Agricultural Value Chains – Evolving Towards Massively Modular Ecosystems?

Daria Taglioni

Selected presentation for the International Agricultural Trade Research Consortium's (IATRC's) 2022 Annual Meeting: Transforming Global Value Chains, December 11-13, 2022, Clearwater Beach, FL.

Agricultural Value Chains - Evolving towards Massively Modular Ecosystems?

Daria Taglioni

IATRC 2022, Clearwater Beach – December 13, 2022

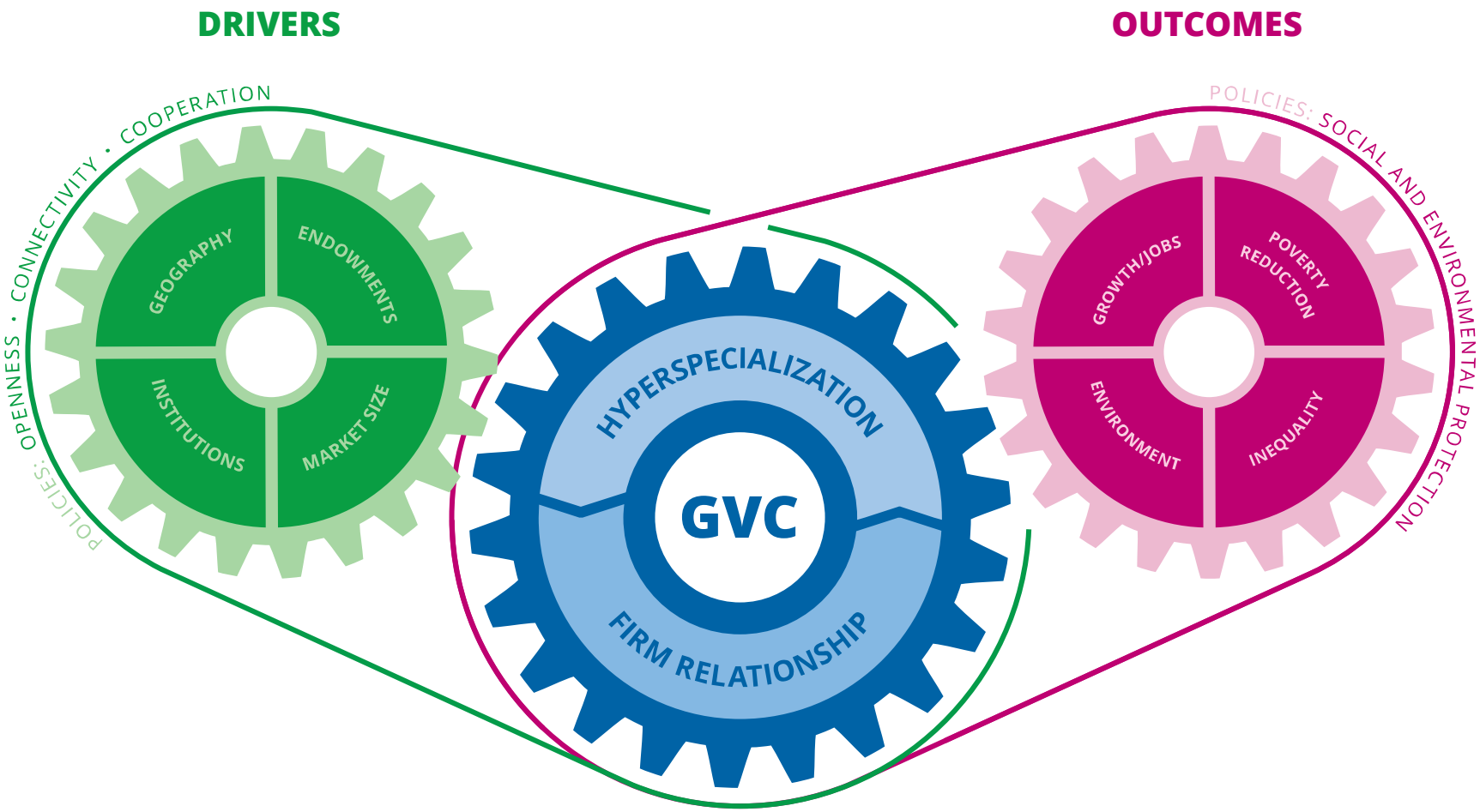
Plan of the talk

- The two distinctive features of GVCs
- Massive modularity: the case of smartphones
- Massive modularity: how relevant for agricultural GVCs?
- Policy implications: tension between decoupling and accommodation

GVCs distinctive features

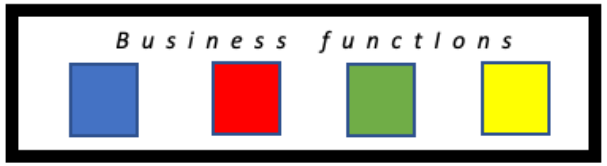
World Bank's World Development Report 2020

GVC–led development: the framework of the WDR 2020



A micro-view of GVCs is necessary to capture some of the contradictory implications of the GVC-led growth model

Industry organization and associated geographic footprint has evolved greatly over time



Multinational Firm:

Ownership across geographies

Strategic objectives: control over inputs, access to capabilities, market access, cost arbitrage

Global Value Chain:

Geographic vertical specialization

Strategic objectives: capturing and protecting high value-added activities in the value chain

Massively Modular Ecosystem:

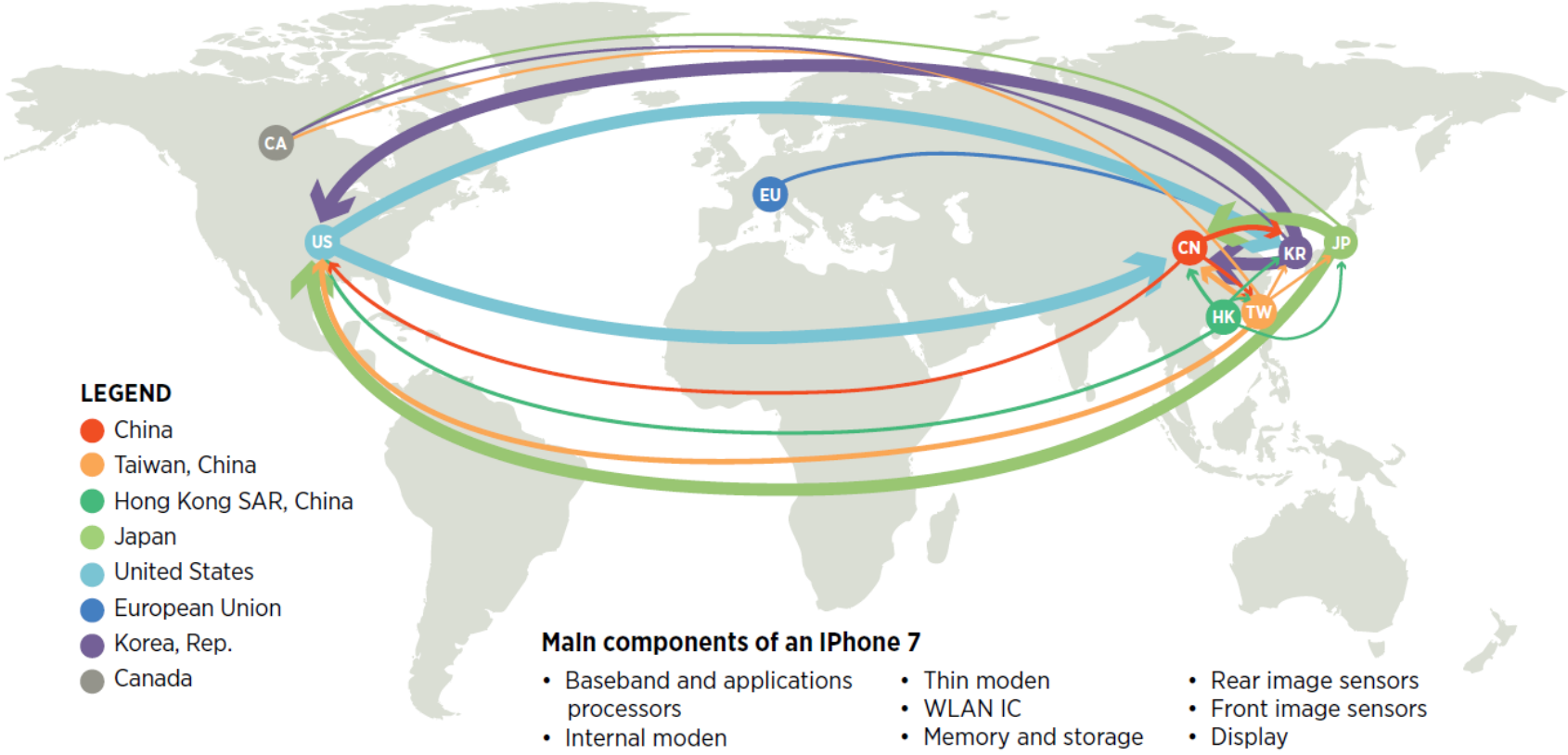
Geographic vertical and lateral specialization, integration and overlap

Strategic objectives: Dominance in niche and influence and/or control over interconnect standards.

Source: Thun, Taglioni, Sturgeon and Dallas (2022)

To explore the implications, focus on a posterchild of globalization: the smartphone

The iPhone 7 had 1,815 individual components traded between eight countries (EU considered one country) across three continents, in 84 different trading relationships.



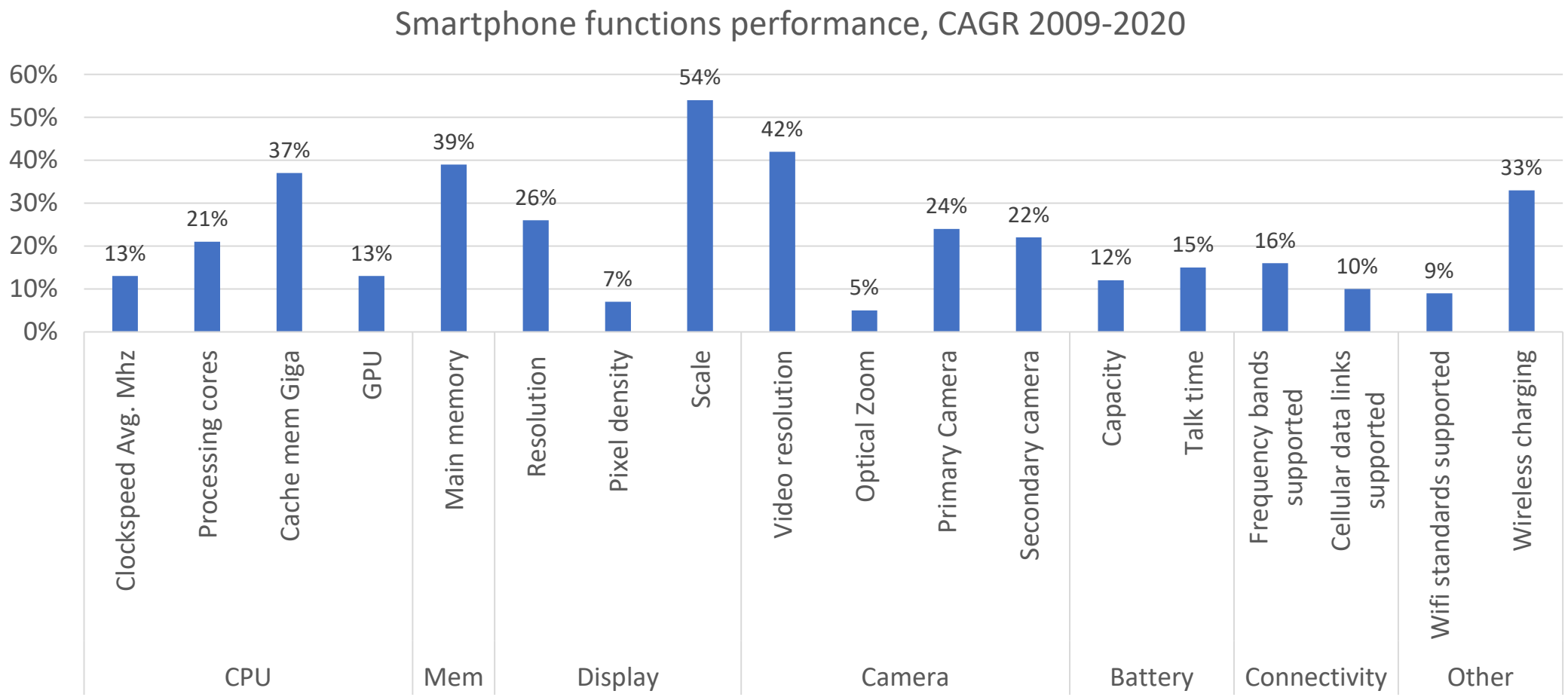
Source: Thun, Taglioni, Sturgeon, and Dallas 2022

2003

2022

- Network – 2G GSM
- Display - Monochrome graphic
- Resolution - 96 x 65 pixels, 4 lines
- Memory card slot - No
- Phonebook – 50 people
- Call records - 10 dialed, 10 received, 10 missed
- Camera - No
- Loudspeaker - No
- Alert types – Vibration/monophonic ringtone
- Wifi – No
- Bluetooth - No
- GPS - No
- Radio - No
- USB – No
- Messaging - SMS
- Games - Snake II and Space Impact
- Languages - Most major European and Asian
- Battery - up to 400 hours standby and talk time up to 4 h 30 min

Mobile handset performance and functional improvements (2009-2020)



Source of data: PhoneDB (https://phonedb.net/), phone specifications database. N=15,544 phone models.

2022

1969

- Modern smartphone has more processing power than the mainframe computers in Apollo 11 mission control.
- Modern smartphones have more than 1 million times more RAM (temporary memory), 7 million times more ROM, and over 100,000 times more processing power than the onboard Apollo Guidance Computer.

