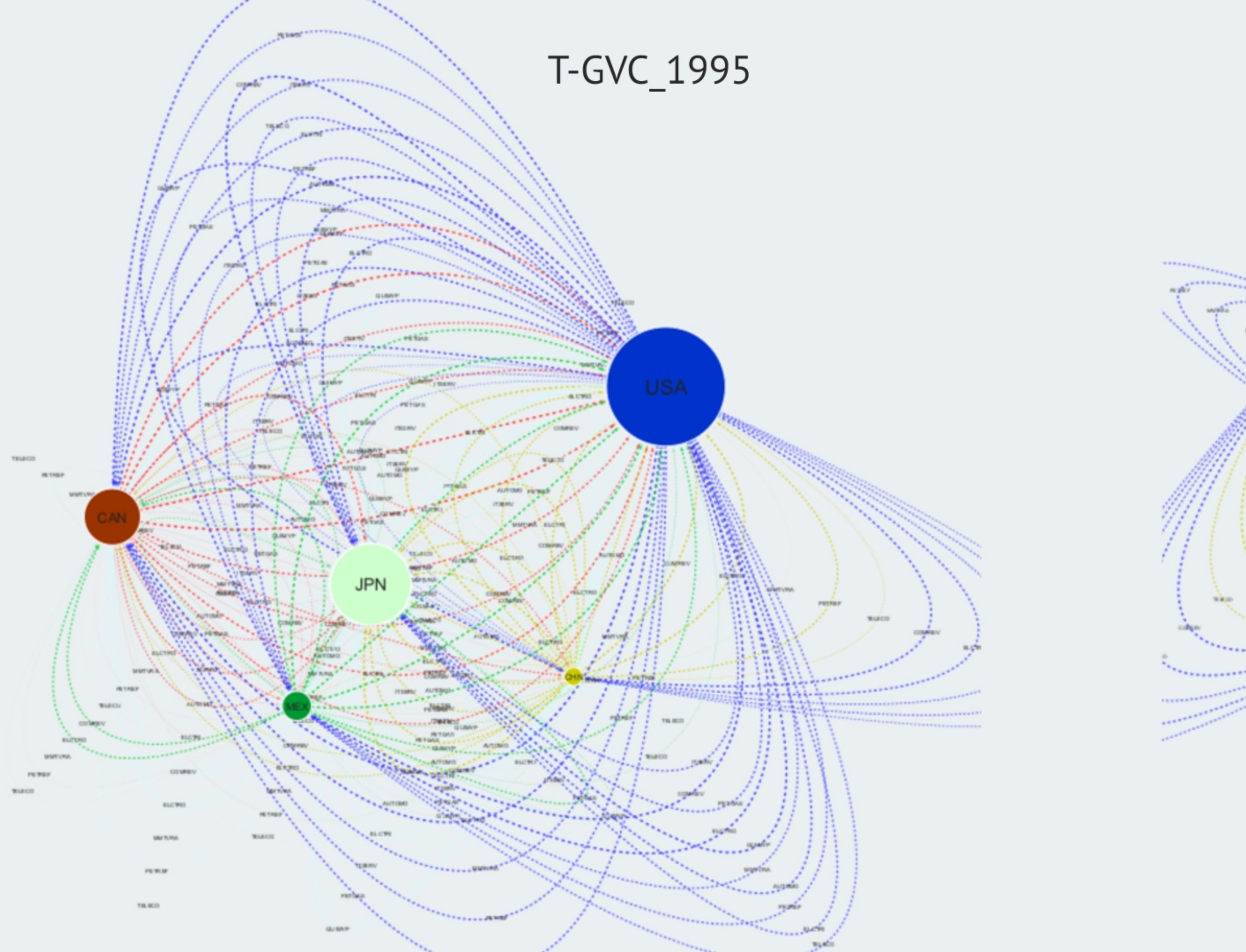


Geopolitical Displacement: The Total Chain networks visually demonstrate how trade links within the USMCA bloc underwent a profound "external reconfiguration" between 1995 and 2022.

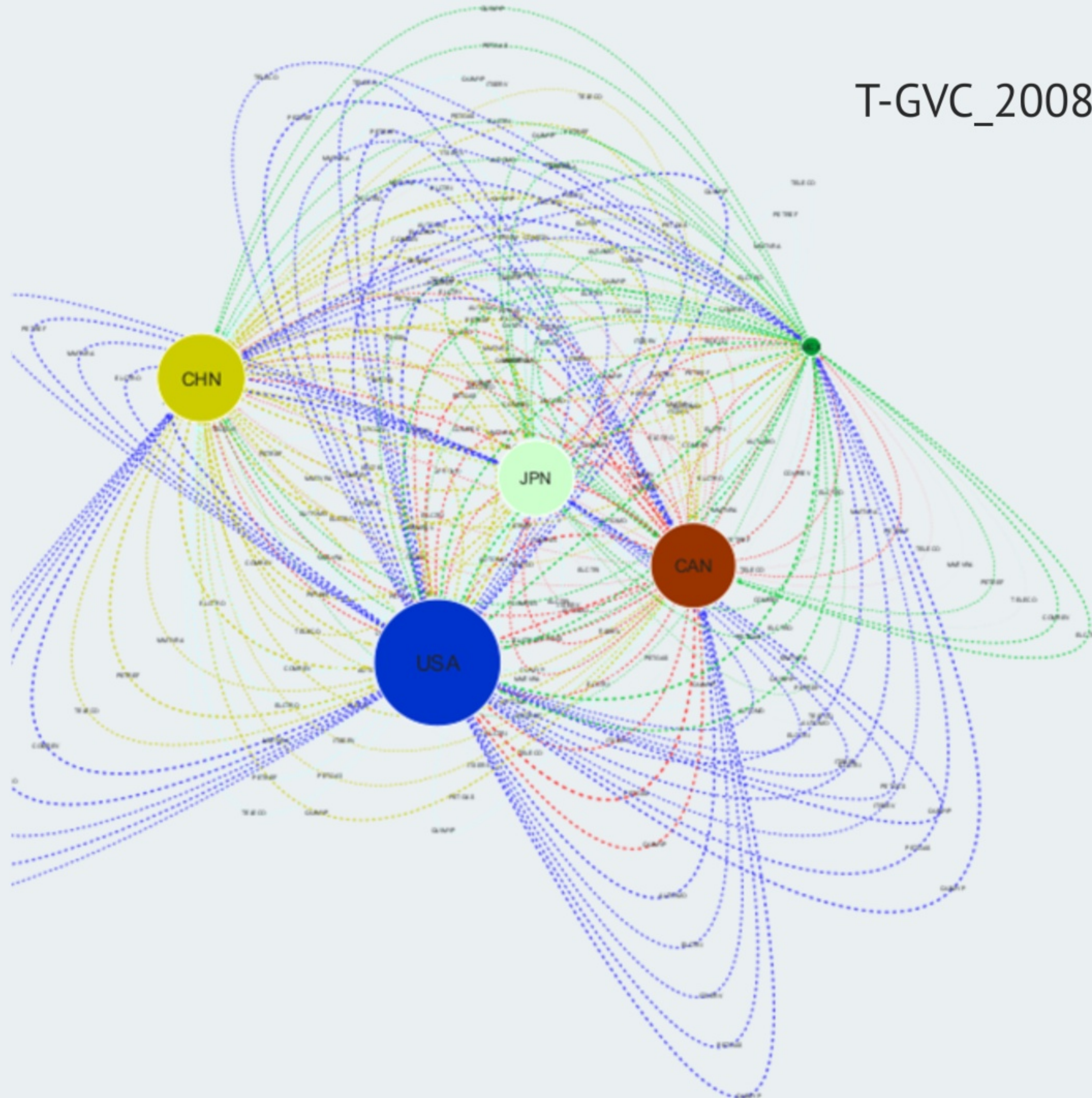
Loss of Regional Sovereignty: The internal production chains among the US, Canada, and Mexico become visually less dense over time, being heavily displaced by external interindustry connections.

Structural Dependence: The North American production network has ceased to be self-sufficient, relying heavily on external nodes to sustain its total manufacturing process.