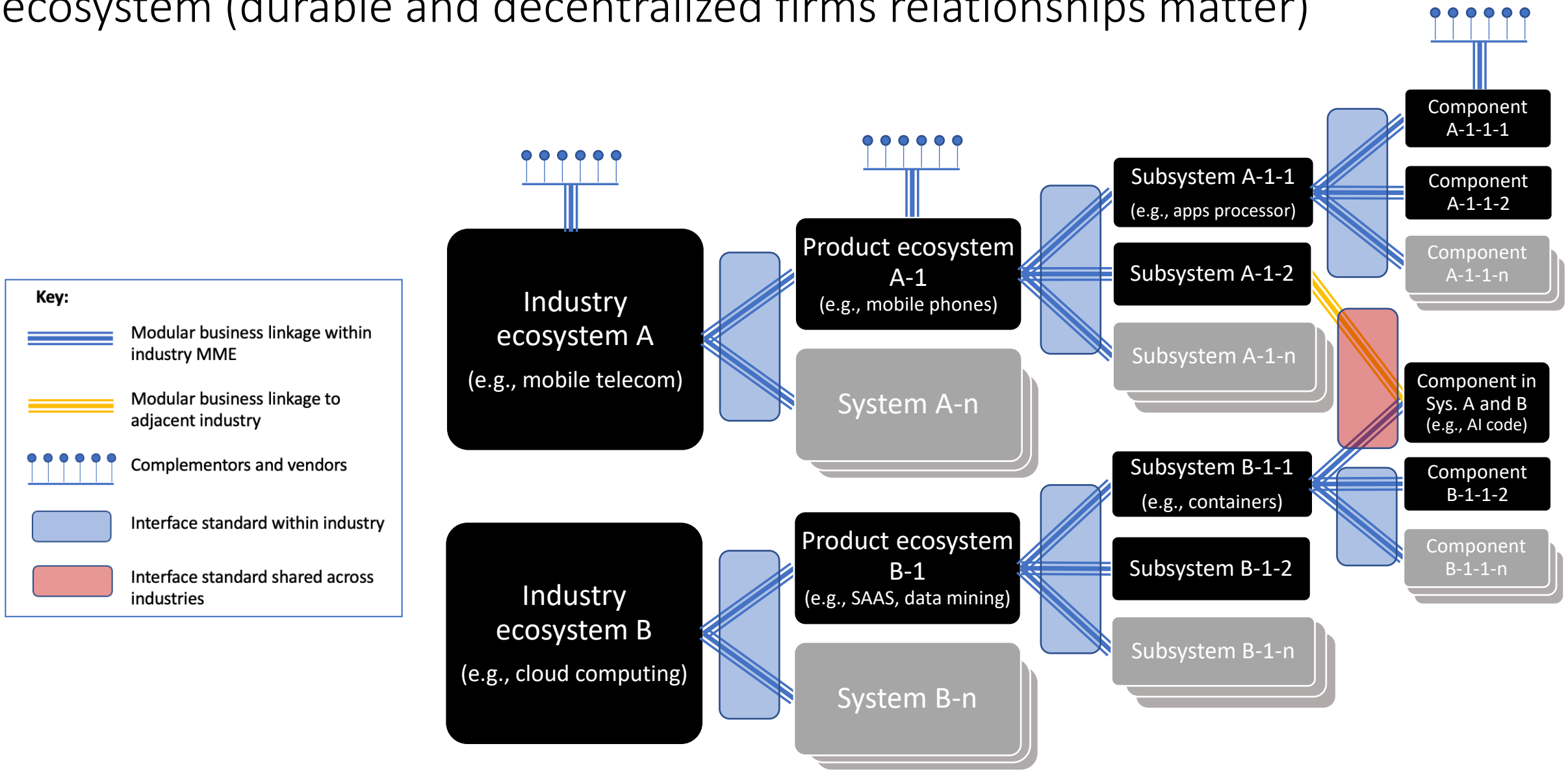
Massive Modularity

Understanding Industry Organization in a Digital Age

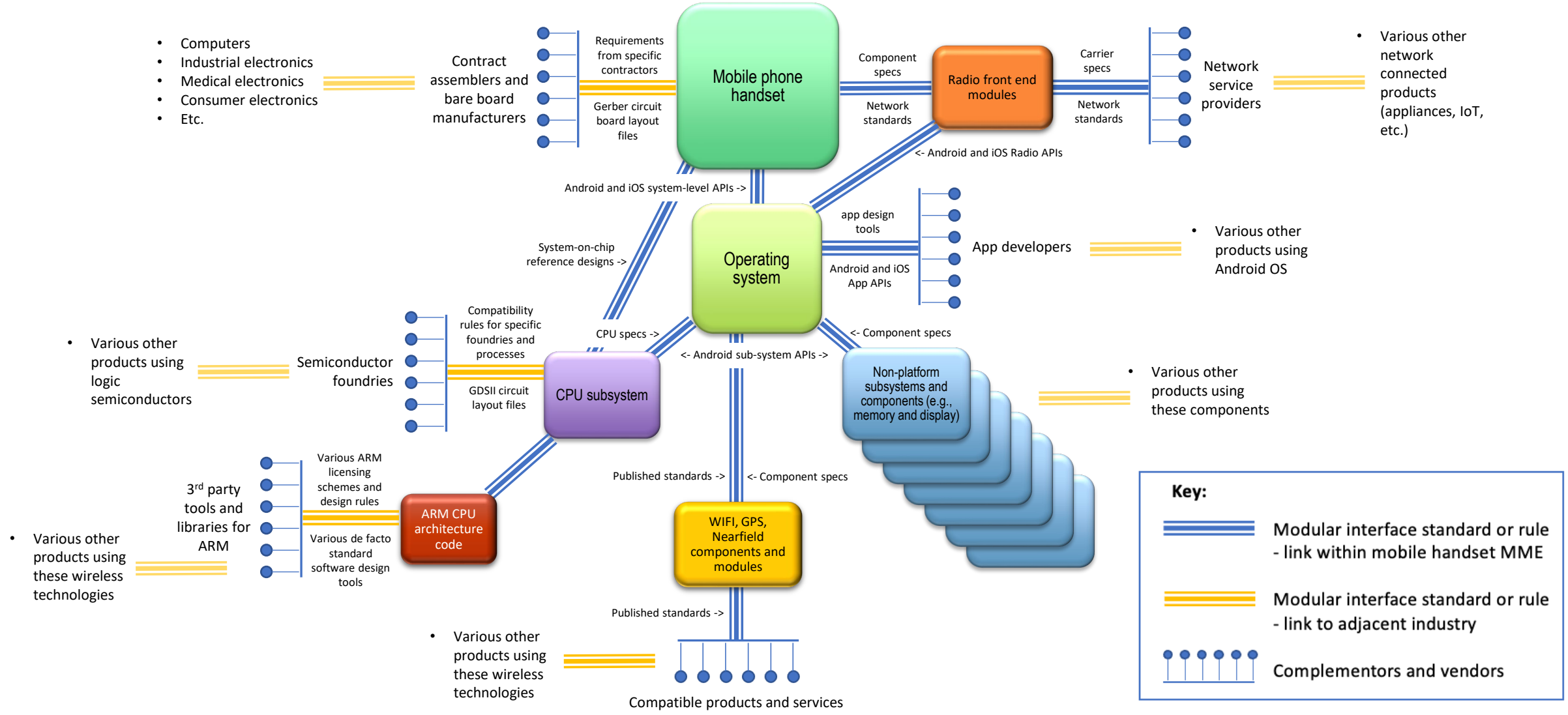
Eric Thun, Daria Taglioni, Tim Sturgeon and Mark Dallas

World Bank's Policy Research Working Paper # 10164.

The smartphone industry can be defined as a massively modular ecosystem (durable and decentralized firms relationships matter)



The mobile handset industry …and a few of its linkages to adjacent industries



Standards supporting modularity in mobile telecom

Mobile telecom-specific standards & platforms

Network connectivity (1G, 2G, 3G, 4G, 5G)
- Hundreds of contributing companies and organizations
- 3GPP (3G and 4G)
- 3GPP and OpenRAN Alliance (5G)

Android OS
- 85-90% of touchscreen smart phones
- Thousands of open source contributors
- Thousands of compatible apps on GooglePlay

CPU: System-on-chip (SoC) - External
- Qualcomm Snapdragon series
- MediaTEK

CPU: System-on-chip (SoC) - Internal
- Apple A-series
- Huawei Kirin
- Samsung Exynos

CPU: ARM system architecture IP
- 90%+ market share
- Licensing structure varies from relational to modular
- 800+ complementors offering tools and compatible code

De facto standard platforms and dominant designs

General ICT standards and systems used in mobile telecom

WIFI: Wireless connectivity (with the internet)
- WIFI Alliance (1k+ companies)

Bluetooth: Wireless connectivity (with compatible devices)
- Bluetooth Special Interest Group (36k companies)

Nearfield: Proximate communication (nearfield)
- E.g., mobile payment
- ISO/IEC JTC 1 (international standard setting body, 1 member from each country)

GPS: Geolocation
- US/Russian/Chinese/etc. government agencies (GPS/GLONASS/BeiDou/etc.)

Cables: Physical connection between devices
- Universal standard bus (USB): physical connection to devices
- USB Implementers Forum - 1,100 company members

Manufacturing: Semiconductor packaging and circuit board assembly roadmapping
- Methods for defining and describing interconnects to substrates
- Assembly technology road mapping, technical planning, test deployment projects, etc.
- International Electronics Manufacturing Initiative (iNEMI, 92 company members)

De jure standard guidelines and infrastructure

Source: Thun, Taglioni, Sturgeon, and Dallas, 2022, “Massive Modularity: Understanding Industry Organization in the Digital Age.”

Focus of the paper: can a product of the likes of a mobile phone be produced within national borders?

Not likely

Why not?

Hypothesis: Because of the confluence of factors along three dimensions together: **technology, industrial organization, and geography**:

1. The digital revolution has changed **industrial organization.**

2. Changes in industrial organization have changed the **geography** of industry.

The argument:

1. Digitization is transforming the organization and geography of industries
    - Once digitized, information can be generated, collected, stored, monitored, analyzed, processed and rekindled in ways not previously possible and at very low marginal costs.
    - When common standards are used as modular interfaces, data can be transferred and put to use with greater ease across organizations and geographic space.
2. We refer to this process as **modularity** and observe the emergence of elaborate **global-scale massively modular ecosystems (MMEs)** associated with digital products, applications, and technologies.
3. In massively modular ecosystems, firm-to-firm relationships **are highly relational but decisions increasingly decentralized**

The **implications for Industrial Organization and its Geography:** three **paradoxes** characterize MMEs:

1. Complexity and hyperscale (complexity at scale)
2. Market concentration and fragmentation
3. Geographic clustering and dispersal

The implications for policy: these paradoxes give rise to a fourth policy-related paradox:

1. Pressure for geographic decoupling: import substitution and indigenous innovation / reshoring, nearshoring, friend-shoring
2. Pressure for accommodation of global economic and technological integration

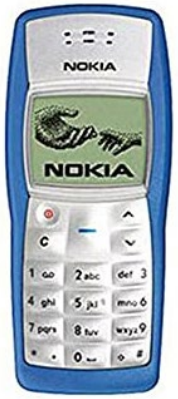
Literature

- **Industrial organization -** Modularity as an industrial organization form (Carliss Baldwin):
  - Baldwin and Henkel 2012; Baldwin and Clark 2000, Murmann and Frencken 2006
- **Technology -** management and innovation:
  - How firms can capture value in modular industrial ecosystems: Teece 2018, Carliss Baldwin 2020, Kretschmer et al 2020, Furr et al 2022
  - Influence over industry architectures: Jacobides et al. 2006; Gawer and Cusumano 2014
  - Winning control in an era of digital platforms: Gawer and Cusumano 2008; Kenney and Zysman 2016; Van Alstyne et al 2016; Cusumano et al 2019
- **Geography:**
  - Sociology literature on global value chains (governance, reshaping): Gereffi et al.; Sturgeon et al.
  - Trade literature on global value chains: Antras and Chor 2021 for a literature review
  - Role of nation-state in structuring global industries: Rodrik and Walt 2021

Smartphone Data

- Bill of materials (BOM) data for 456 mobile handsets produced between 2008 and 2019 (IHS Markit)
  - Component, component type, dimension, name of component vendor
- Matched with:
  - Vendor's HQ geographic location, and when relevant vendor's parent company HQ.
  - Market data, including sales units and revenue by brand and by model for 130 mobile devices (OMDIA).
  - Handset specifications, including information on the approximate retail price, release date of the model, network technology used, etc. (Teoalida and PhoneDB, covering 10,262 and 15,440 phone models, respectively).
  - Open-source commit (software contributions) from Android Open-Source Project.
  - Individual company contributions to 3GPP technical specifications (individual work items, personnel, involvement in process from initial proposal to final publication).

The launch of the smartphone in the market is associated with a major increase in modularity in mobile telecom



2003

- High levels of vertical integration
- Relational ties with key suppliers (e.g. Texas Instruments)
- No standard modular interface between operating system (OS) and applications

2007

- Closed platform for hardware (and developed in-house)
- Open platform for apps governed through the application program interface (API)

Rapid increase in modularity

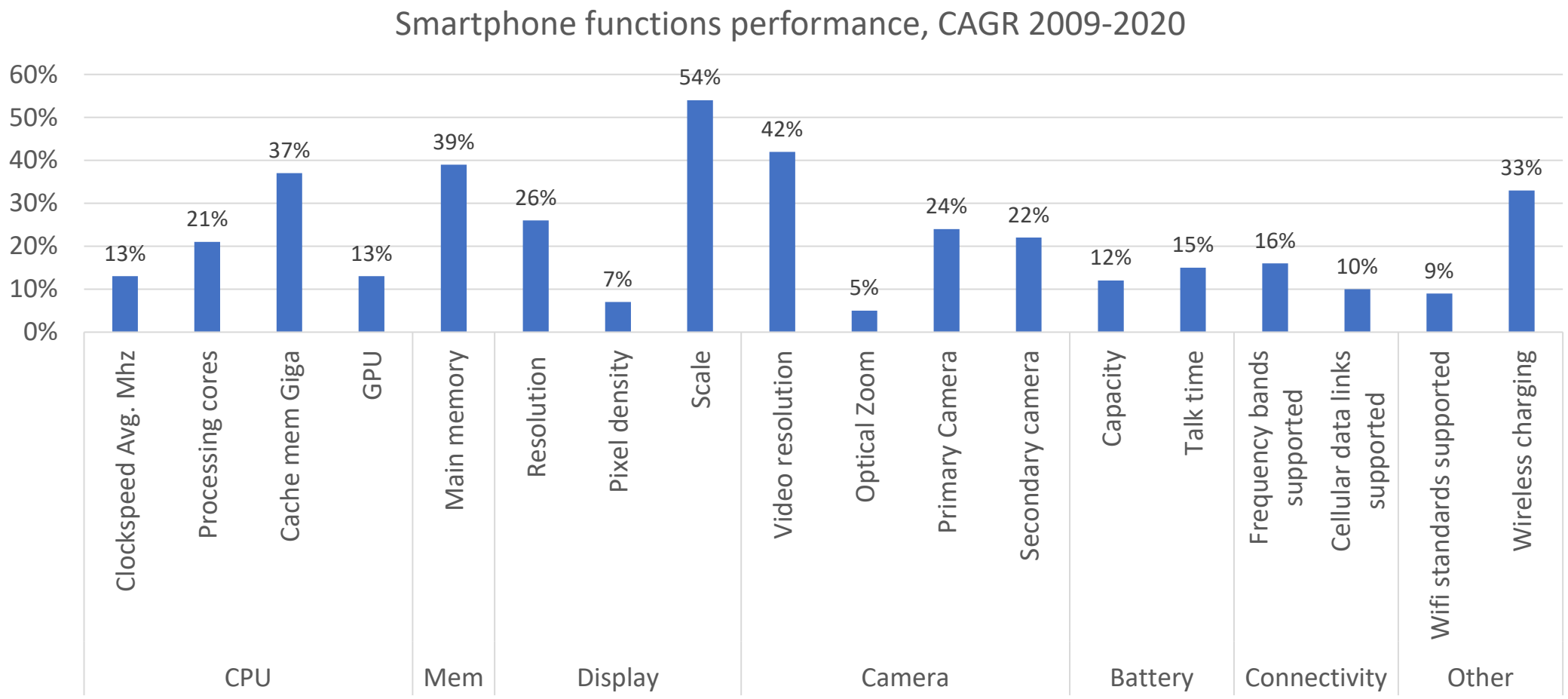
android

2008

- Partially open-source code offered free to any compatible handset
- Open platform for apps

Complexity at scale in smartphones

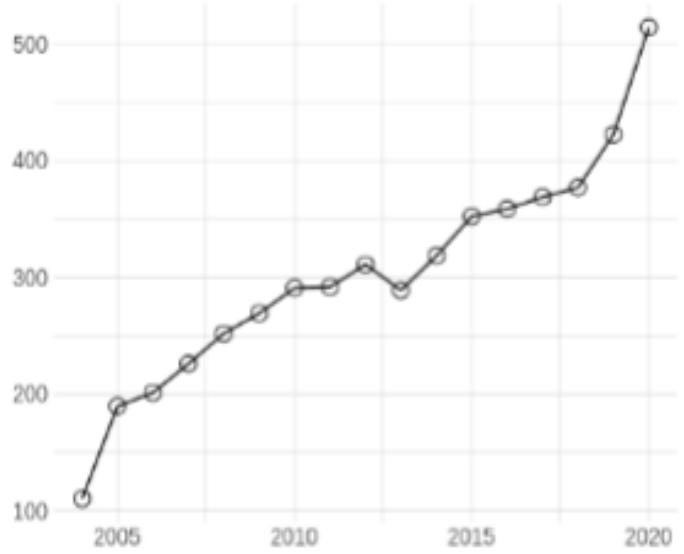
Complexity of the product increased greatly: Mobile handset performance and functional improvements (2009-2020)



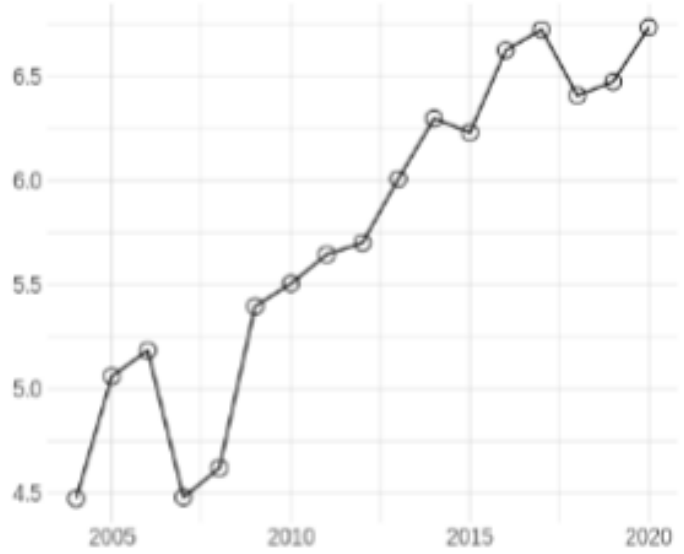
Source of data: PhoneDB (https://phonedb.net/), phone specifications database. N=15,544 phone models.

Growing complexity of the product was associated with a parallel growth in complexity of the value chain: evolution of the number of components and suppliers

Average # components per device



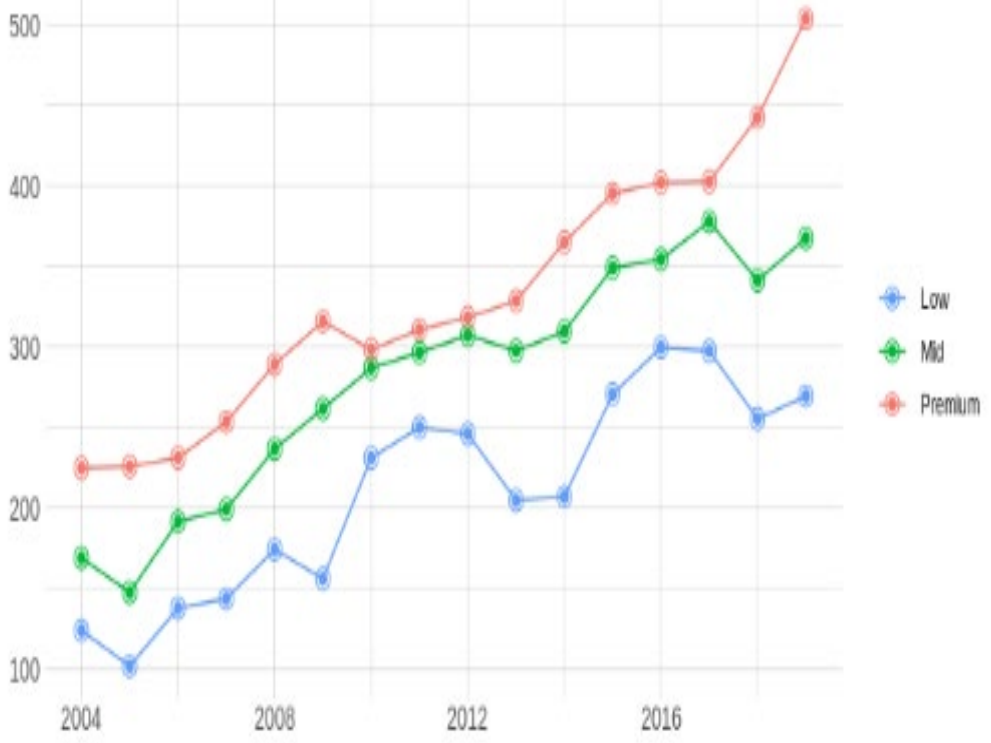
Average # suppliers per device



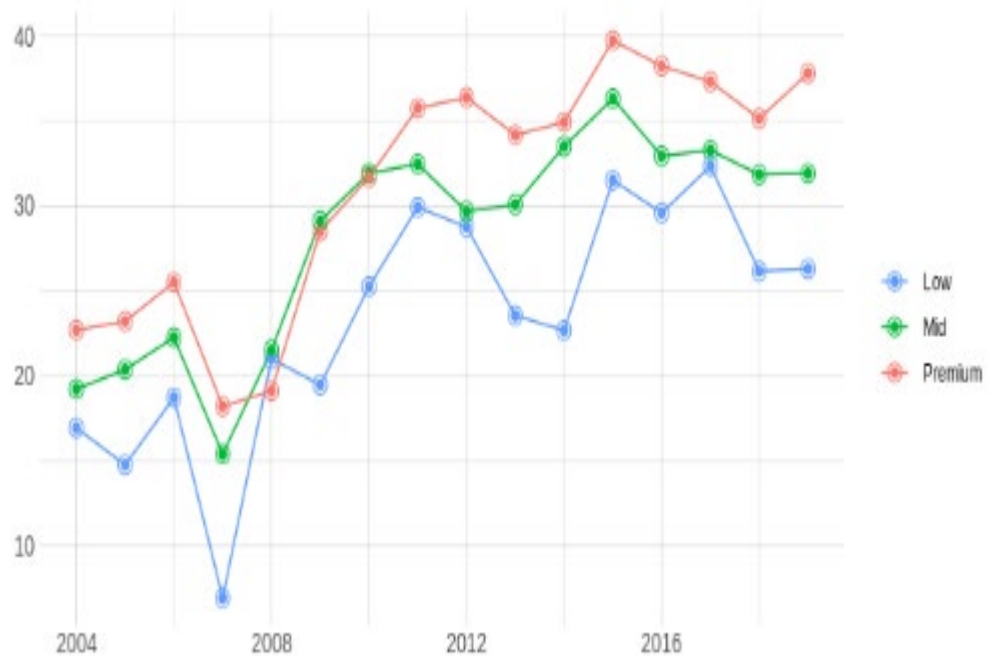
Note: phones are classified per tertial of total costs