T-GVC_1995

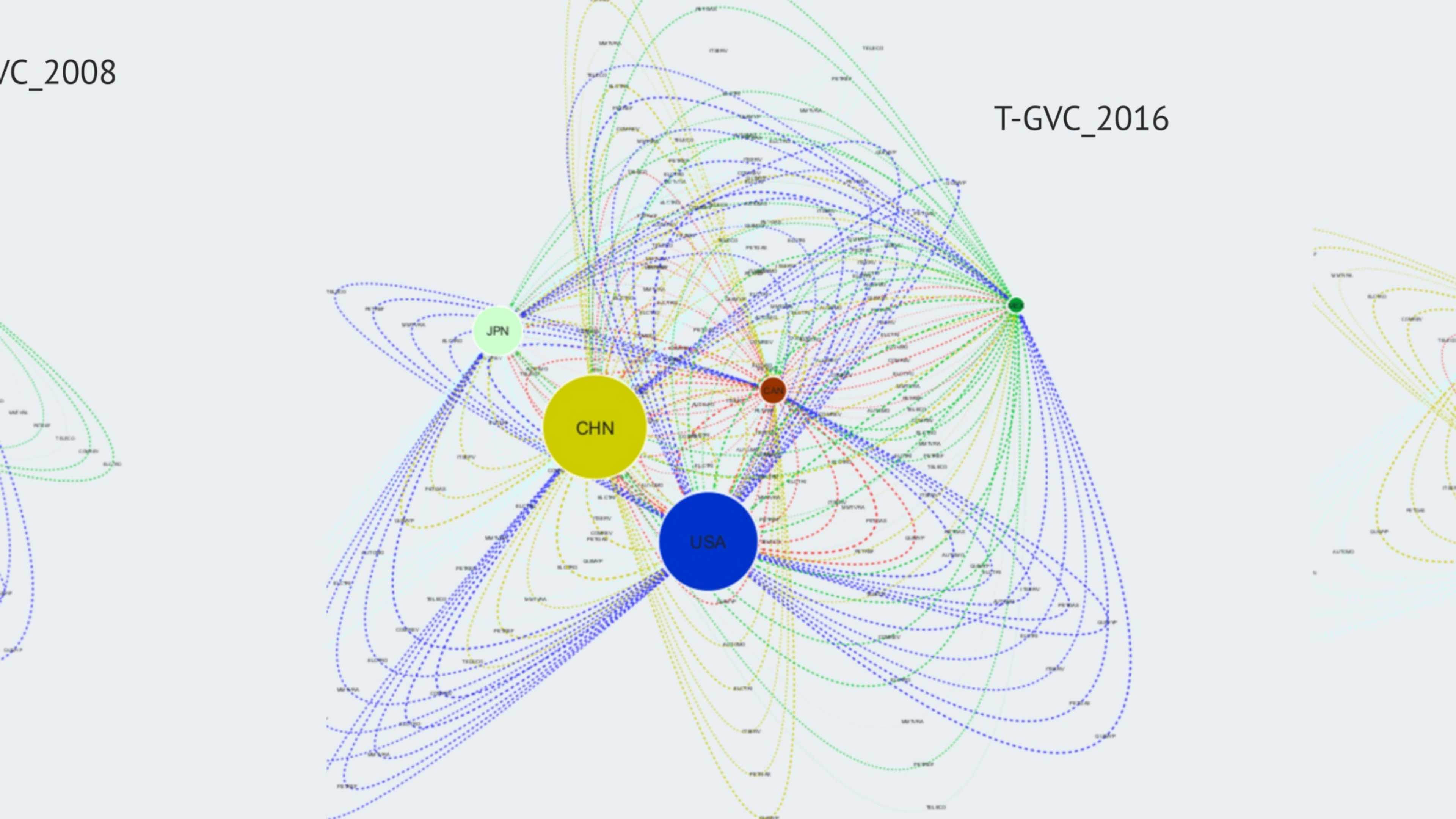


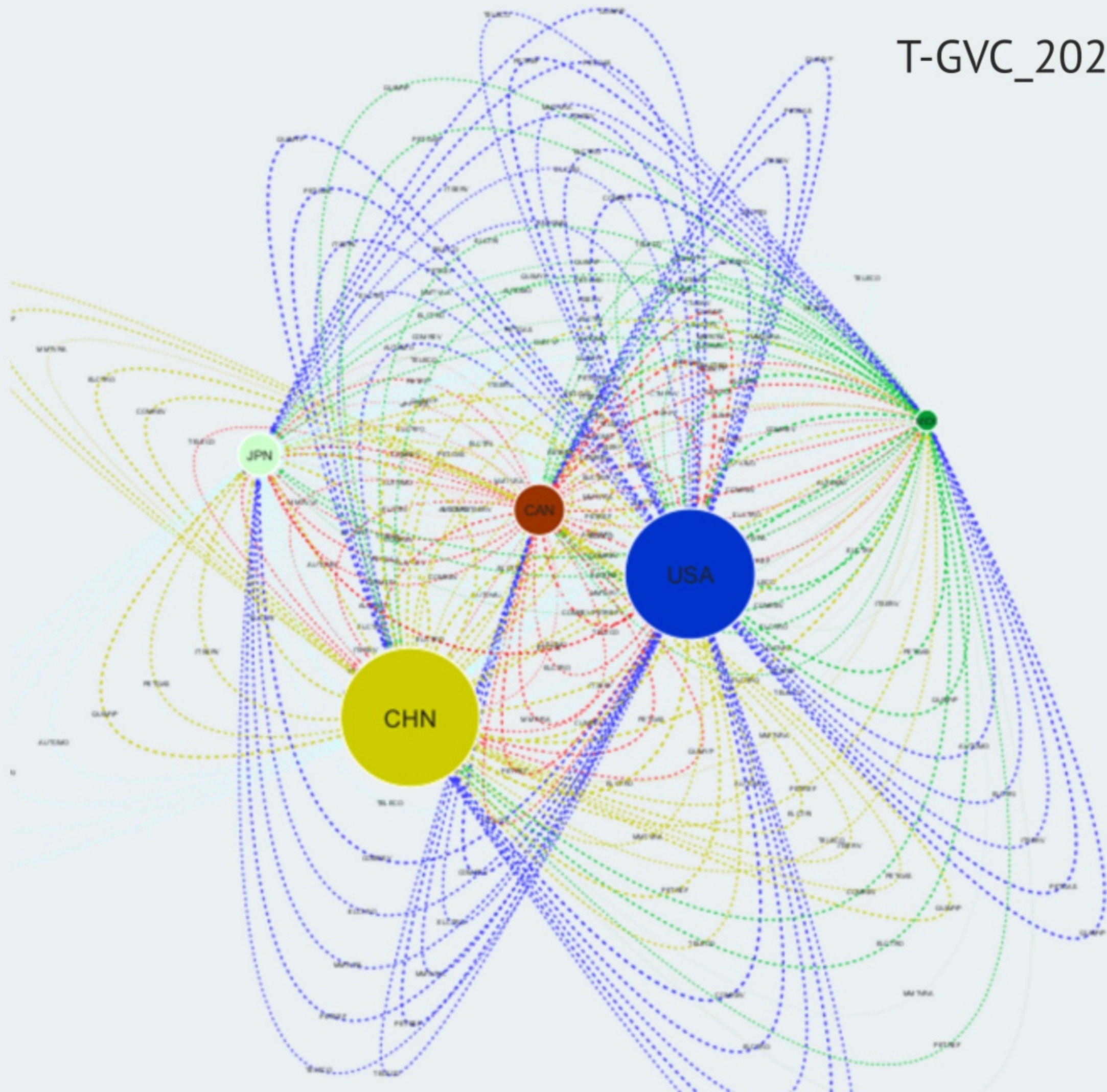
T-GVC_2008



/C_2008

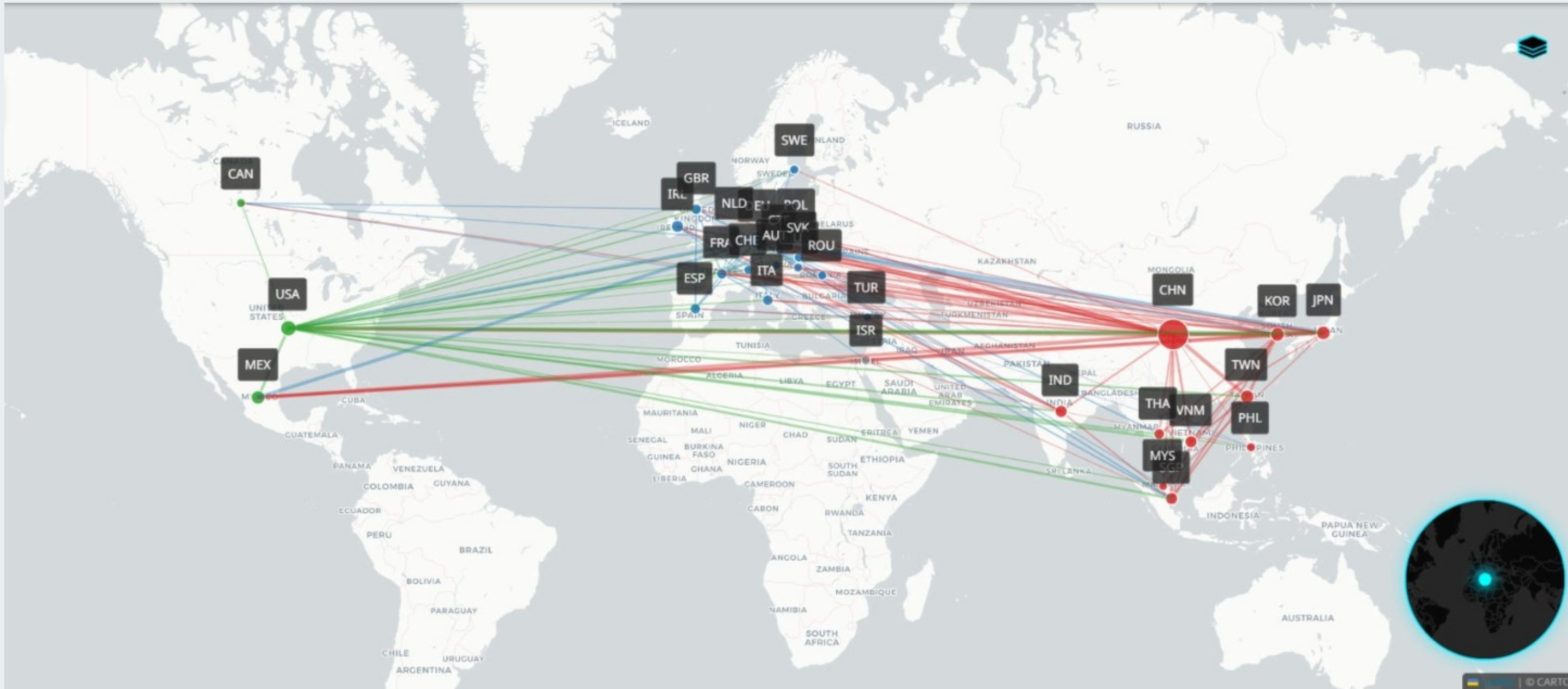
T-GVC_2016





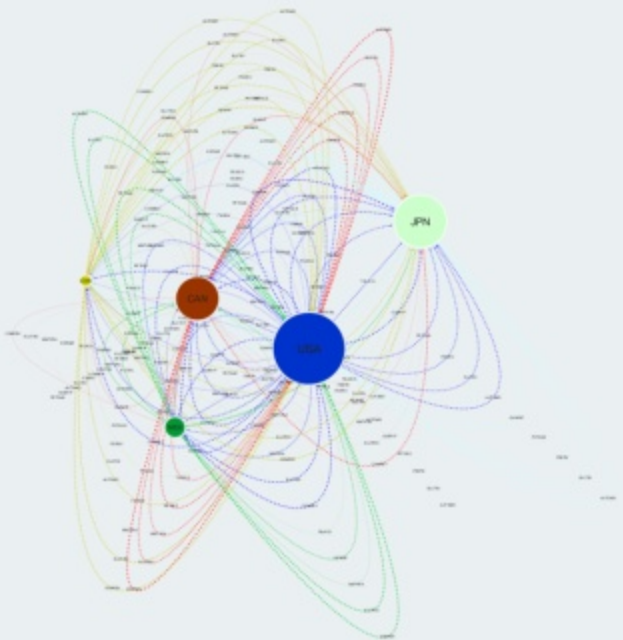
Value Chain Analysis

Analyzing global value chains using OECD data reveals patterns of trade that indicate a strong interdependence among Mexican, US, and Canadian industries. The insights derived from this analysis aid in understanding the domestic and foreign content of exports, providing critical information for industrial policy decisions.