Number of components and suppliers per device increased across all device ranges

components per device range

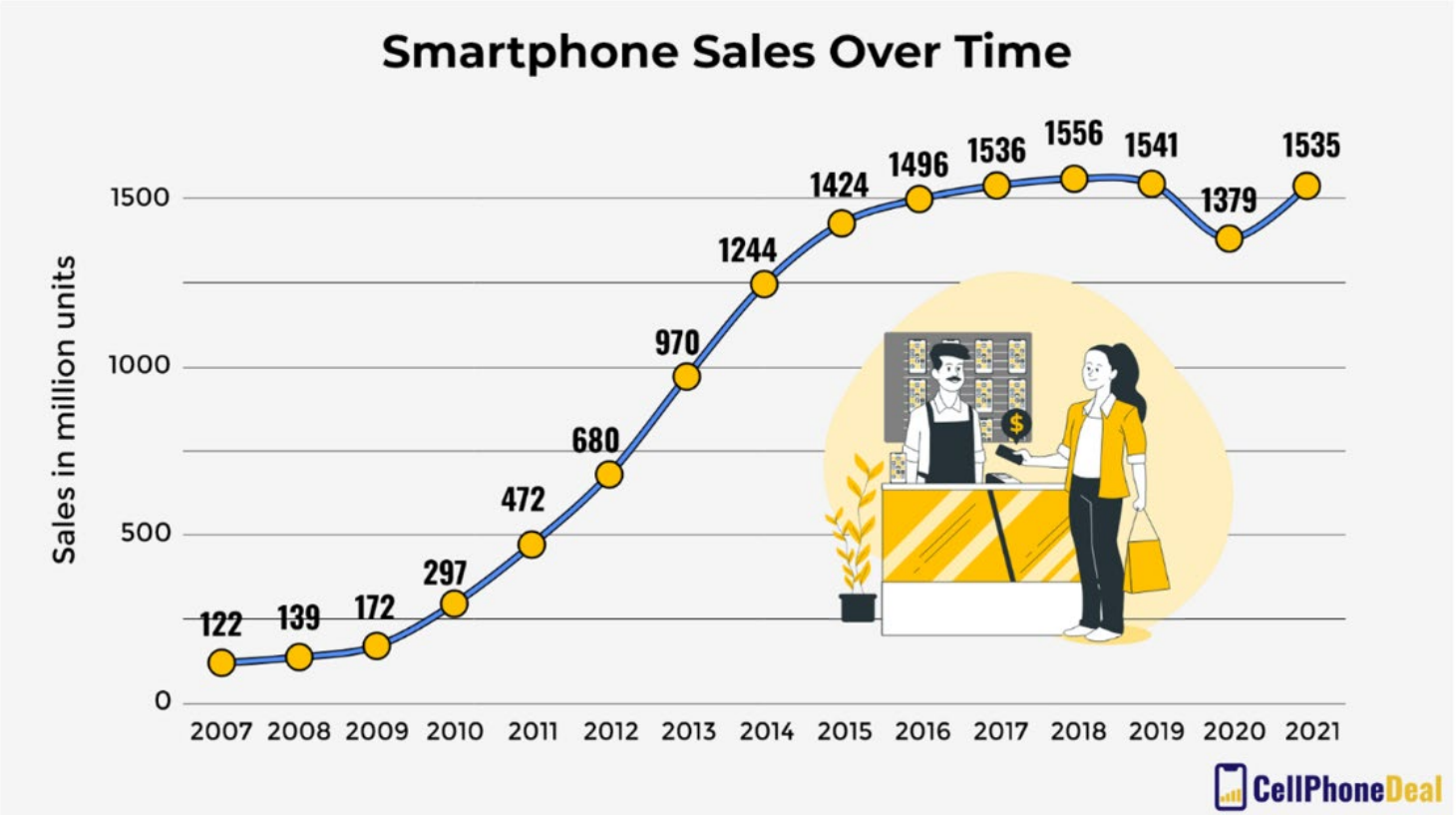


suppliers per device



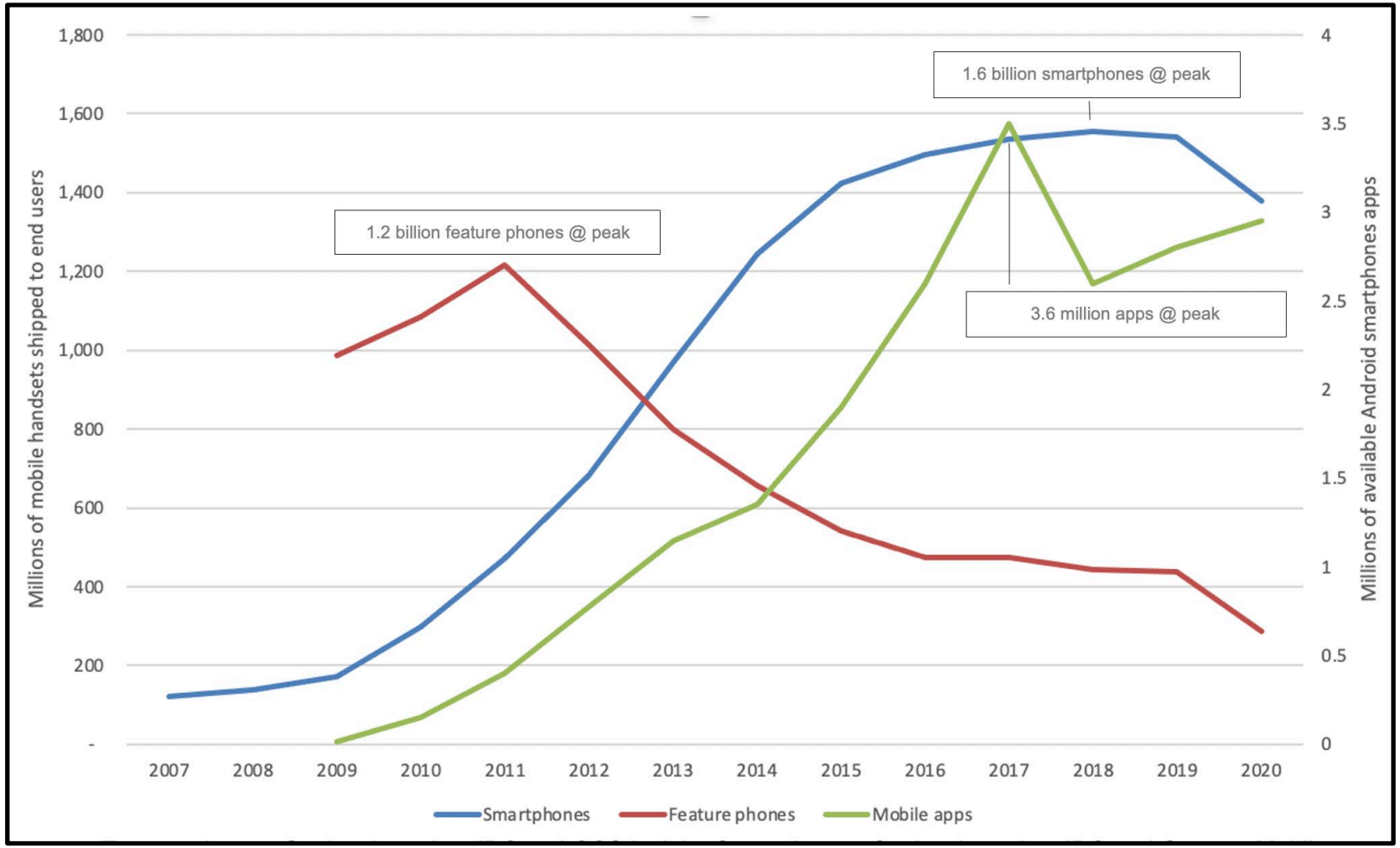
Note: phones are classified per tertial of total costs

Scale increased in parallel: “Smartphone” shipments, 2007 – 2020



Source: CellphoneDeal. Note: this chart excludes feature phones. Similar numbers from other sources include Statista, IDC and Gartner (2007)

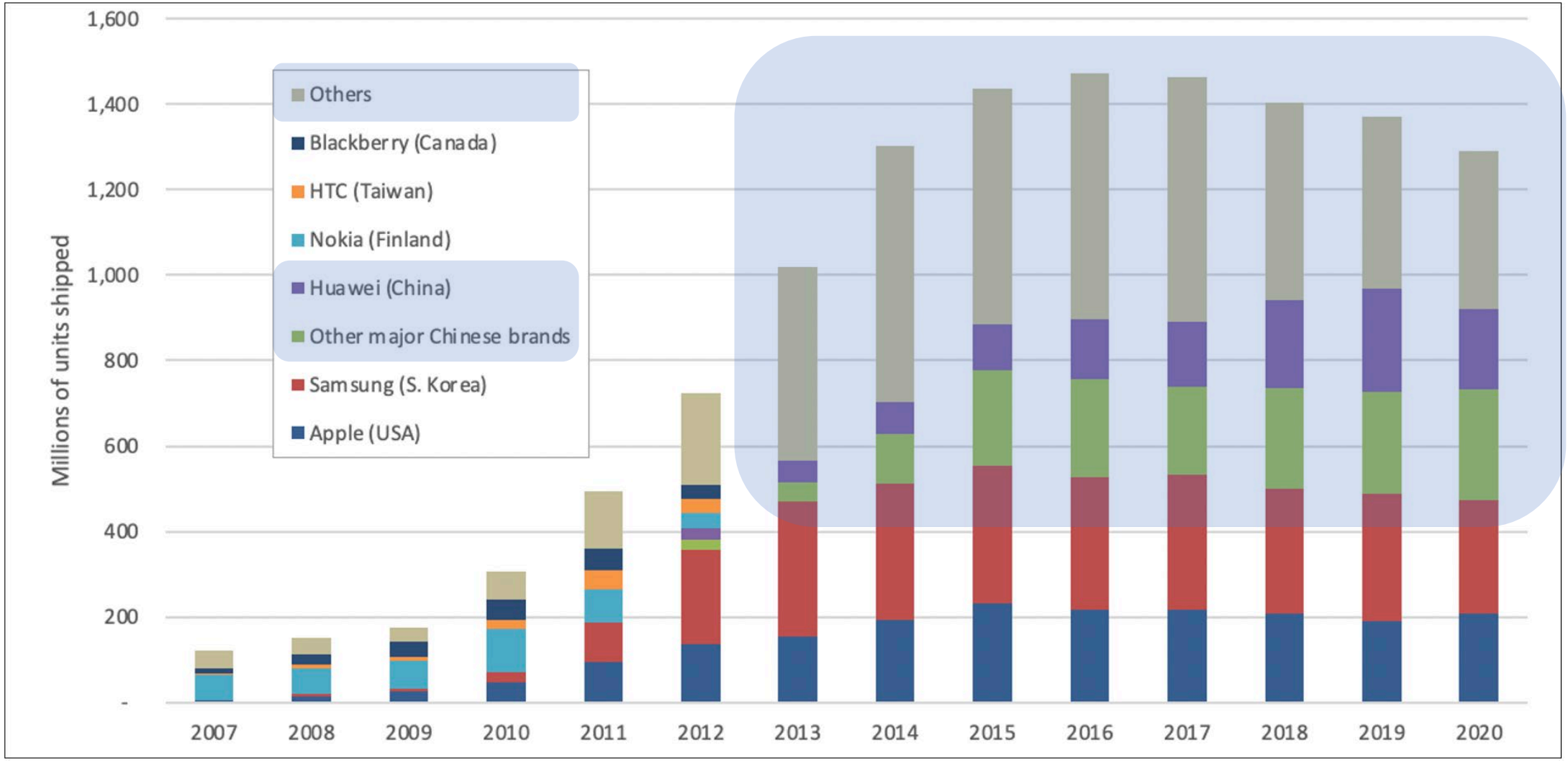
Scale of associated products and services also increased: Mobile handset shipments and available smartphone apps, 2007-2020



Sources: Feature phones: Statista based on IDC and CCS Insight; Smartphones: Statista based on IDC and Gartner; Mobile apps: Statista based on data from Google, App Annie, and AppBrain, as published by AppBrain.
Note: In Summer of 2018 Google removed a large number of apps due to an update to the company's Developer Policy.

Market concentration and fragmentation in smartphones

At the product level, a trend of market fragmentation can be observed: "Smartphone" shipments by brand, 2007 – 2020



Source: Adapted from Statista based on data from IDC and Gartner (2007)
Note: this chart excludes feature phones.

Market fragmentation is also visible when looking at supported apps: Android apps

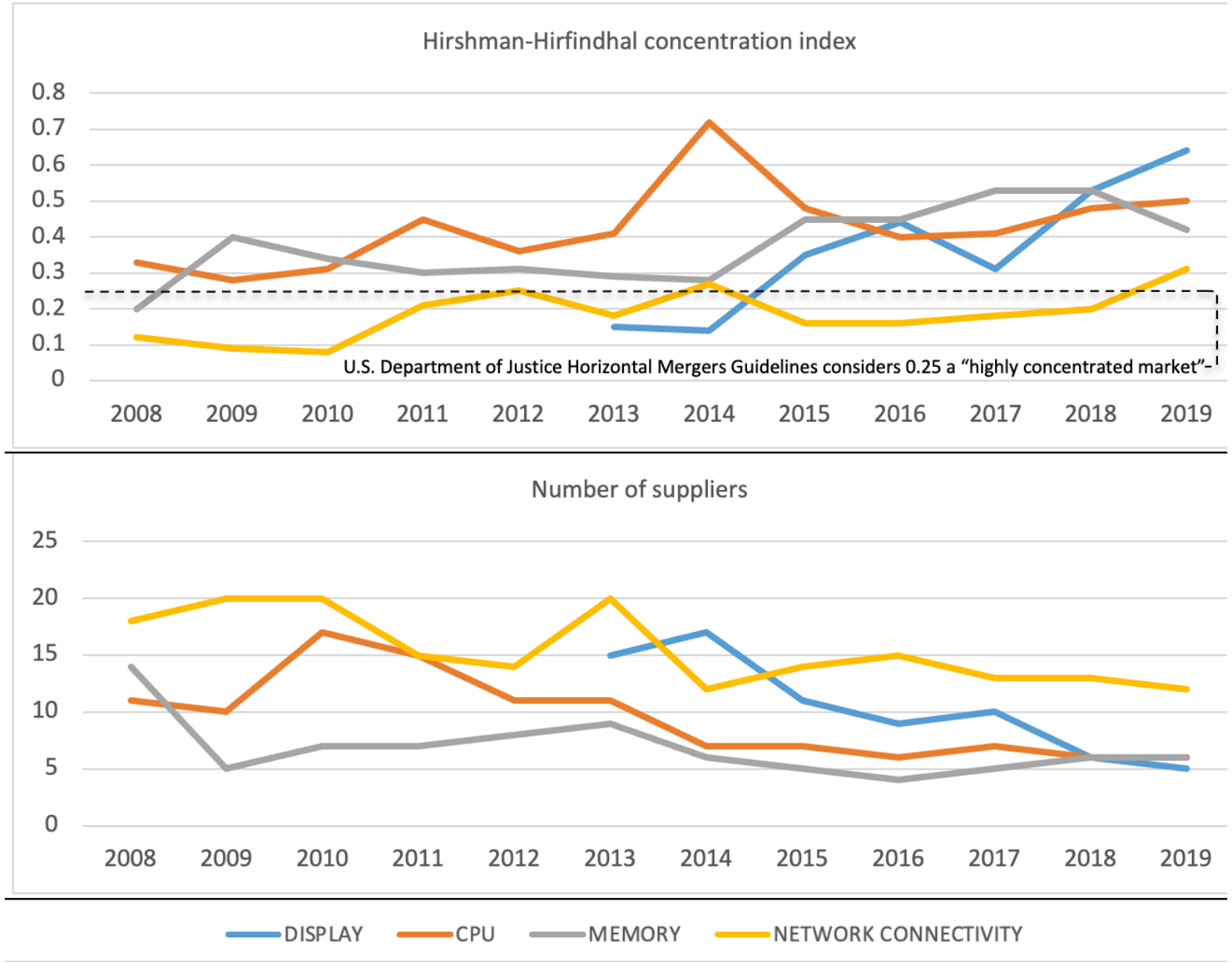
App releases by country, 2017

	Share of releases
United States	33.50%
China	15.90%
India	5.10%
United Kingdom	3.30%
Brazil	2.80%
Germany	2.80%
Japan	2.40%
France	2.10%
Russia	2.10%
Canada	1.90%

Source: Statista based on data from AppFigures

Non-OECD countries make a strong showing

But market concentration increased at the sub-system level: Sub-systems 2008-2019

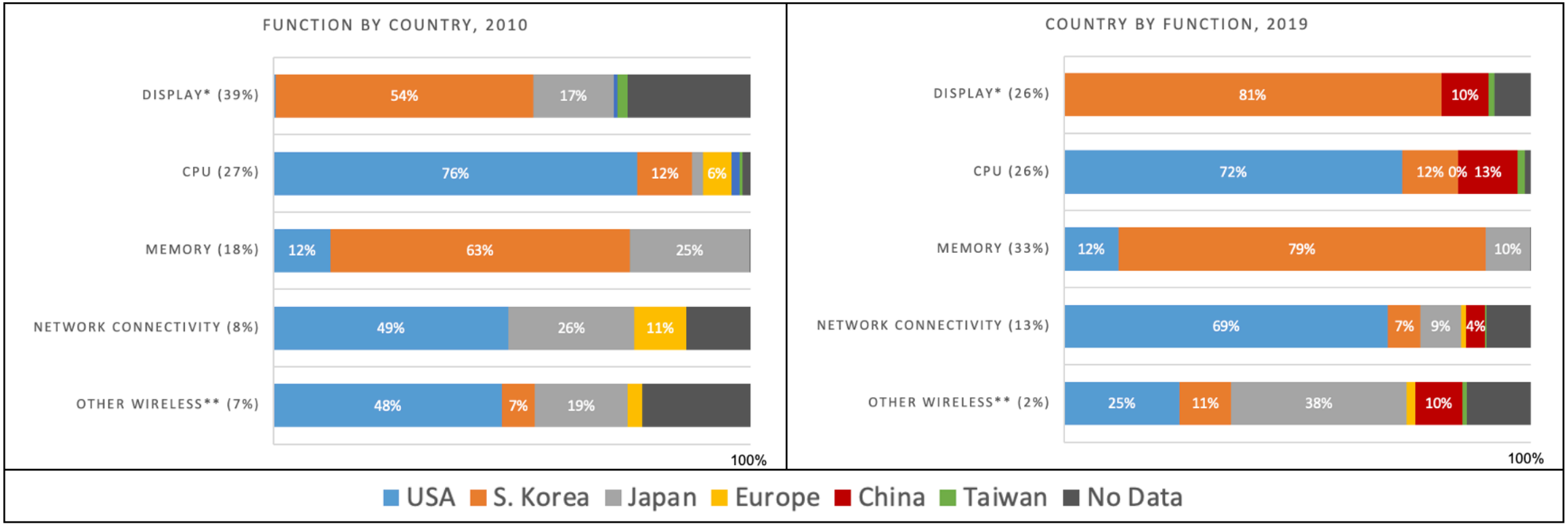


Source of data: IHS Markit and Techinsights

Geographic clustering and dispersal in smartphones

Geographic clustering of individual functions – Sub-systems

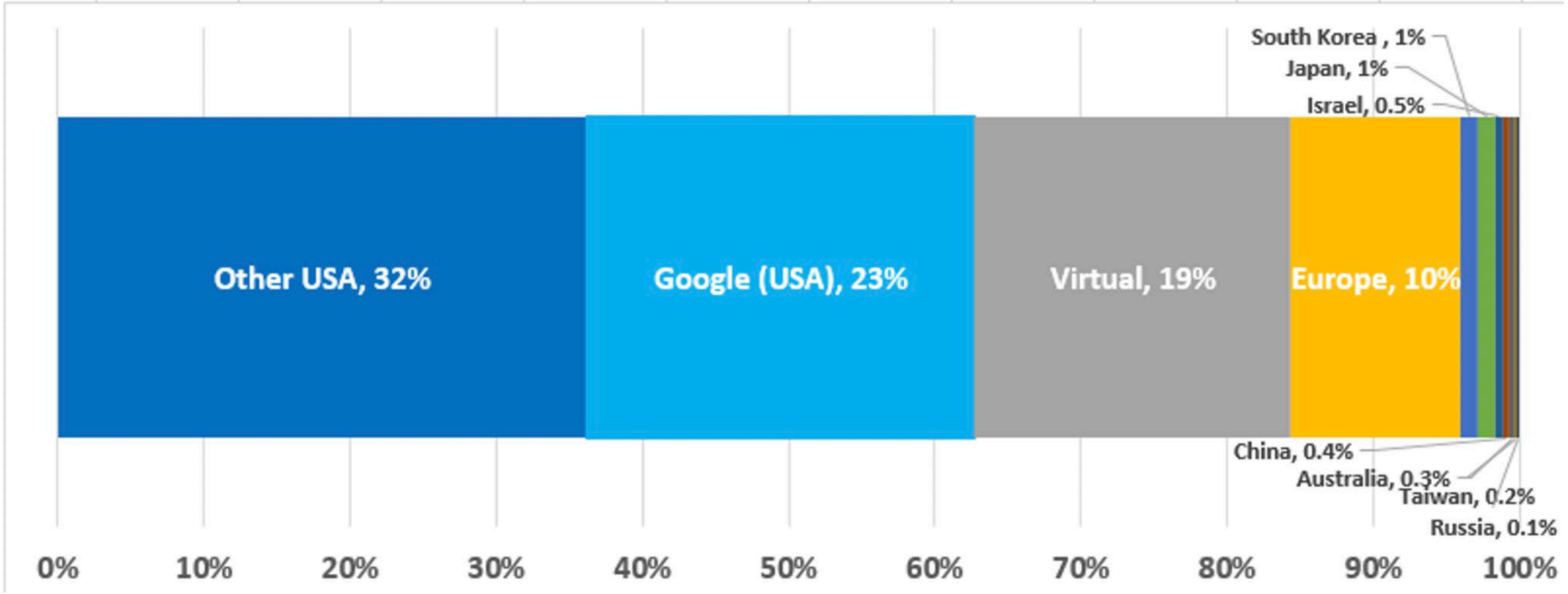
Mobile handset share of value added in five main functions, by geography of ownership



Source of data: IHS Markit and Techinsights

Market concentration is high also in associated industries: U.S. dominates Android open-source contributions

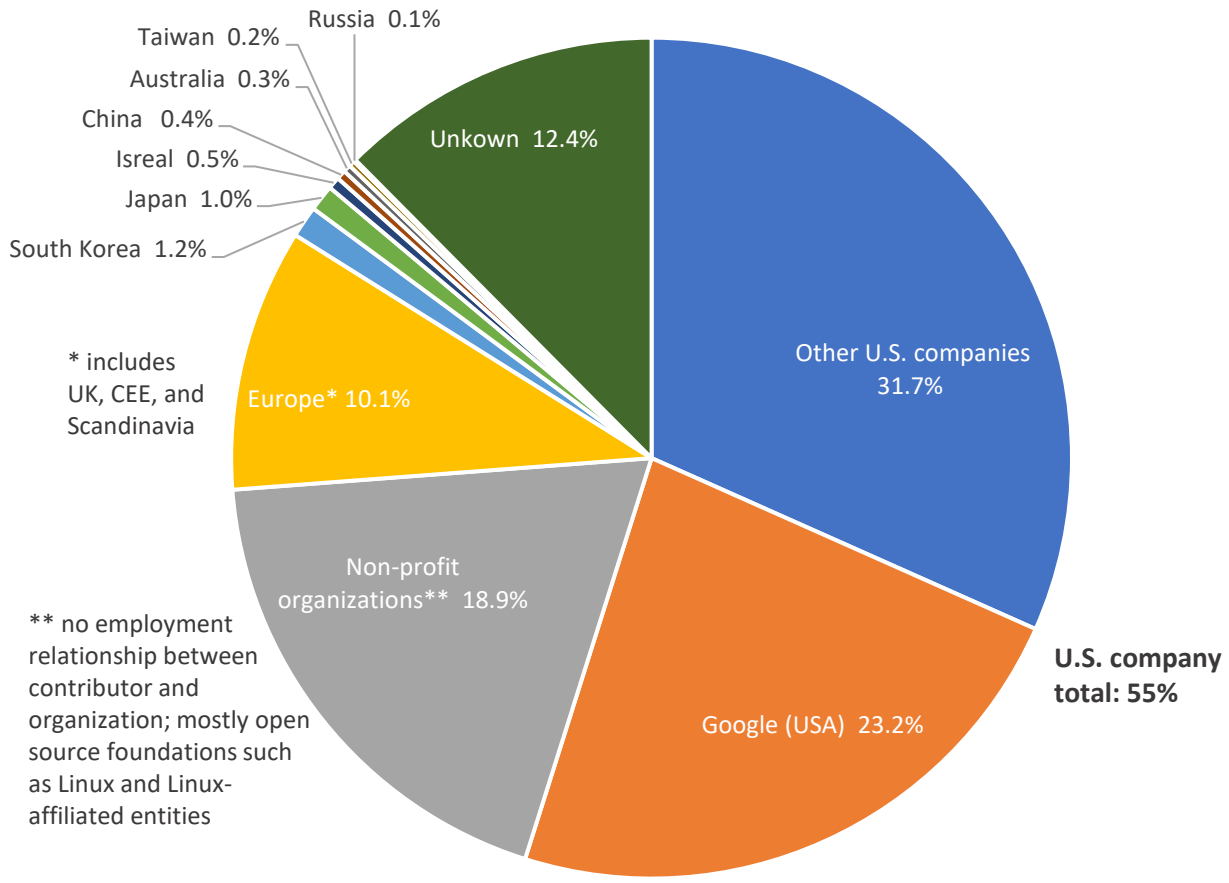
Contributions (code commits) to Google's distribution of Android mobile phone OS (about 10 million since 2008)



Source: Courtesy of Jing-ming Shiu at National Cheng Kung University, Taiwan. Data scraped from Android Open-Source Project website (https://source.android.com/). Note: 'Virtual' includes private individuals and individuals who contribute to open-source organizations, but who do not have a formal employment relationship with the organization, such as Linux contributors.

Geographic dispersion – Operating system contributions (as well as devices, apps)

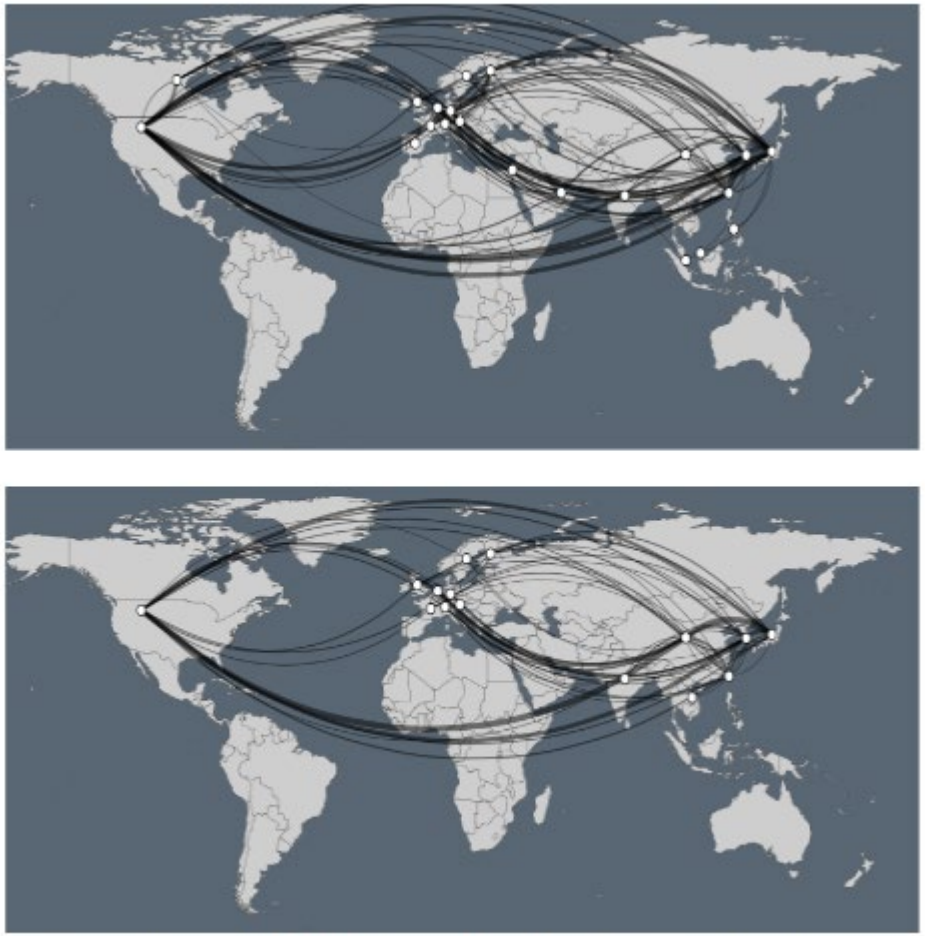
Contributions (code commits) to Google's distribution of Android mobile phone OS (about 10 million since 2008)



As of 2017, only 35% of Android apps were developed within the United States.

Android is both concentrated in Google (platform owner) and dispersed (open source contributors and app makers)

Geographic clustering and dispersal



Notes: Network of the GVCs of smartphones before 2012 (top panel) and after 2017 (bottom panel). Network representation of the total amount exchanged

Less connected firms exit, new entrants are more interconnected

	Before 2012	[2013:2016]	[2017:2020]
# of different countries (nodes)	21	16	15
# of different Buyers	18	12	11
# of different Sellers	13	10	9
Number of supply links (edges)	224	154	130
SD of # links by supplier (indegree)	4.68	4.16	3.81
SD of # links by buyer (outdegress)	4.73	3.88	3.66

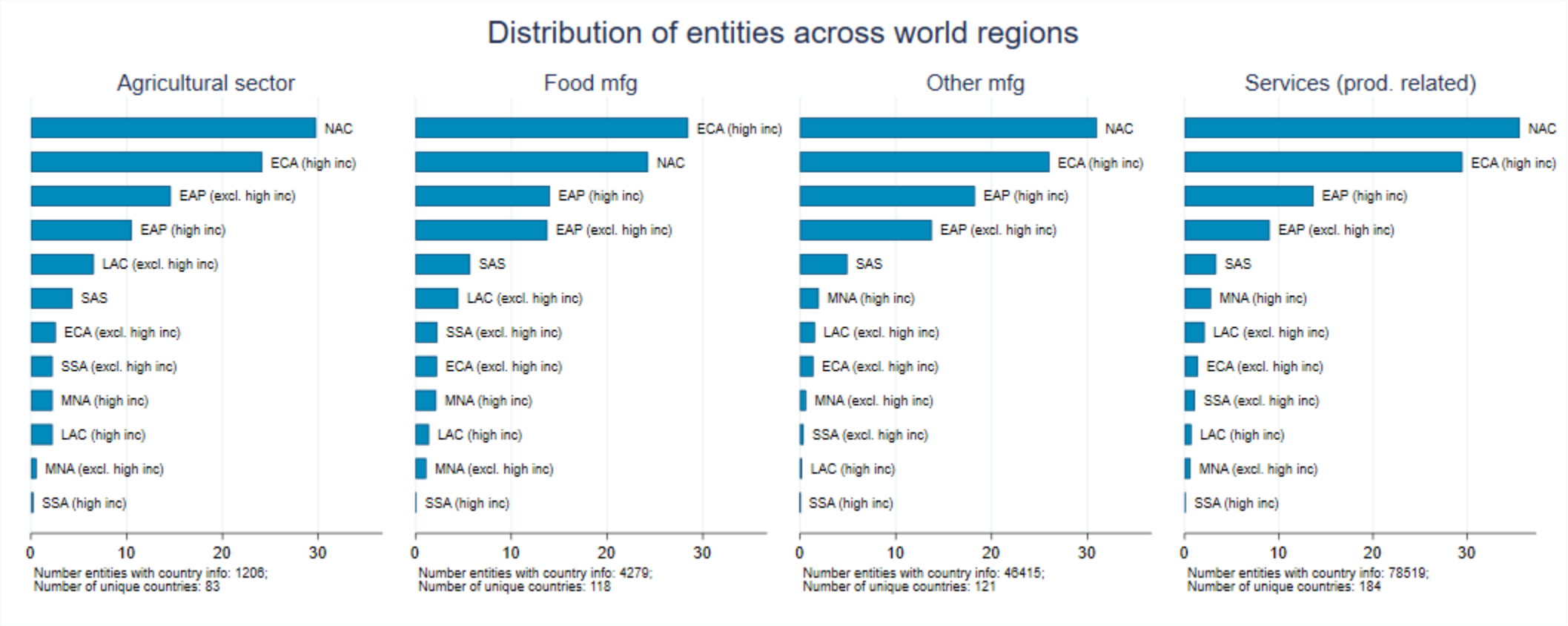
Massive Modularity: does it apply to agricultural GVCs too?