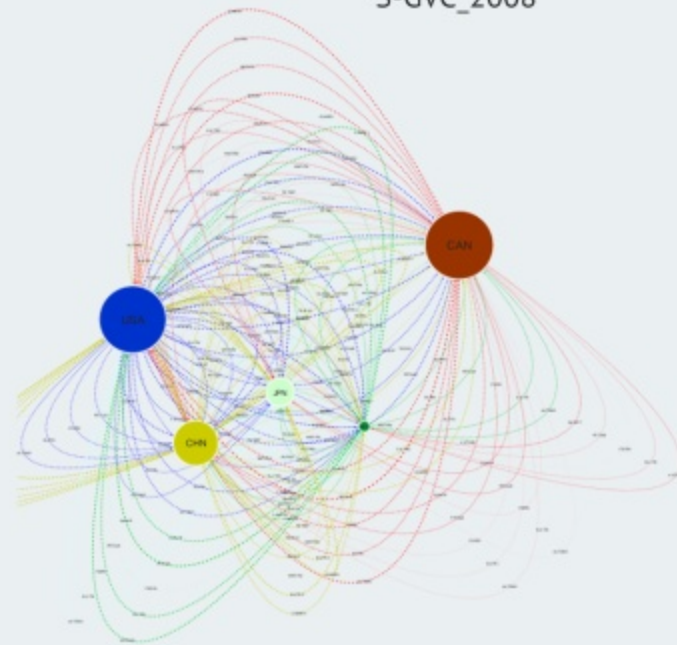


S-GVC

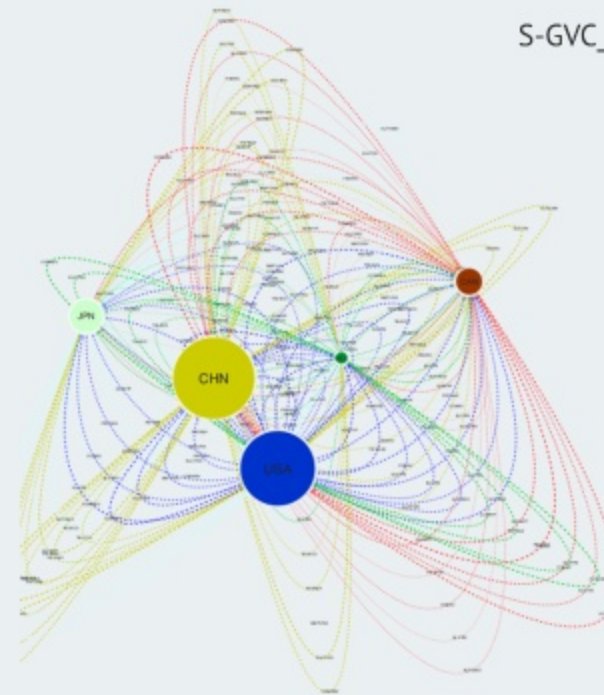
S-GVC_1995



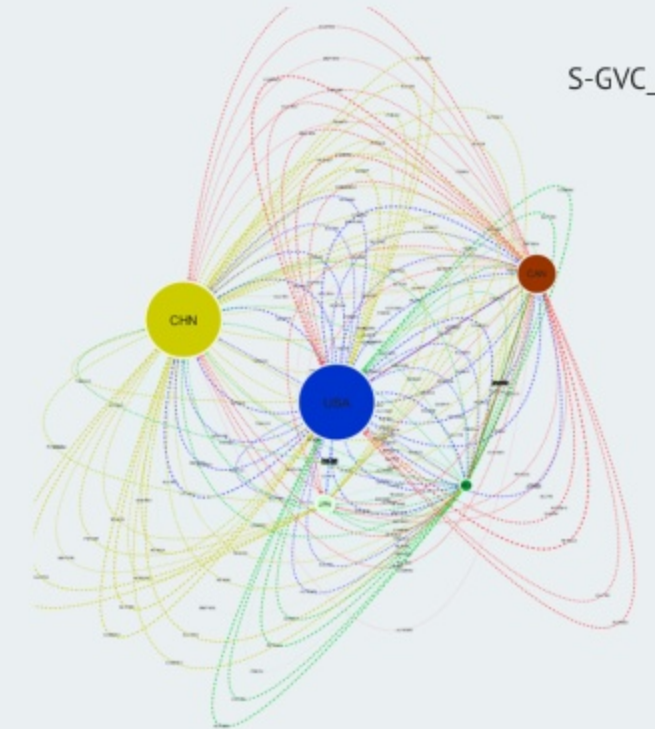
S-GVC_2008



S-GVC_2016



S-GVC_2022



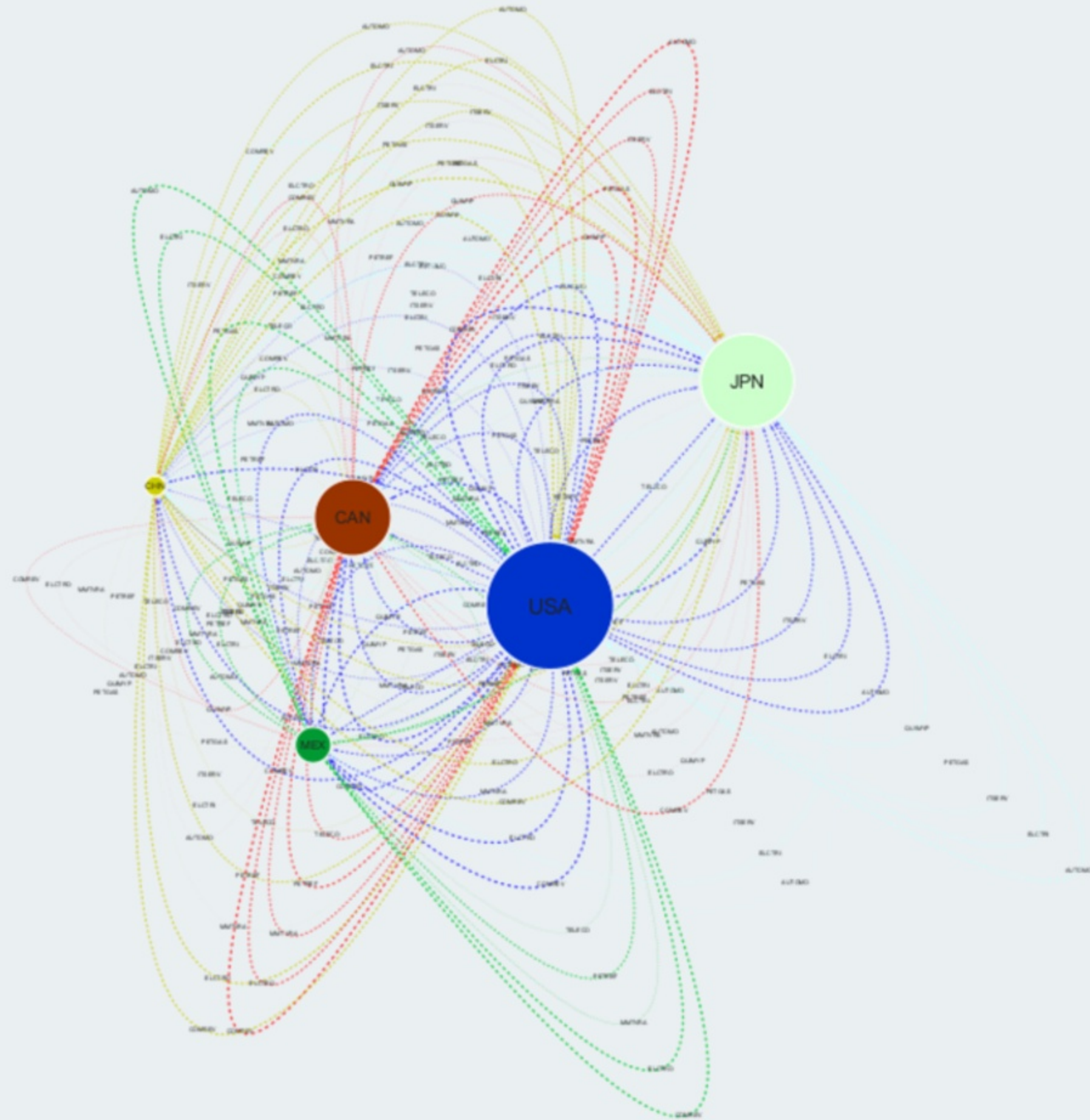
Simple Chains (S-Chain)

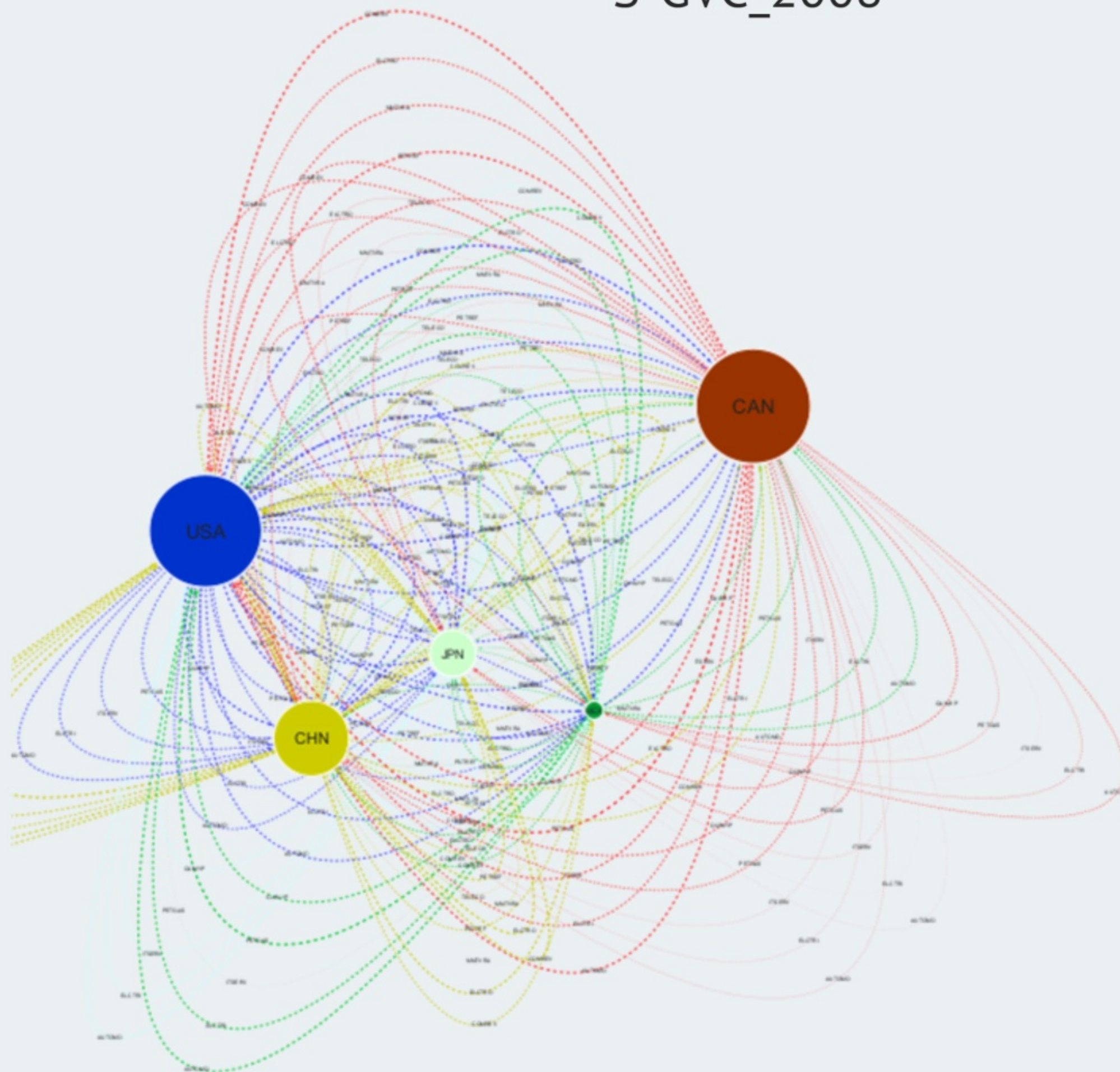
Value-added that crosses a single border and is consumed in the destination country.

Show more stable and localized interindustry paths.