Anne Beck and Daria Taglioni (work in progress)

Data

- FactSet entity relationship data from 2012-2022
  - 1,4 million relationships formed by 170,000 entities, global coverage since 2016
  - Derived from annual reports / filings, investor presentations, press releases, company websites
  - Information on
    - relationship type (customer, supplier, competitor)
    - ownership and production / technology / financing partnerhips
    - start and end date provided
  - Matched with
    - entity's industry (NAICS 6-digit level) and headquarter location
    - ownership structure identifying entity's parents
    - sales data from entity's balance sheet

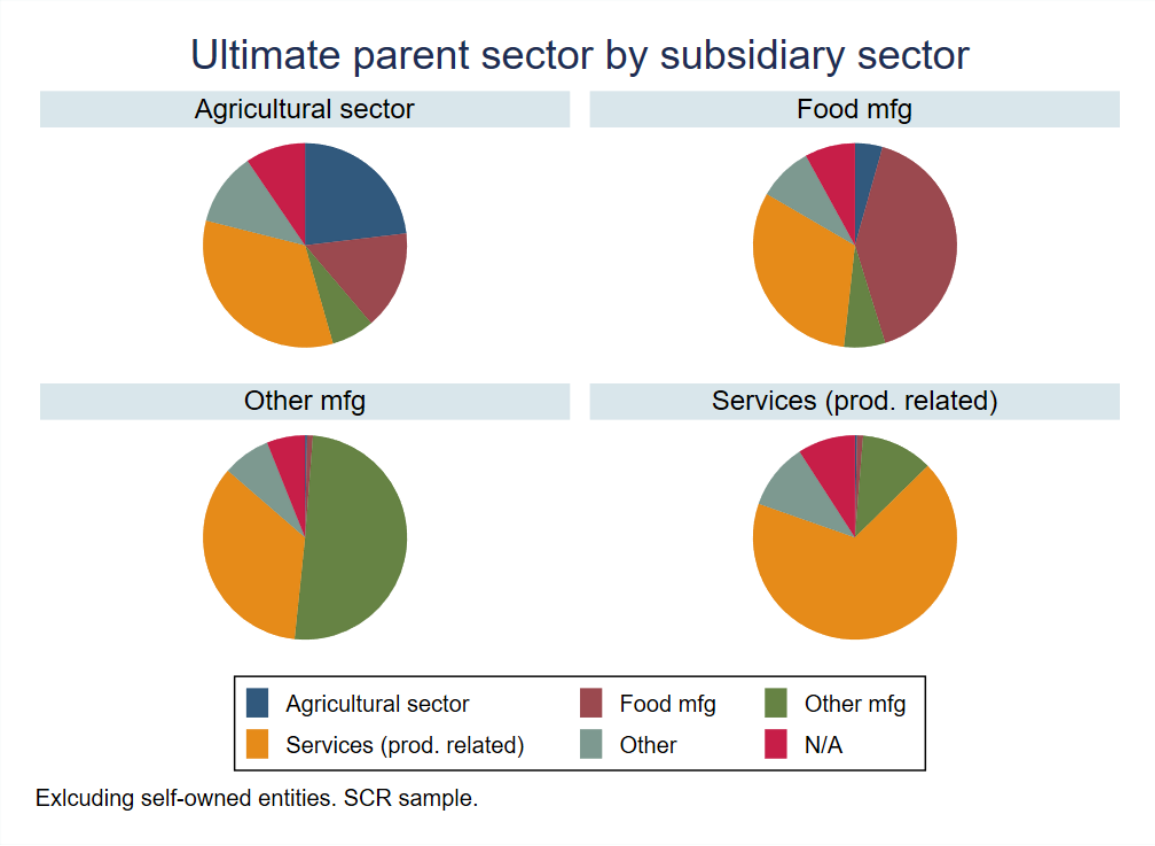
Data: distribution of entities across regions in our dataset



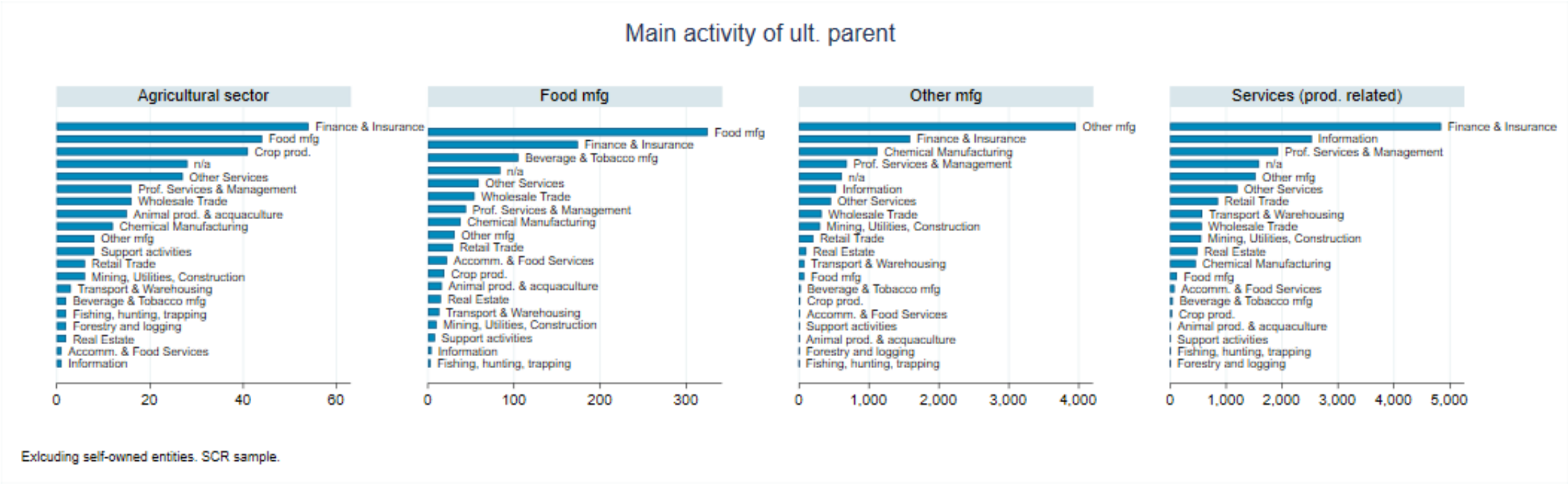
Data: ultimate parent

Most ultimate parents of manufacturing and service sector entities appears to be a manufacturing or service sector entity (especially for service sector).

There are considerably fewer agricultural entities whose ultimate parent is an agricultural company.



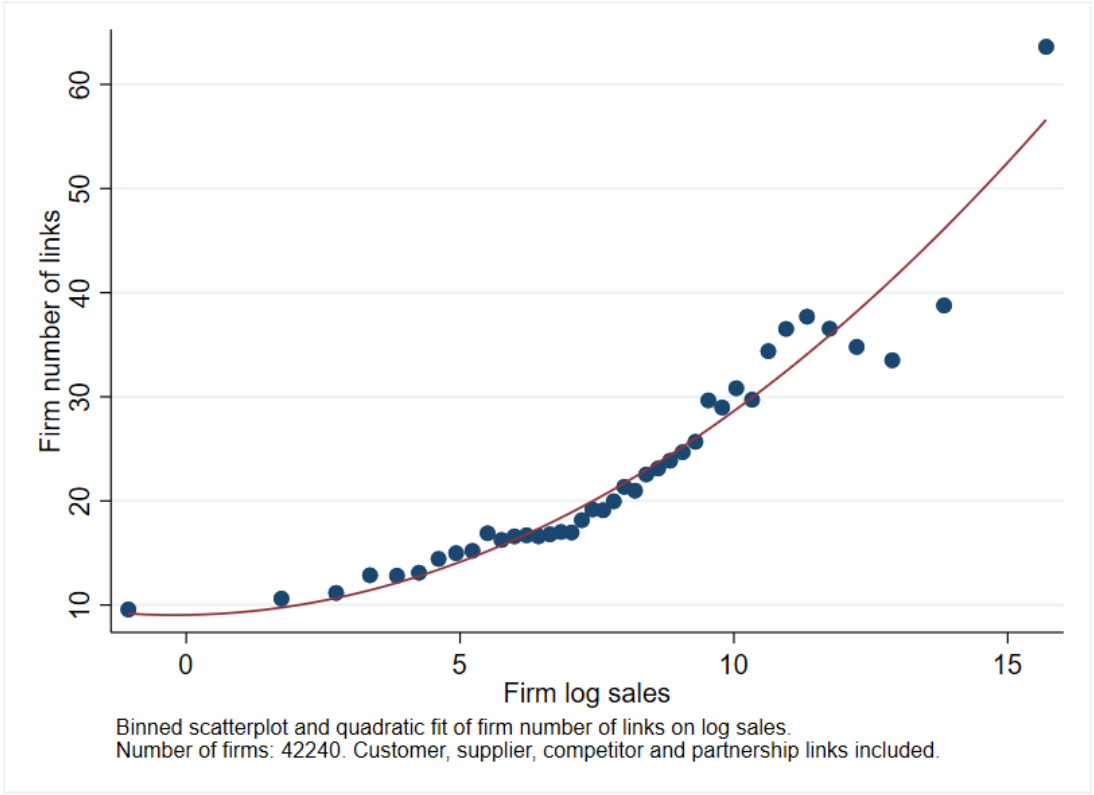
Data: ultimate parent



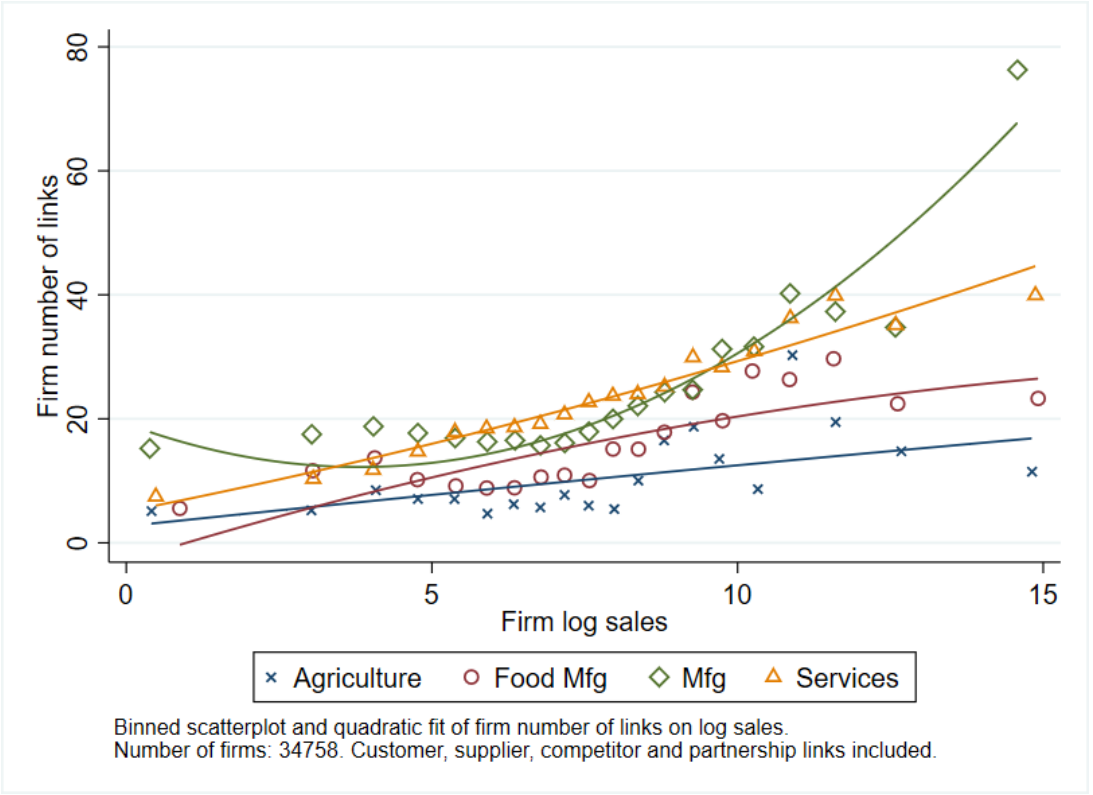
Exlcuding self-owned entities. SCR sample.

The three paradoxes of the smartphone industry: do they apply to other industries in general and to agri-related GVCs in particular?

Complexity of the value chain and scale growth

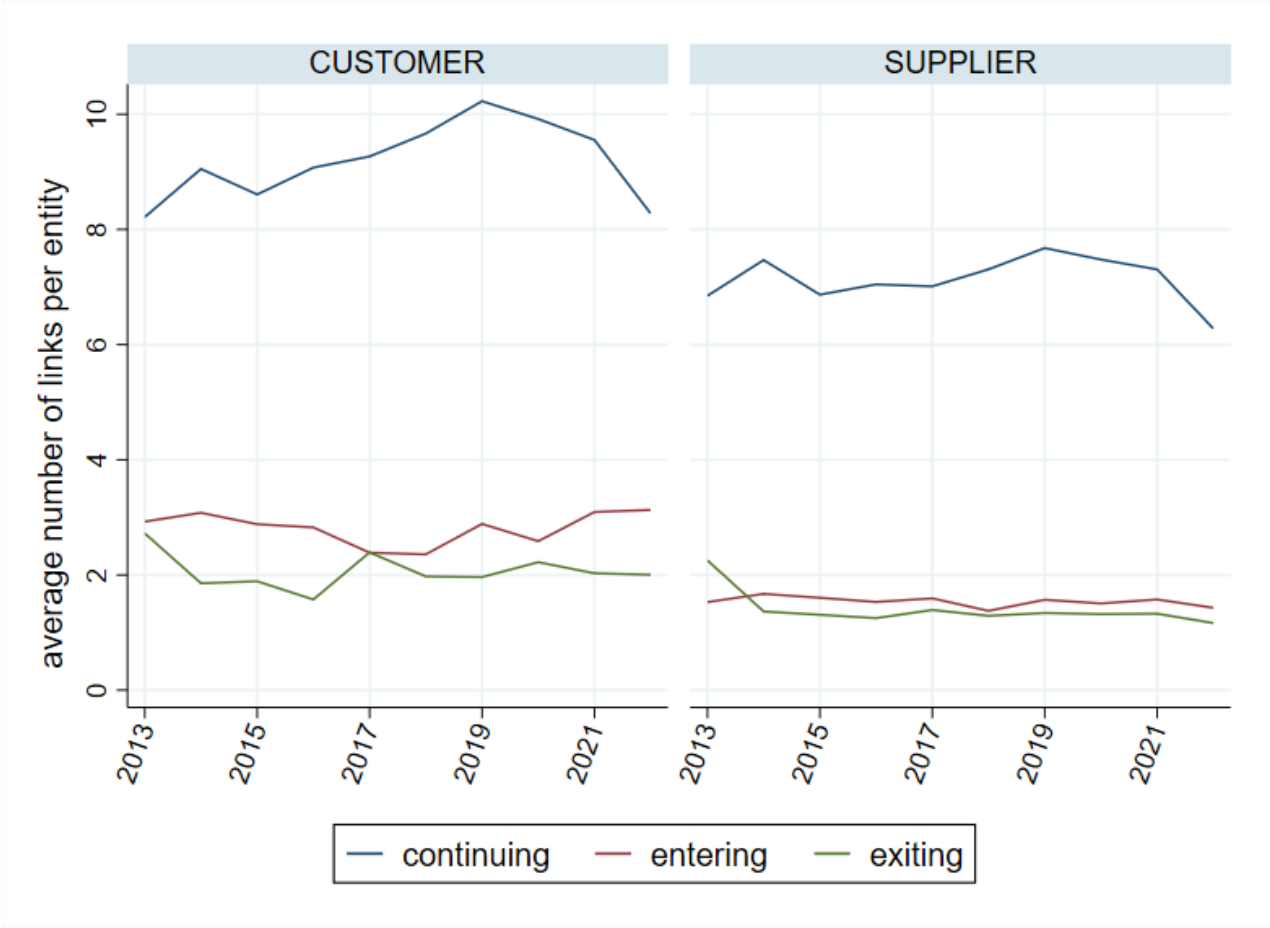


Binned scatterplot and quadratic fit of firm number of links on log sales.
Number of firms: 42240. Customer, supplier, competitor and partnership links included.

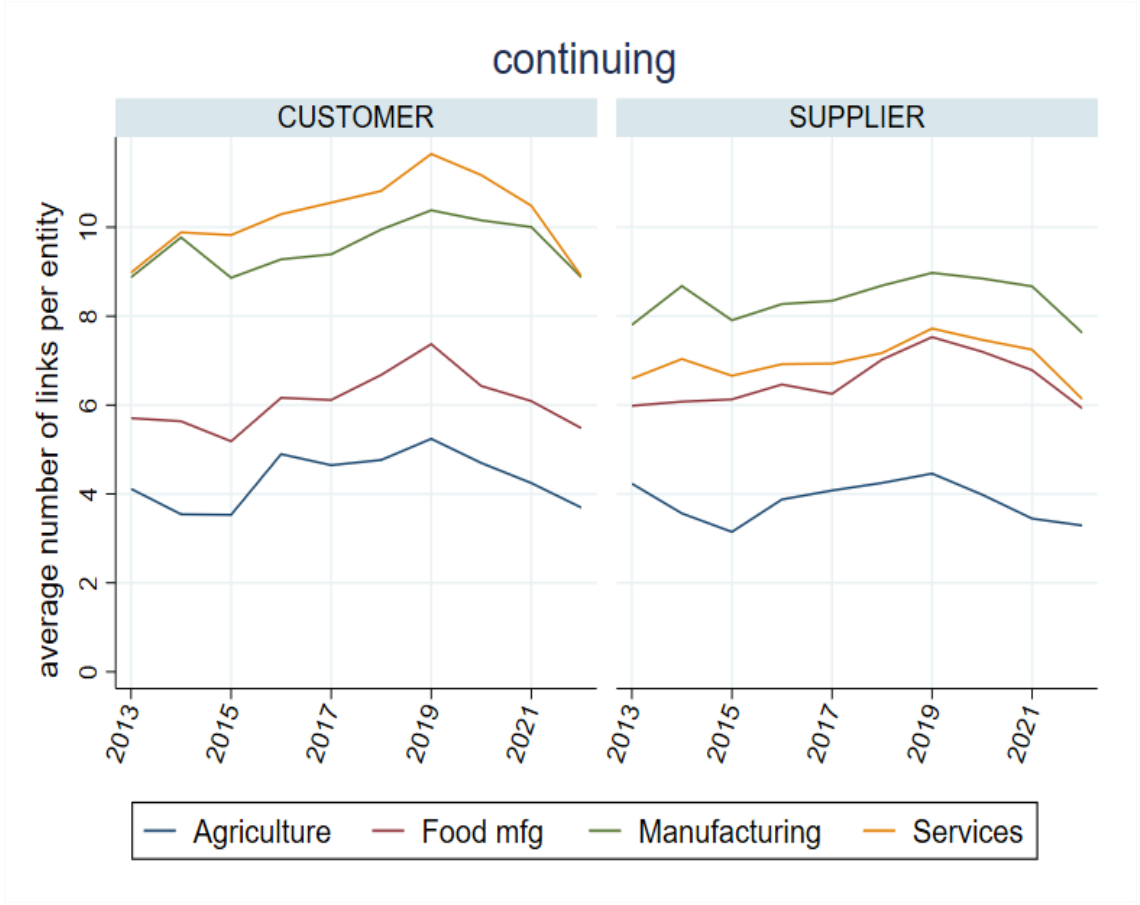


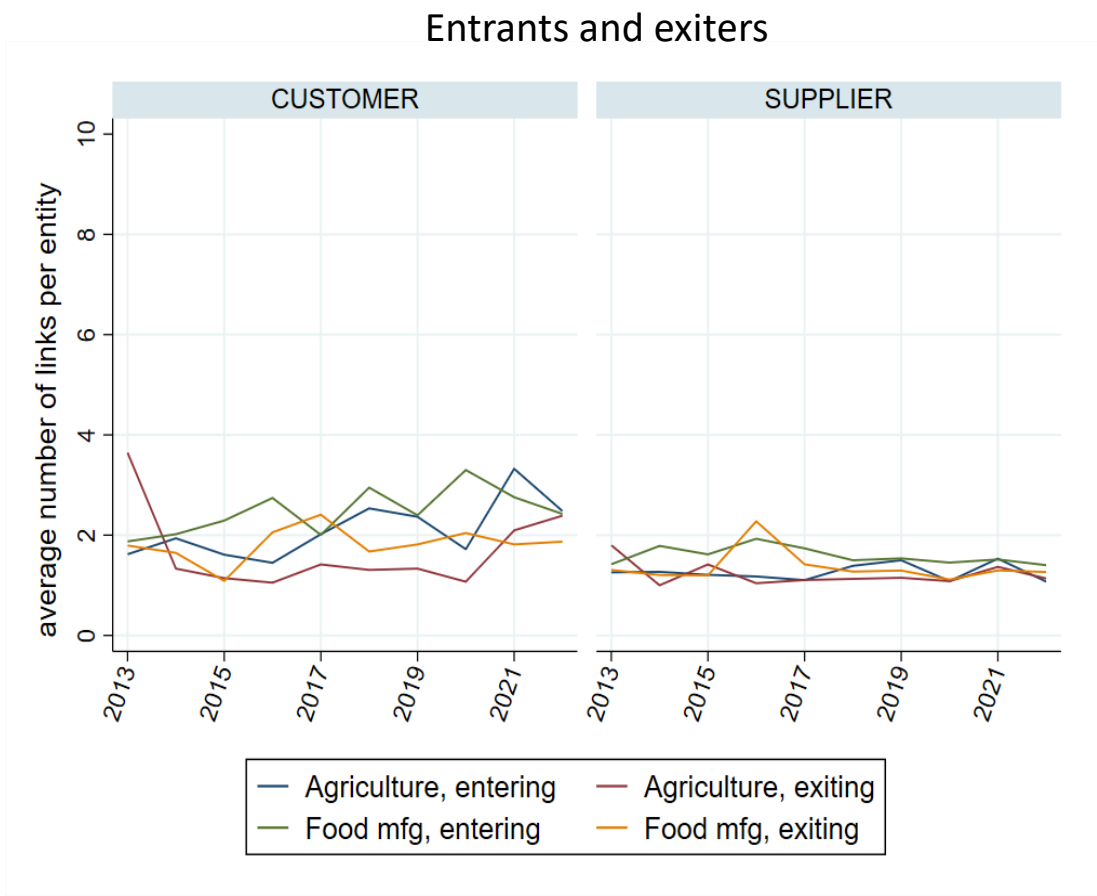
Binned scatterplot and quadratic fit of firm number of links on log sales.
Number of firms: 34758. Customer, supplier, competitor and partnership links included.

Increasing fragmentation: exiters less connected than entrants



Agriculture and agribusiness firms have less supply-chain relationships, but patterns are similar to firms in manufacturing and services

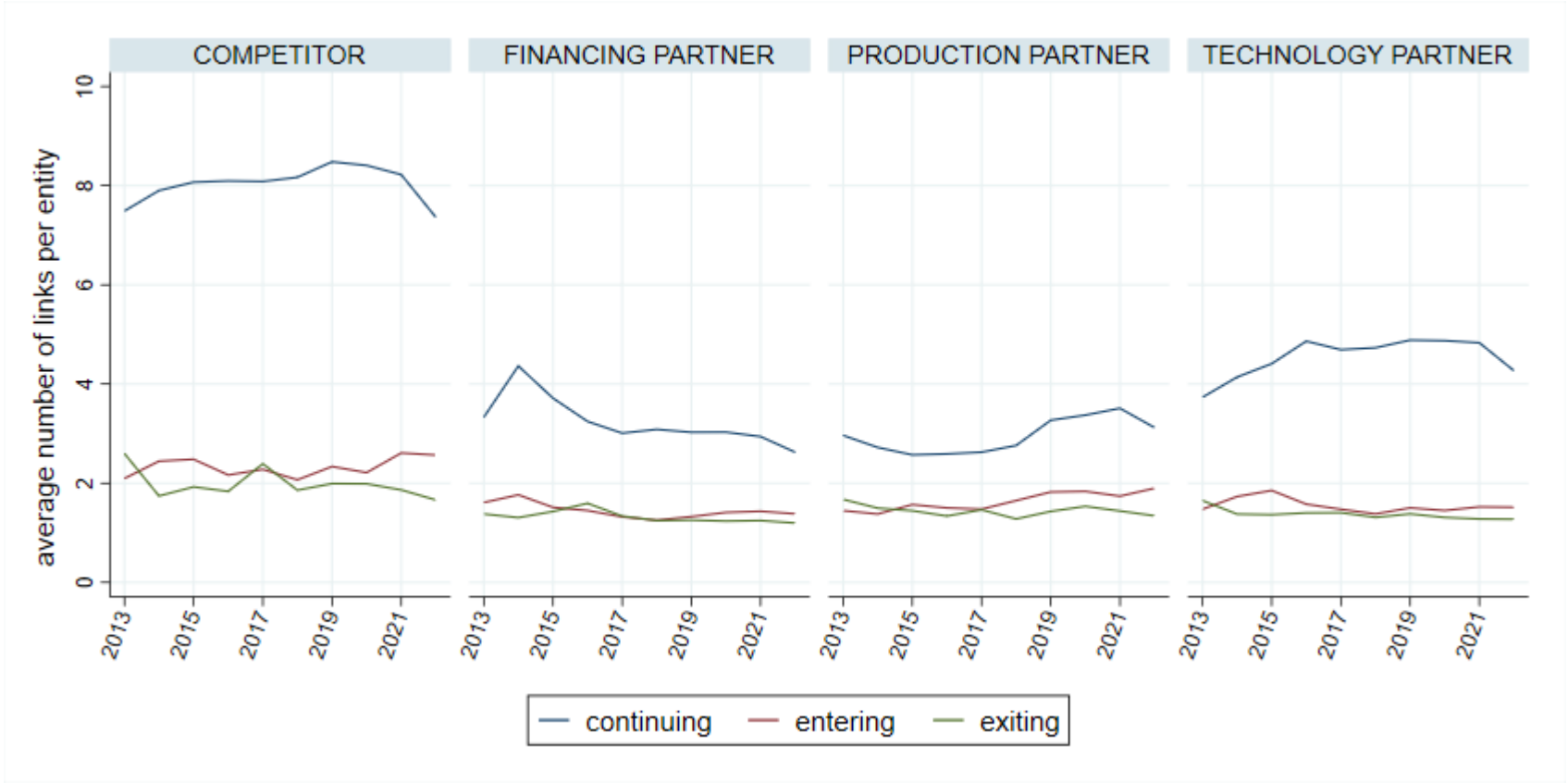




Average duration of supply chain relationships in agriculture is also somewhat lower than in manufacturing and services