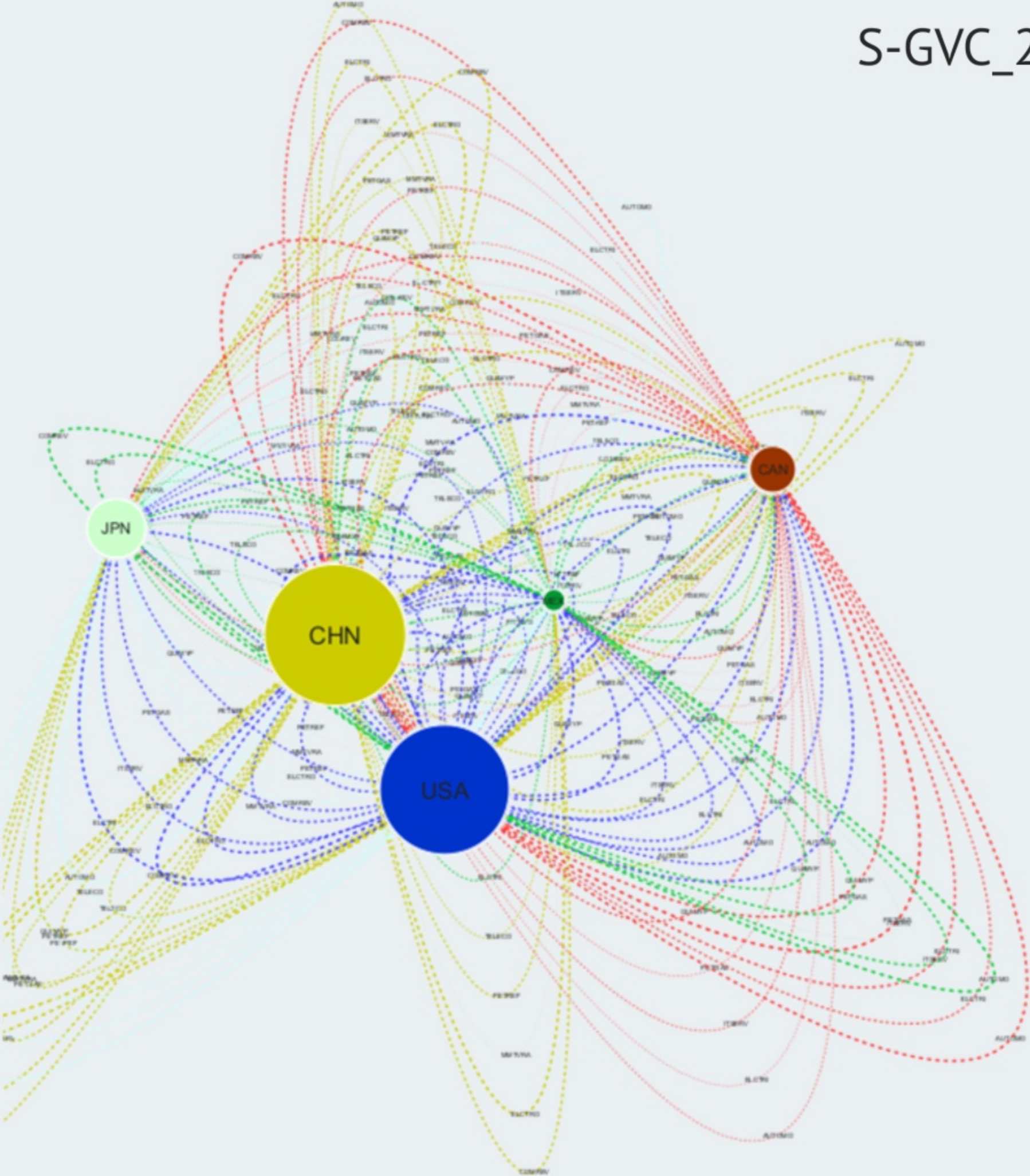
Represent traditional trade structures within the bloc.

S-GVC_1995

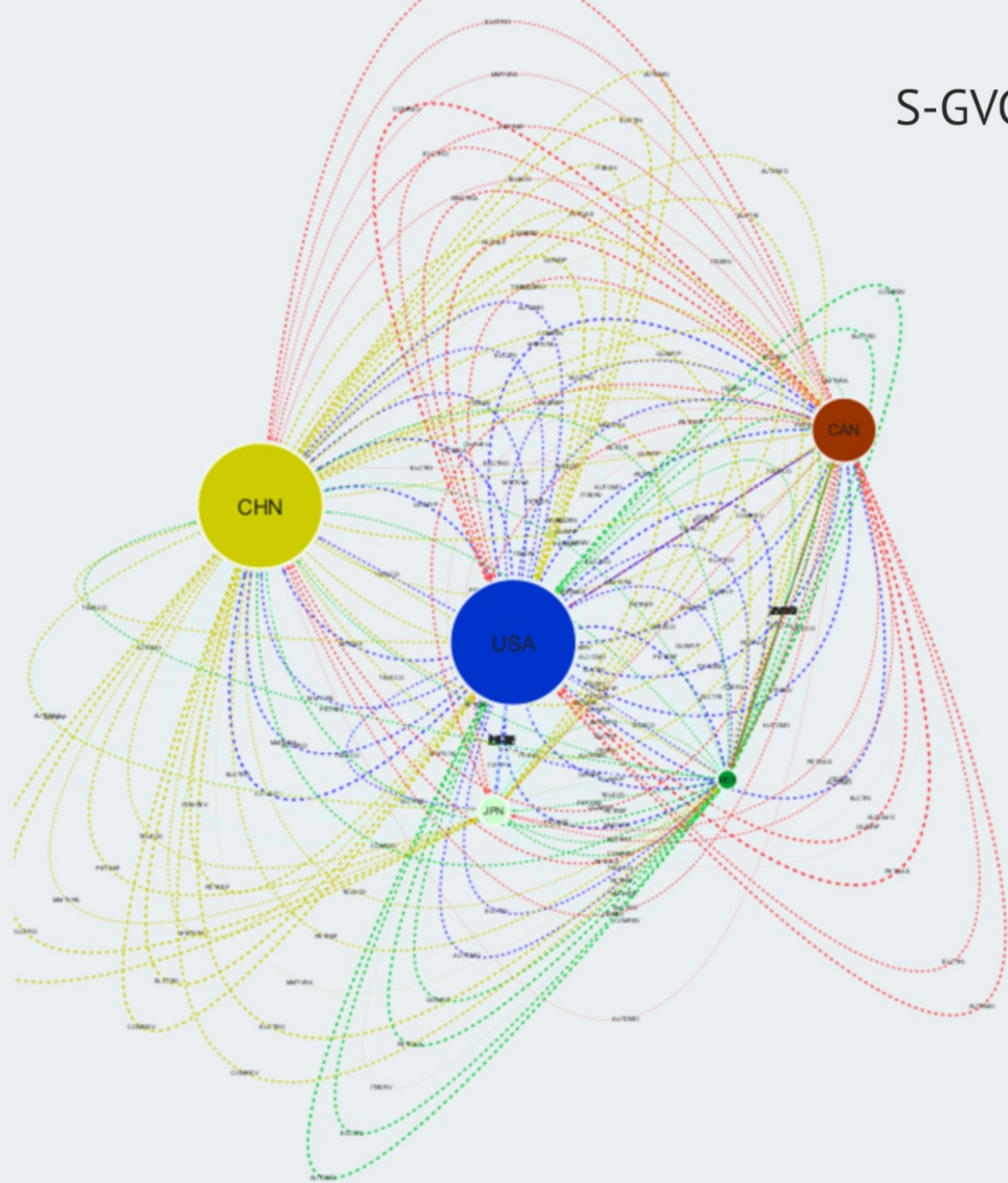




S-GVC_2016



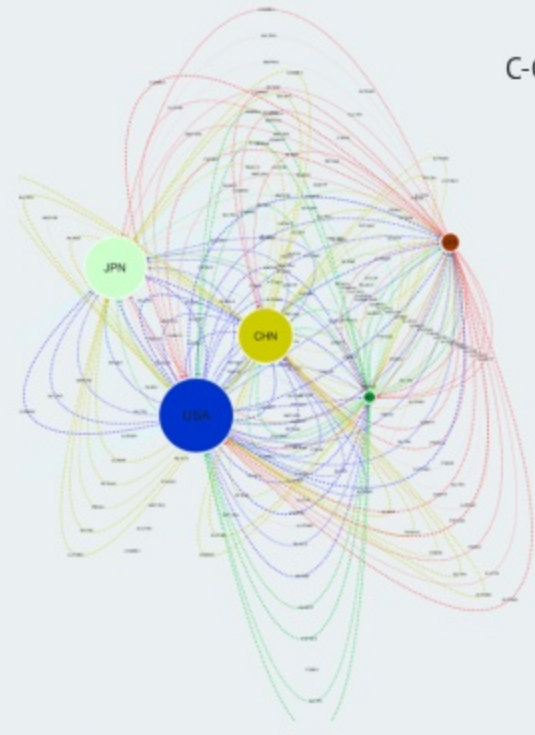
S-GVC_2022



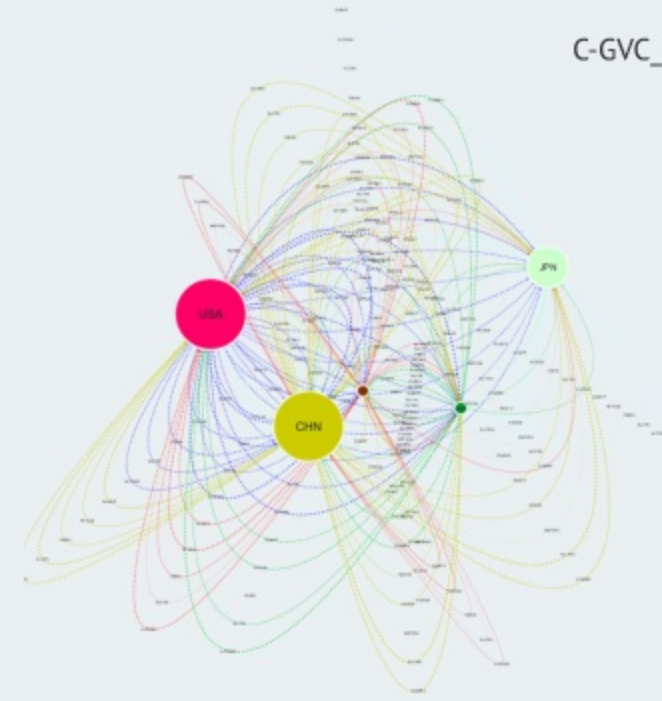
C-GVC



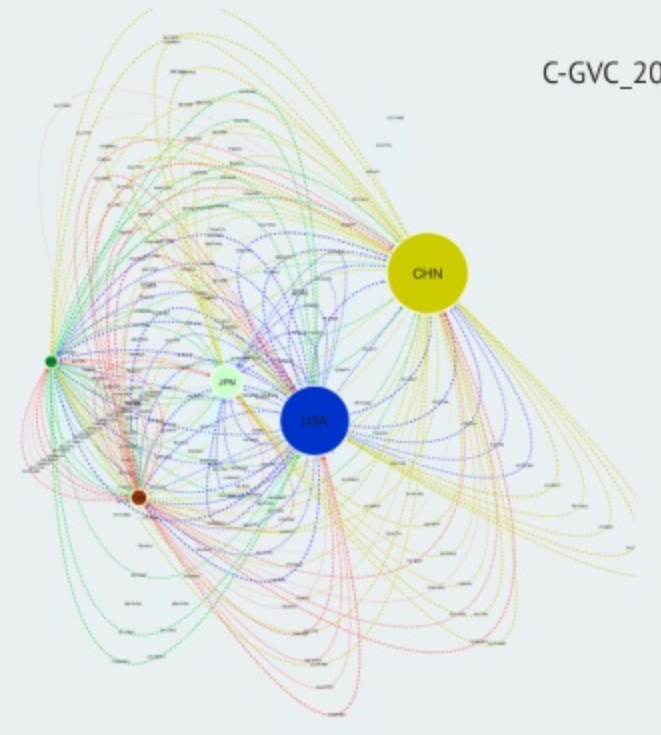
C-GVC_1995



C-GVC_2008



C-GVC_2016



C-GVC_2022

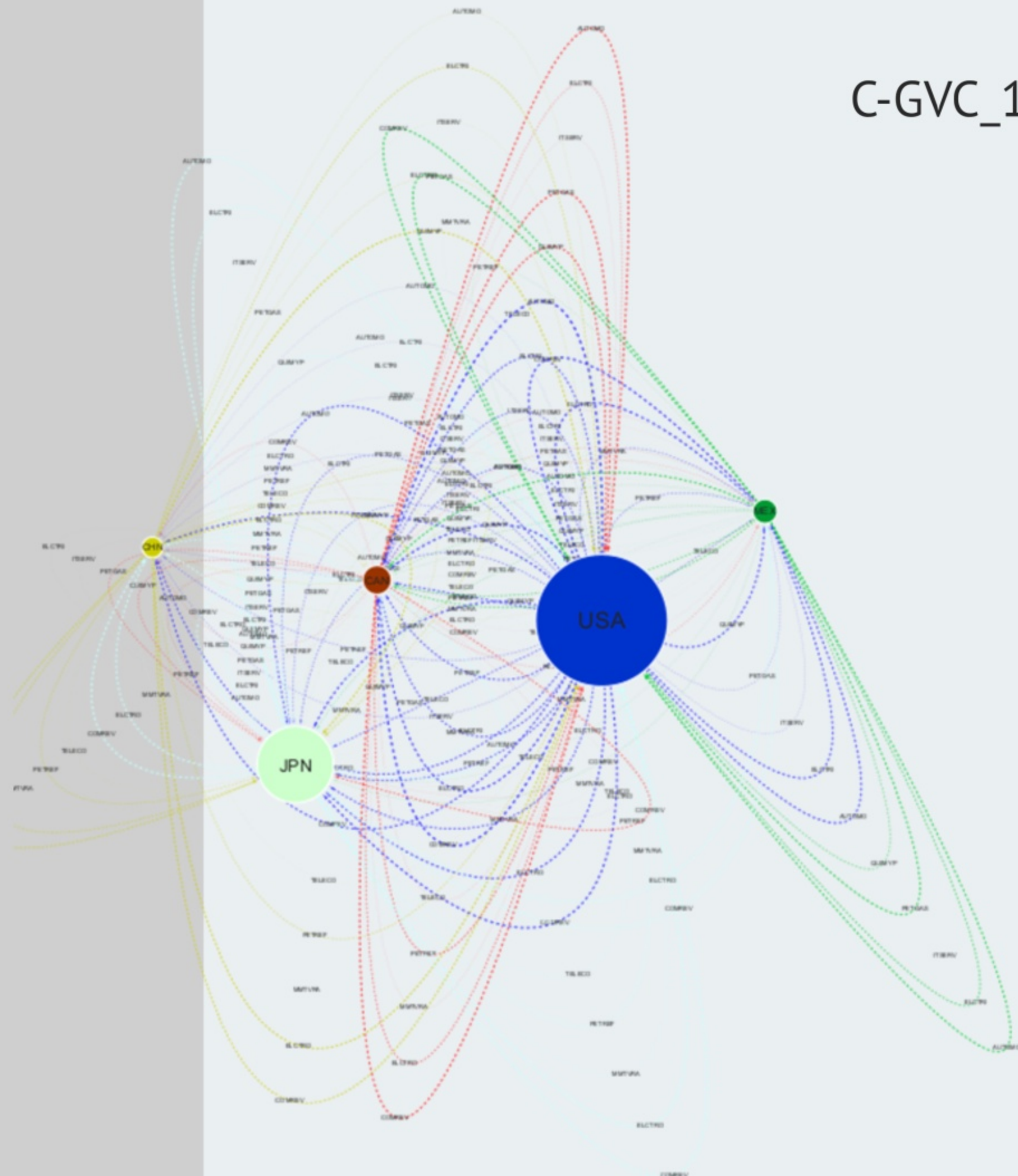
Complex Chains (C-Chain)

Value-added that crosses multiple borders during the production process (highly fragmented).

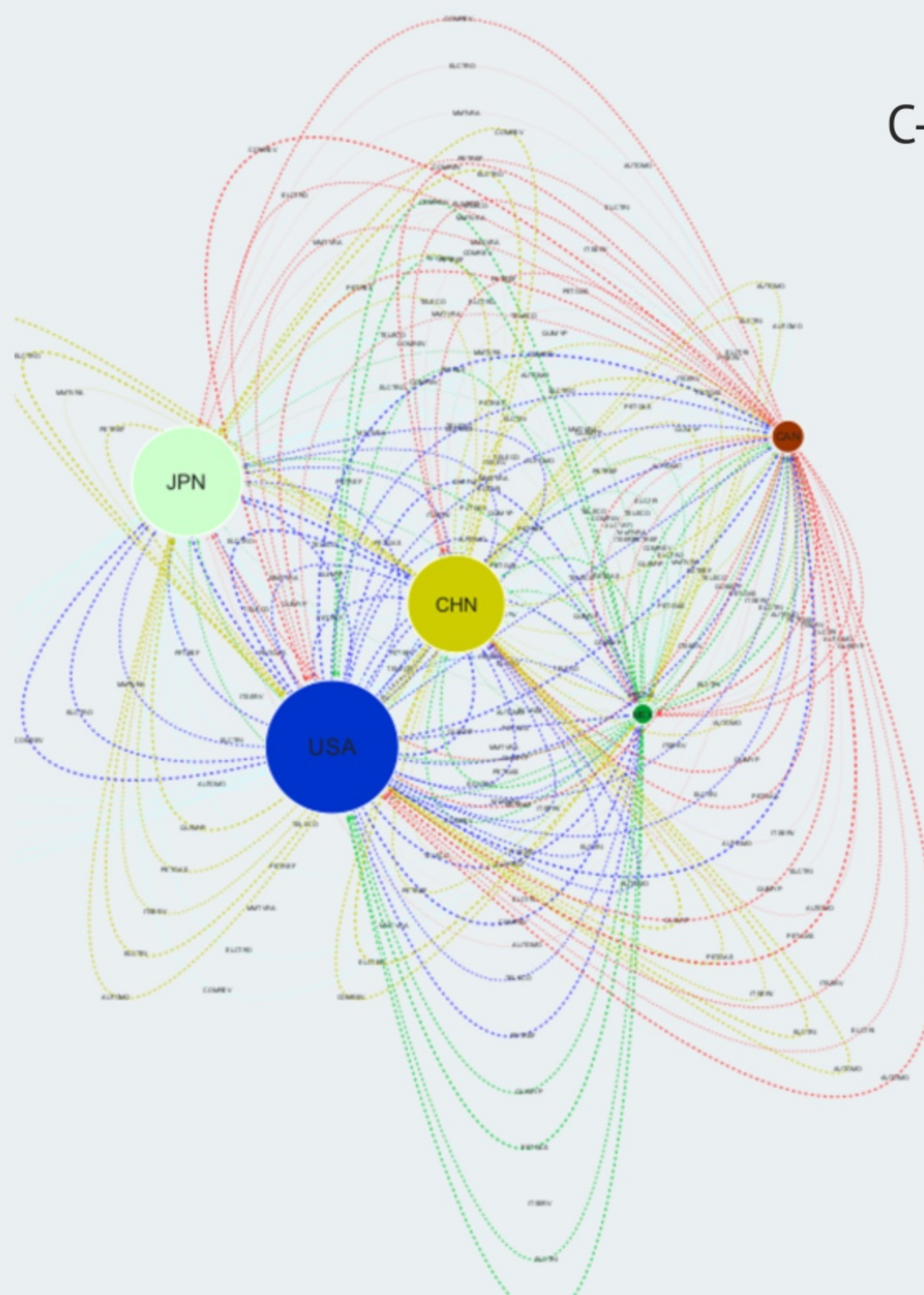
These networks explode in density by 2022.

Visual evidence of the "Nearshoring Paradox": assembly in Mexico requires deeper, more complex global loops.bloc.

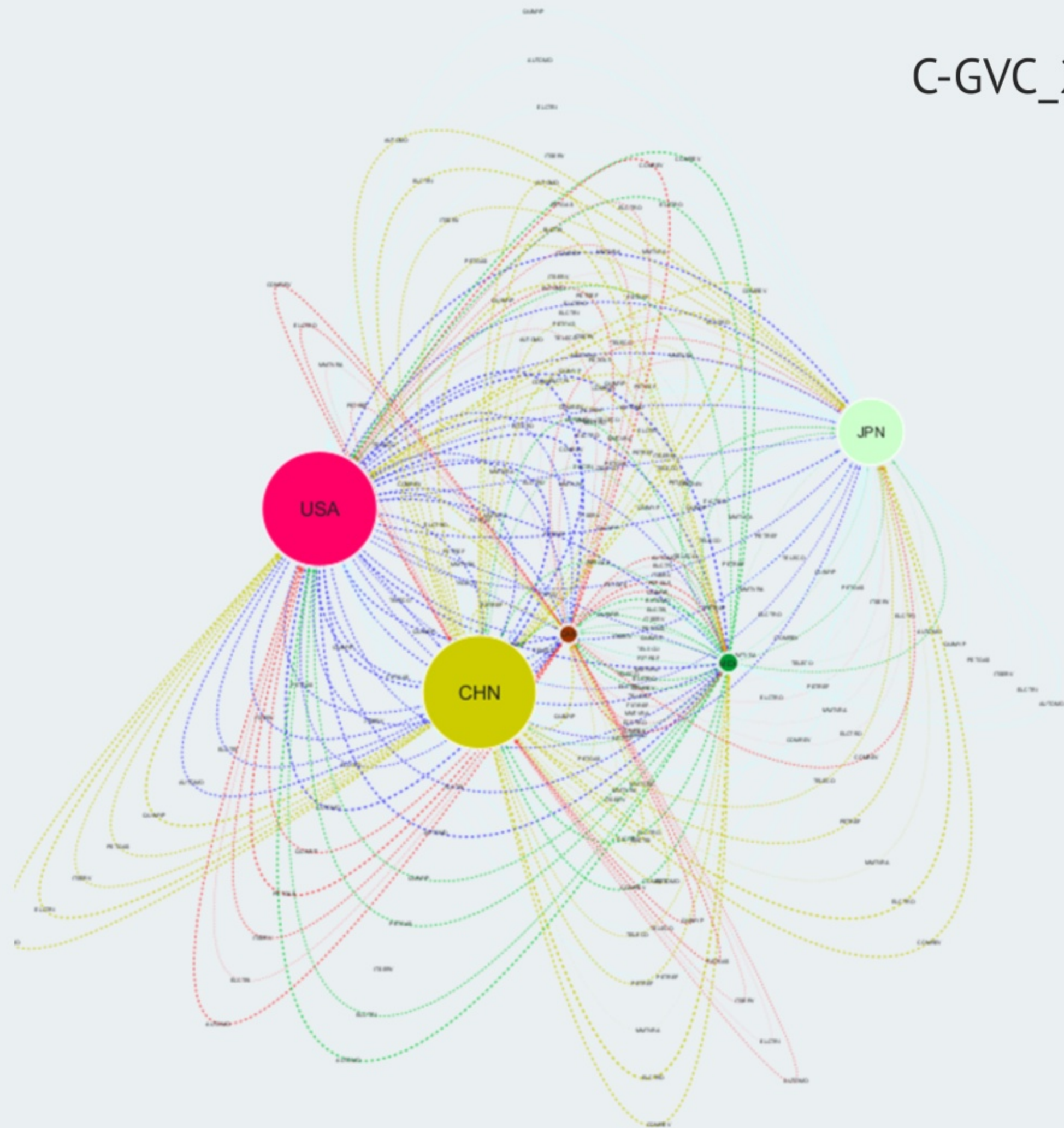
C-GVC_1995



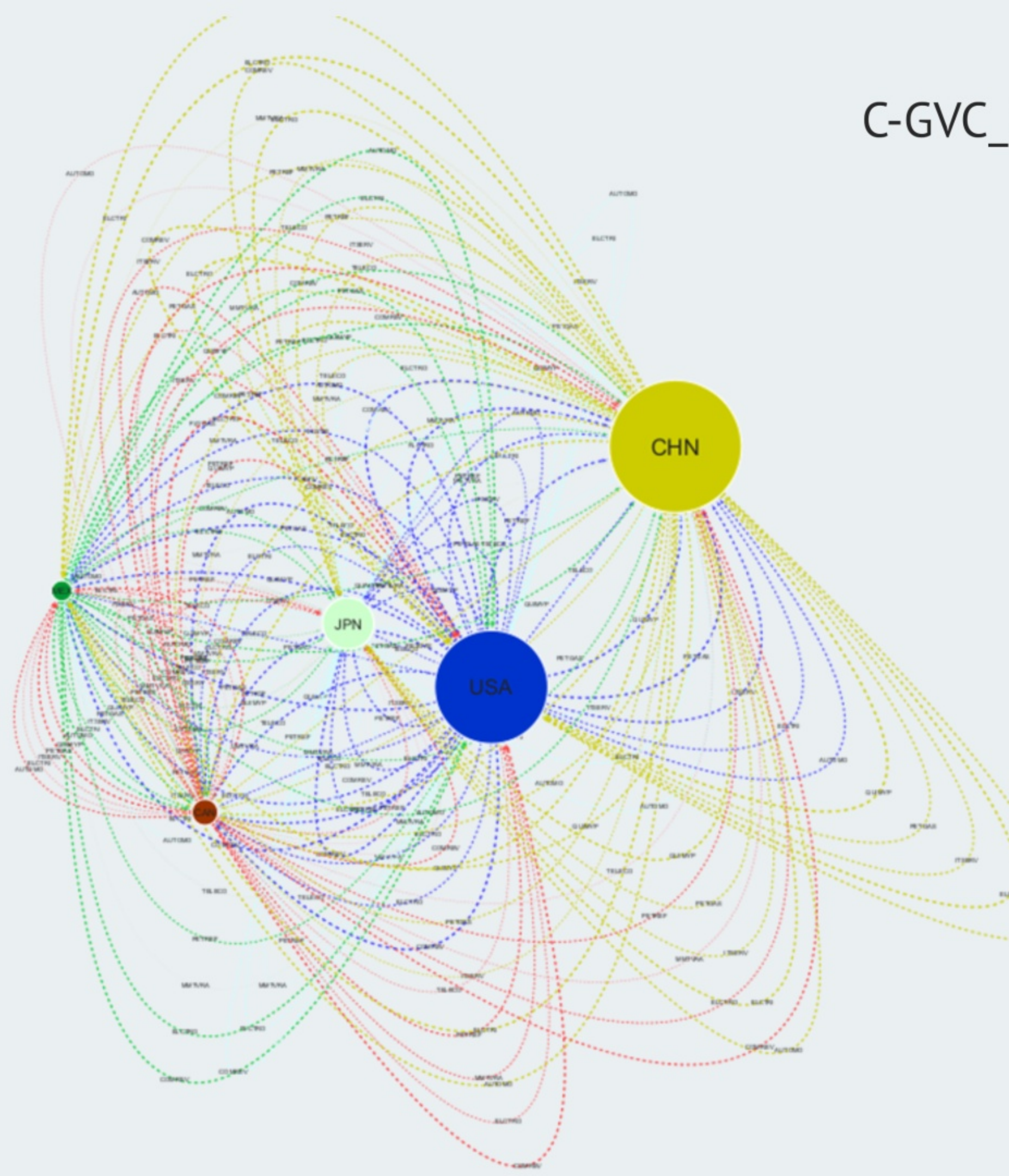
C-GVC_2008



C-GVC_2016



C-GVC_2022

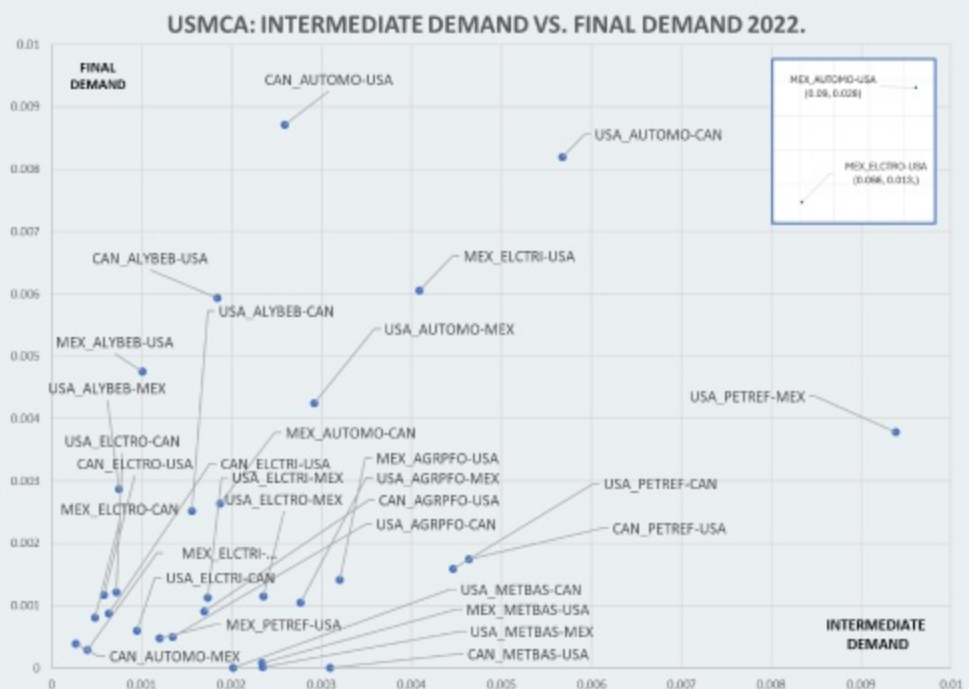
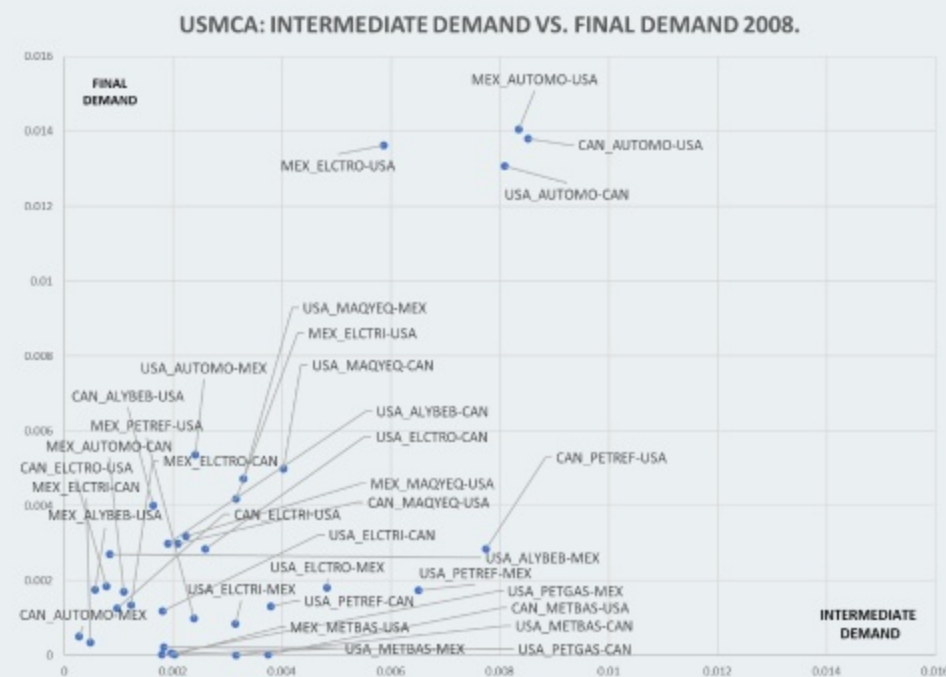
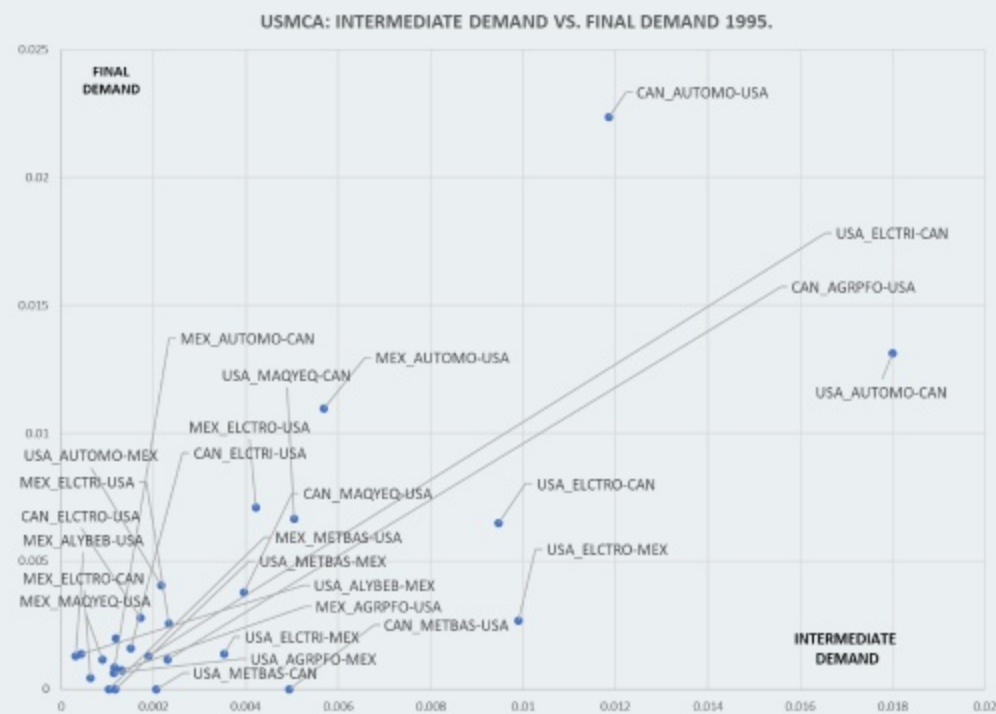


The Mexican Export Paradox & Regional Clusters

The Paradox: Despite booming gross export volumes, Mexico exhibits a severely depressed Domestic Value Added (DVA).

Dynamic Industries: High-volume sectors (Automotive and Electronics) operate under advanced assembly / maquiladora strategies.

US & Canada Clusters: Maintain high-DVA structures rooted in mature, integrated domestic industrial networks.



Dynamic Industry Integration & The Intermediate Supply Role

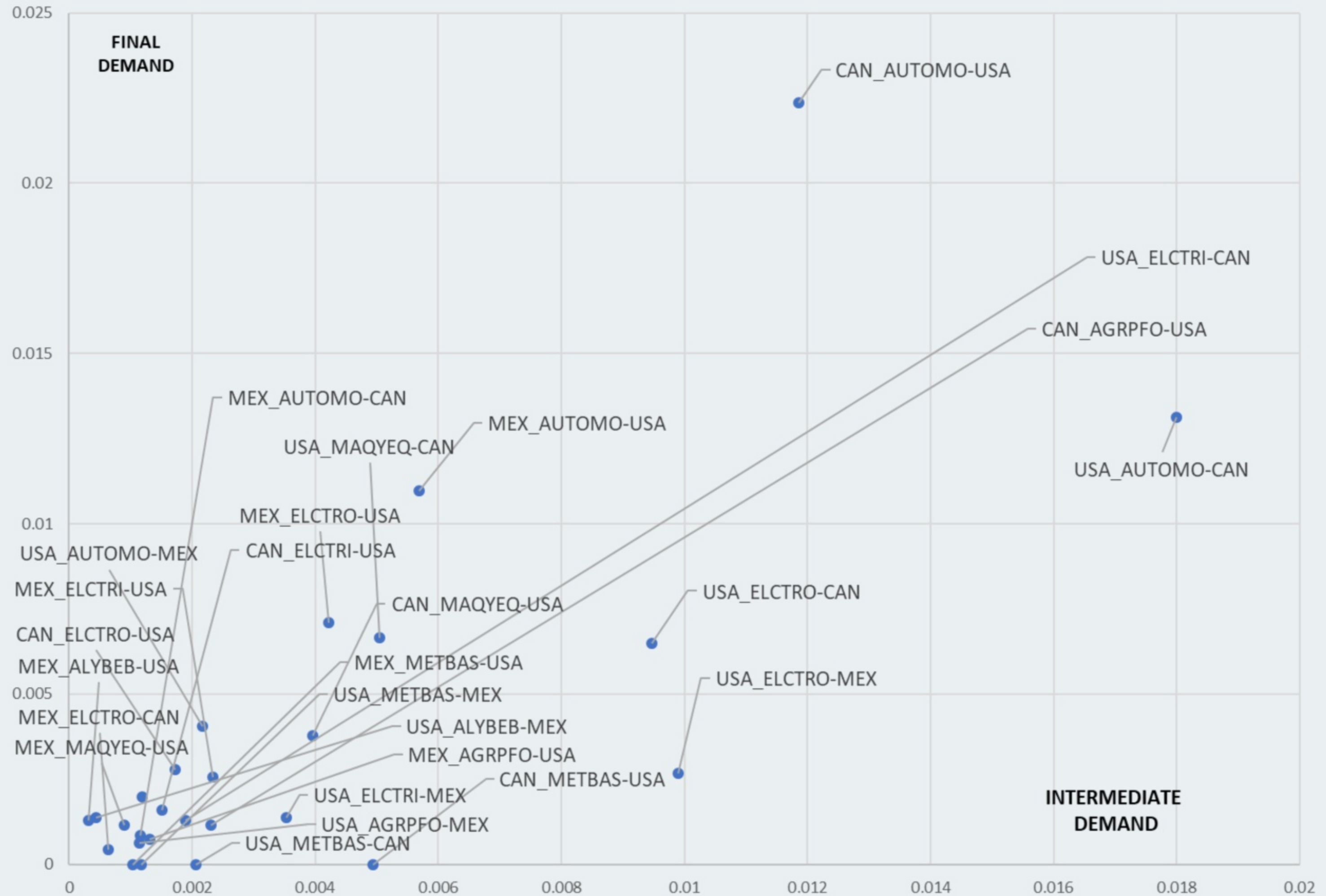
Asymmetric Integration Profiles:

Clustering analysis reveals a stark contrast in how member nations capture value within the trade framework. US and Canadian Ecosytems: Demonstrate strong mutual integration, primarily producing final goods characterized by high domestic content.

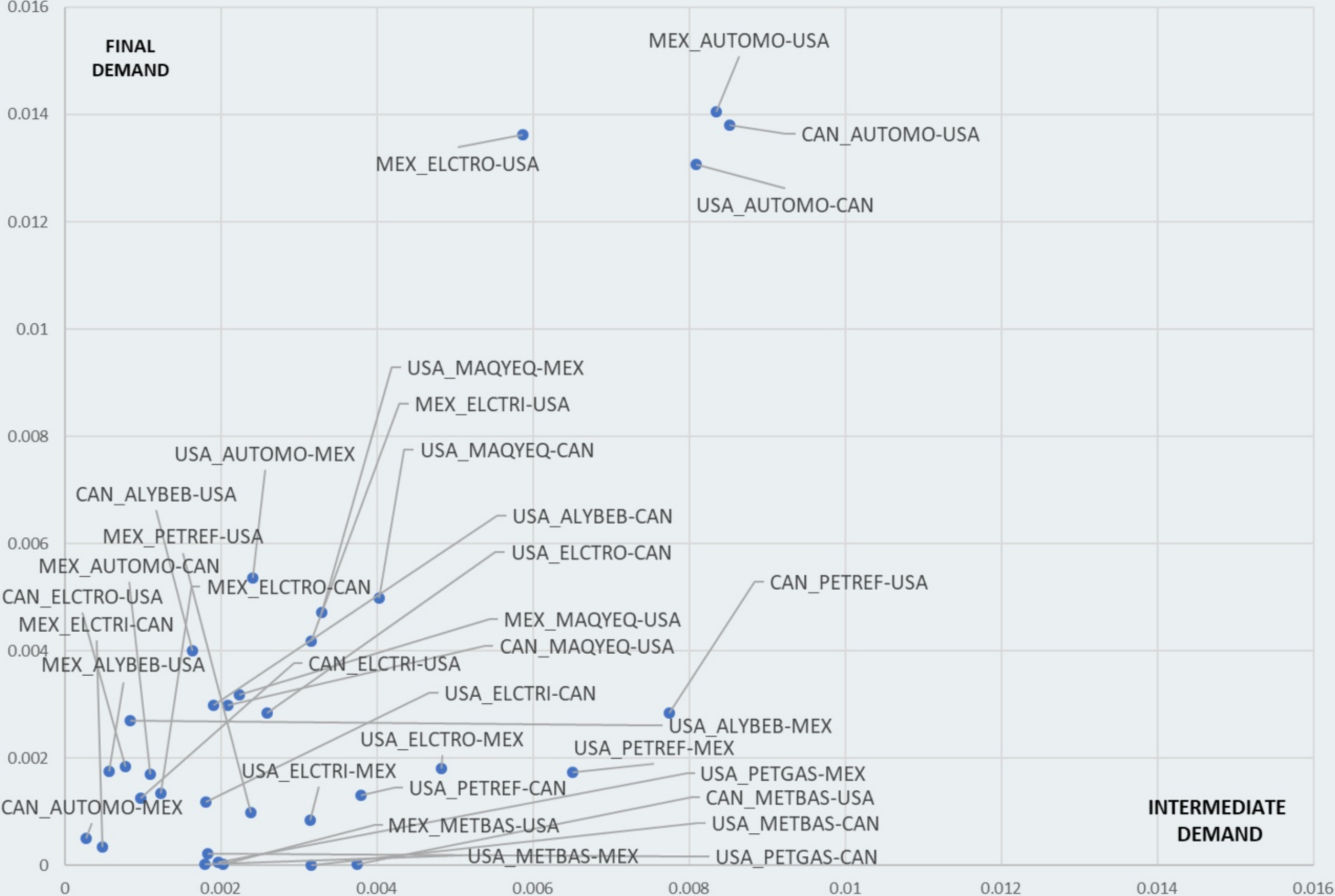
The Mexican Contrast: Mexican exports are structurally distinct, typically dominated by low-value assembly activities with a heavily depressed domestic component. Intermediate Supply Role: Mexican industries serve as critical providers of intermediate inputs within the USMCA, significantly influencing the broader dynamics of final production in the United States.

The Automotive \& Electronics Focus: Despite boasting impressive gross export volumes, these key sectors rely intensely on imported components, suggesting a functional persistence of maquiladora-style assembly over innovative manufacturing.

USMCA: INTERMEDIATE DEMAND VS. FINAL DEMAND 1995.



USMCA: INTERMEDIATE DEMAND VS. FINAL DEMAND 2008.



Reflections: The Displacement of Traditional Suppliers

Supply Chain Realignment

In recent decades, Chinese enterprises have emerged as highly influential players inside the USMCA supply chain.

Input Substitution: China increasingly provides various components and industrial materials previously sourced from traditional North American suppliers.

Competitiveness Pressures: Regional suppliers face severe challenges maintaining market share when competing against lower-cost Chinese manufacturing loops.

Sovereignty & Vulnerability

Heavy reliance on external inputs prompts rising concerns regarding economic sovereignty and domestic job security across the region.

Sectoral Impact: Vulnerabilities are highly concentrated in strategic sectors like automotive and electronics.

Long-Term Tradeoffs: While initial cost-savings are evident, the long-term structural trade-off includes acute vulnerability to supply disruptions and rising geopolitical tensions.

Strategic Responses & Shifts in Supply Chain Networks

Active Policy Exploration: In response to the expanding footprint of external suppliers, USMCA nations are evaluating frameworks to reinforce local production capabilities and curb external dependencies.

Resilience Vectors: Key initiatives focus on accelerating technological innovation, providing targeted support to domestic industries, and incentivizing reshoring/nearshoring processes.

Network Diversification: Recent trade network data displays a clear realignment in global supply chains; corporations are actively diversifying their input channels to mitigate risks tied to single-market concentrations.

Future Outlook:

As pressure from competitive external inputs persists, North American governments will likely be forced to redefine their trade rules and industrial strategies to champion domestic industrial sovereignty.

Conclusions

The examination reveals a critical framework of structural asymmetry and the need for robust industrial policies in Mexico to strengthen its position within the USMCA framework.

Conclusions: Structural Asymmetry and Trade Dynamics

Core Finding:

The empirical examination exposes a deep, persistent framework of structural asymmetry within the USMCA, emphasizing an urgent need for a robust industrial policy turn in Mexico.



Conclusions

The Domestic Value Deficit:

Mexico behaves primarily through assembly hubs characterized by vast export volumes but structurally low Domestic Value Added (DVA). The manufacturing matrix continues to demonstrate an intense, binding dependency on foreign inputs to sustain its export capacity.

Value Capture Constraints:

This deep import reliance systematically limits Mexico's ability to capture and retain economic value internally. The value capture barrier is most visible precisely in its most dynamic globalized sectors: automotive and electronics.

Urgent Policy Recommendations & Final Reflection

Strategic Industrial Reform:

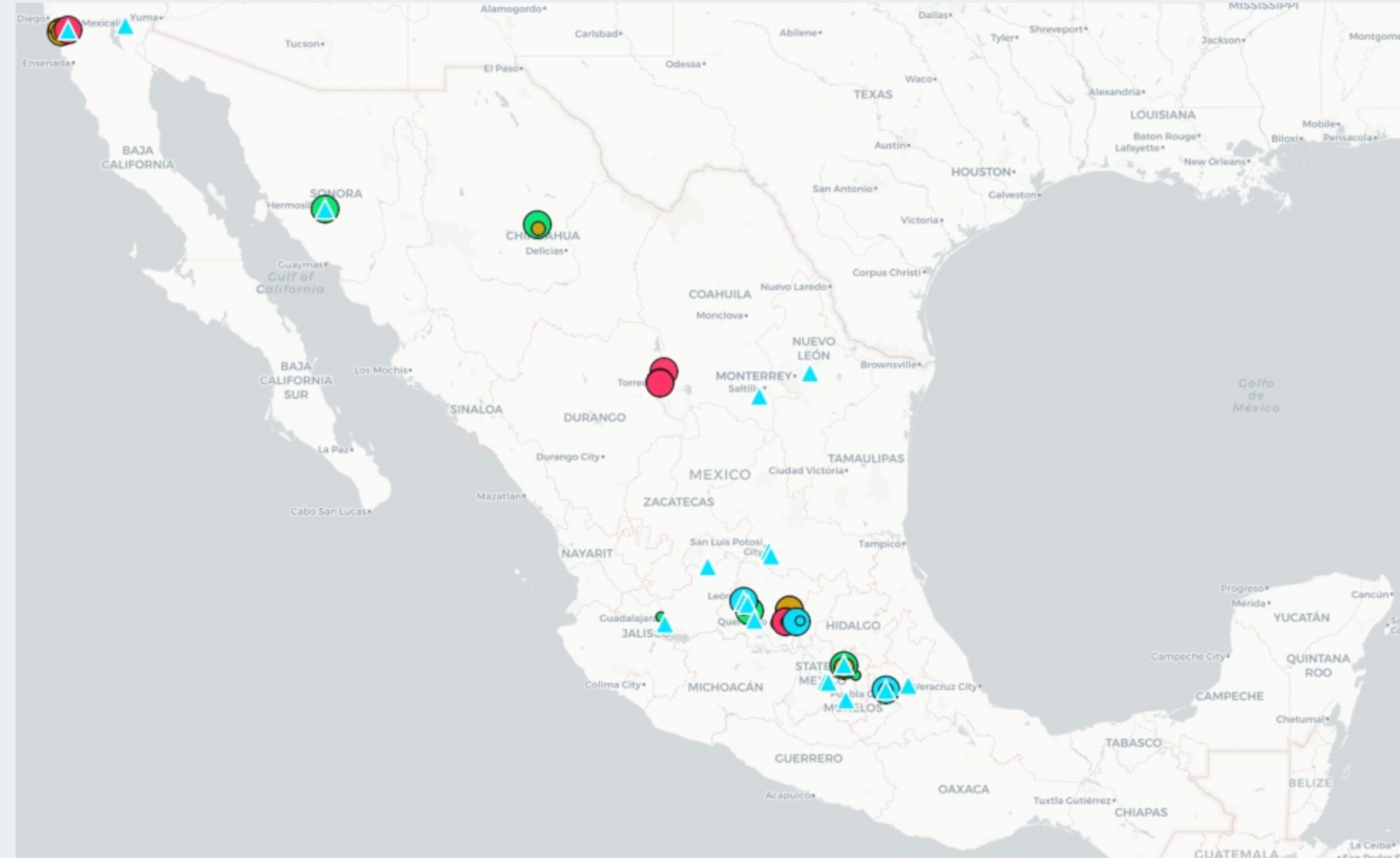
To resolve structural disparities, Mexico must transition its current economic strategy away from simple gross export volume towards local value creation and reduced input reliance.

The Treaty Review Window:

As the formal USMCA treaty review approaches, Mexico faces a vital institutional opportunity to design and present a comprehensively restructured industrial policy.

Final Reflection:

Failure to aggressively pivot towards high-DVA development models may permanently deepen internal socioeconomic inequalities and severely constrain Mexico's developmental prospects within North America

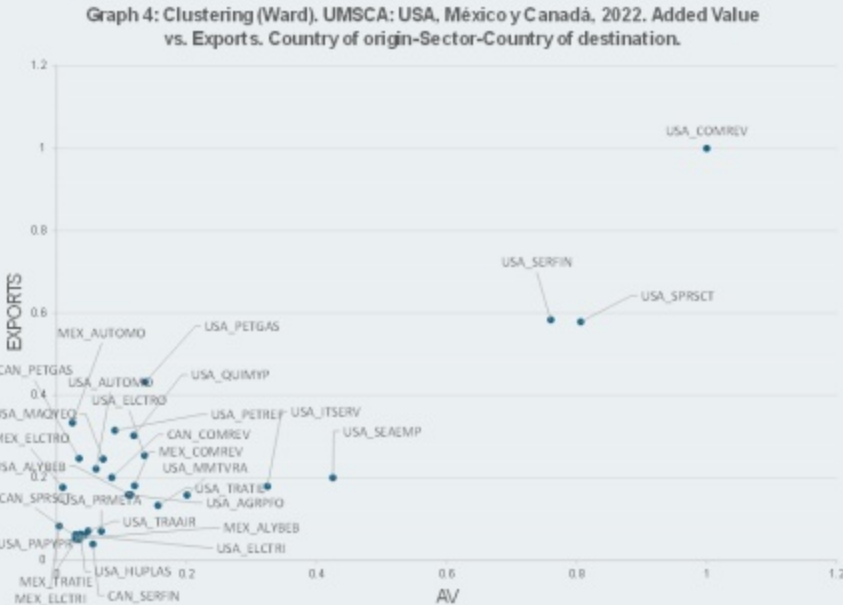




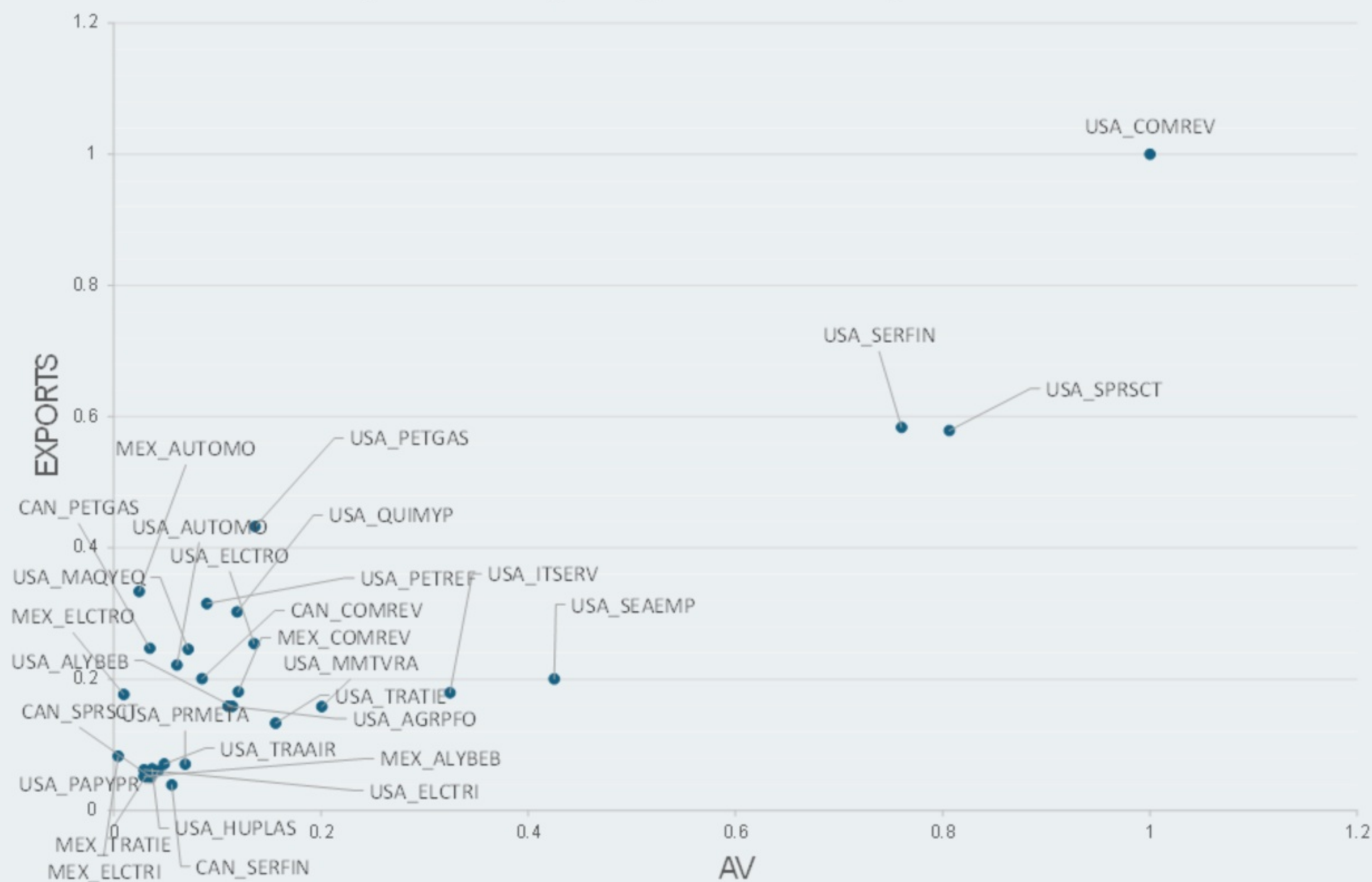
The inter-industry structure of the USMCA countries analysis: network GMRIO and data science approach

Authors: Bouchain, Méndez, Hernández, and Quiroga
(IIEc-UNAM)

VALUE ADDED-EXPORTATIONS DENDOGRAMS



Graph 4: Clustering (Ward). UMSCA: USA, México y Canadá, 2022. Added Value vs. Exports. Country of origin-Sector-Country of destination.



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