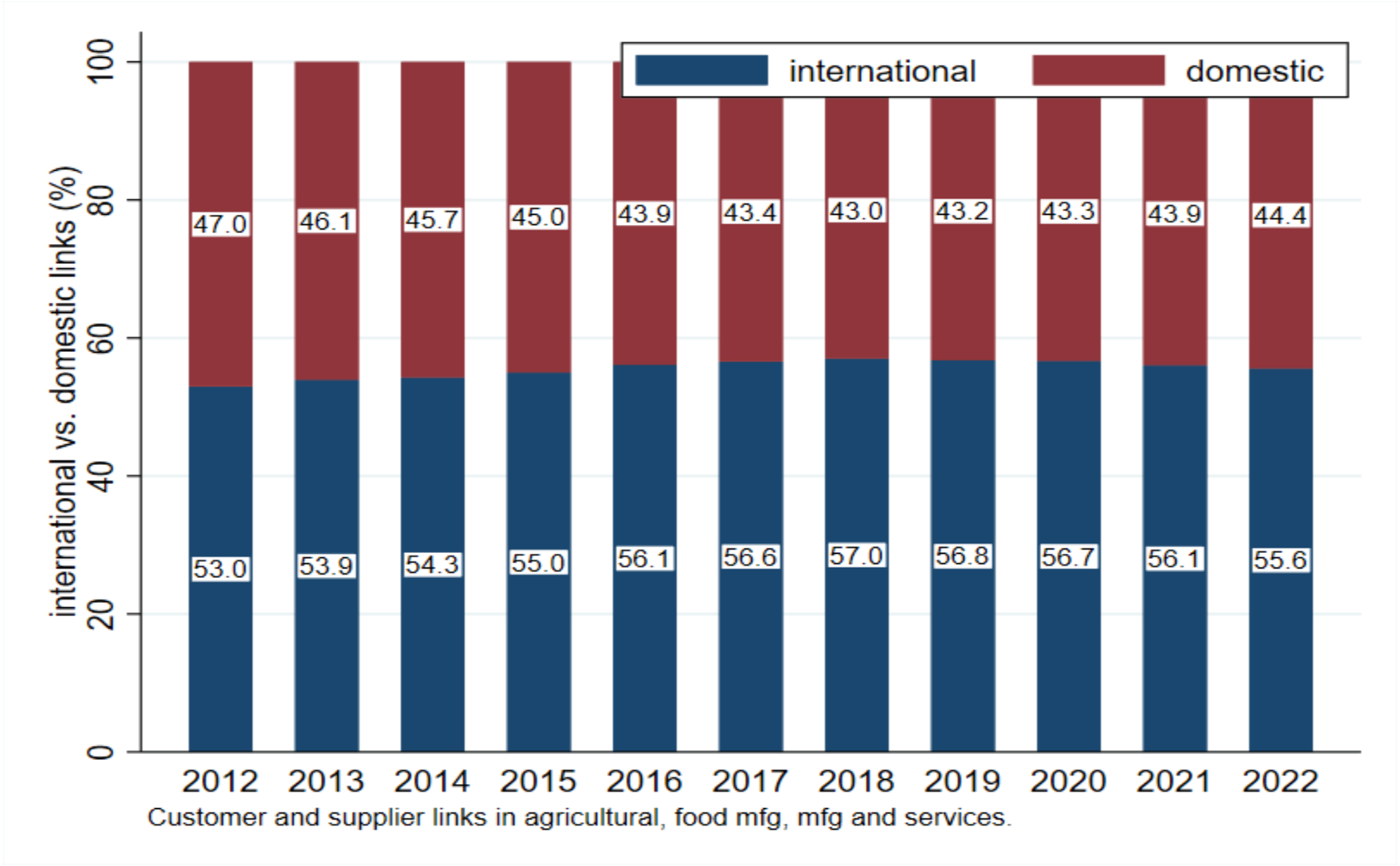
- Agriculture = 3-4 years
- Agribusiness (food and beverage) and services = 4 years
- Other manufacturing = 4-5 years

Same message on fragmentation when looking at firms' connectedness in ownership and partnership data



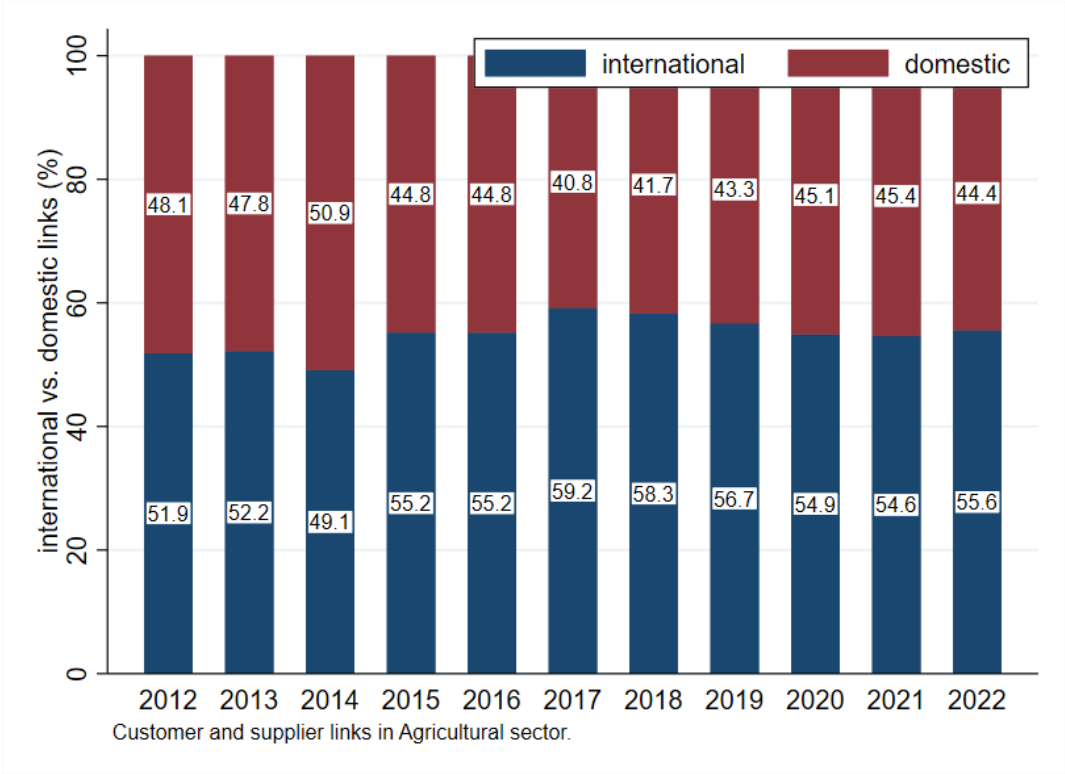
Evidence of market concentration

Geographic dispersal: average number of international links is growing, despite recent shocks

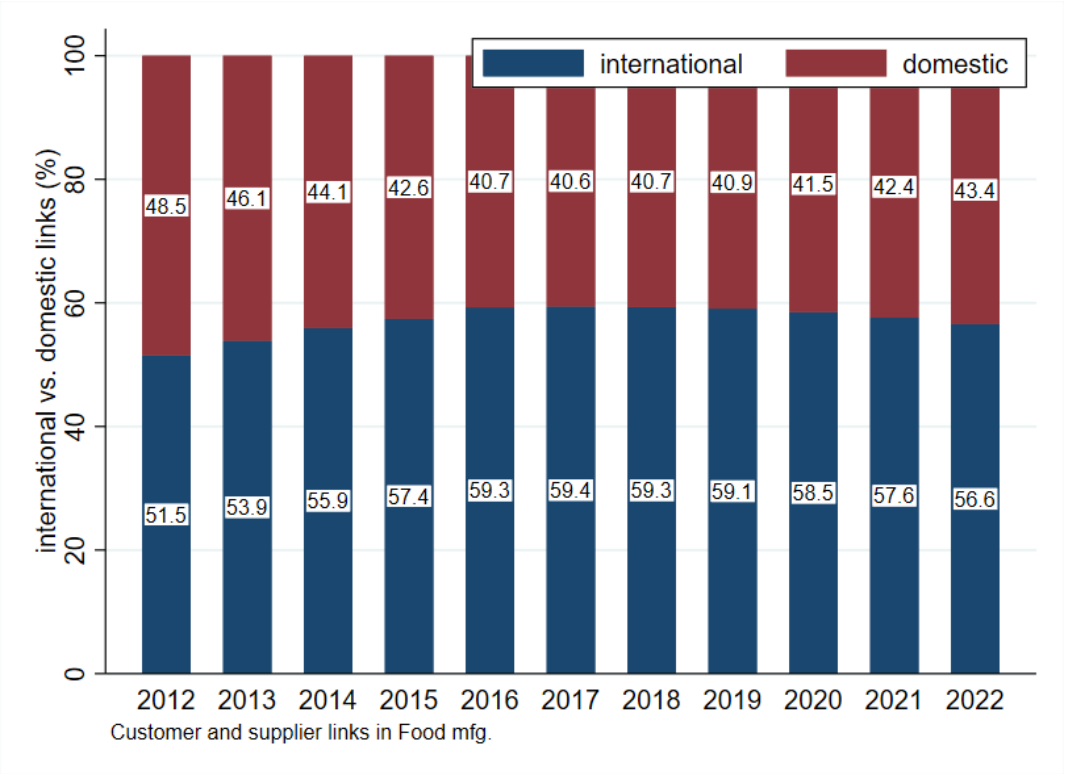


Cross-border supply chain links in agri-related GVCs are growing in number too

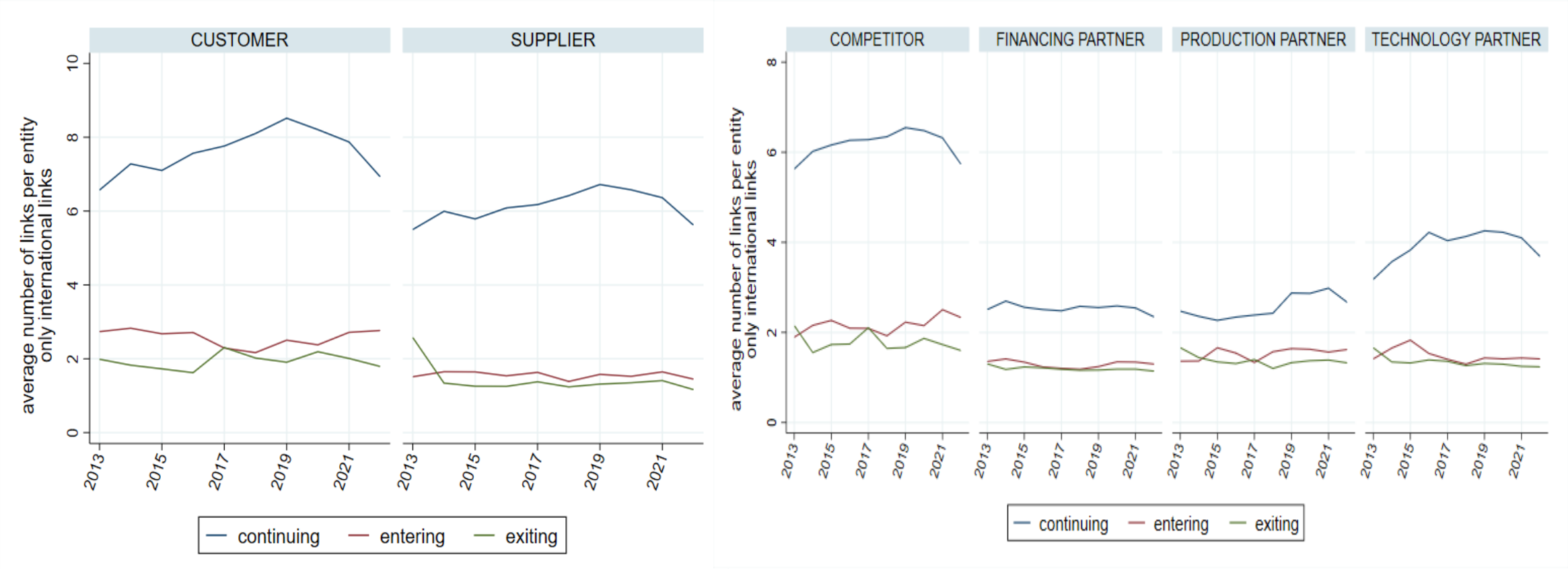
Agriculture



Agribusiness



Geographic dispersal: new entrants are more connected than exiters also across borders

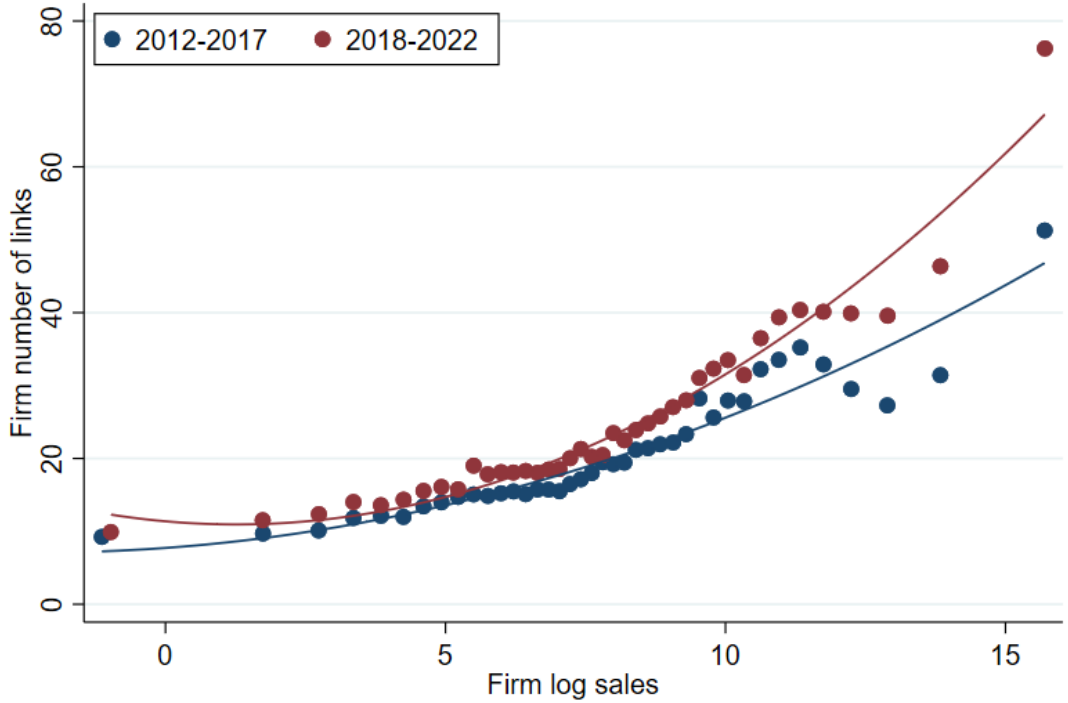


Evidence of geographic clustering

Policy implications in a world where GVCs veer towards massive modularity

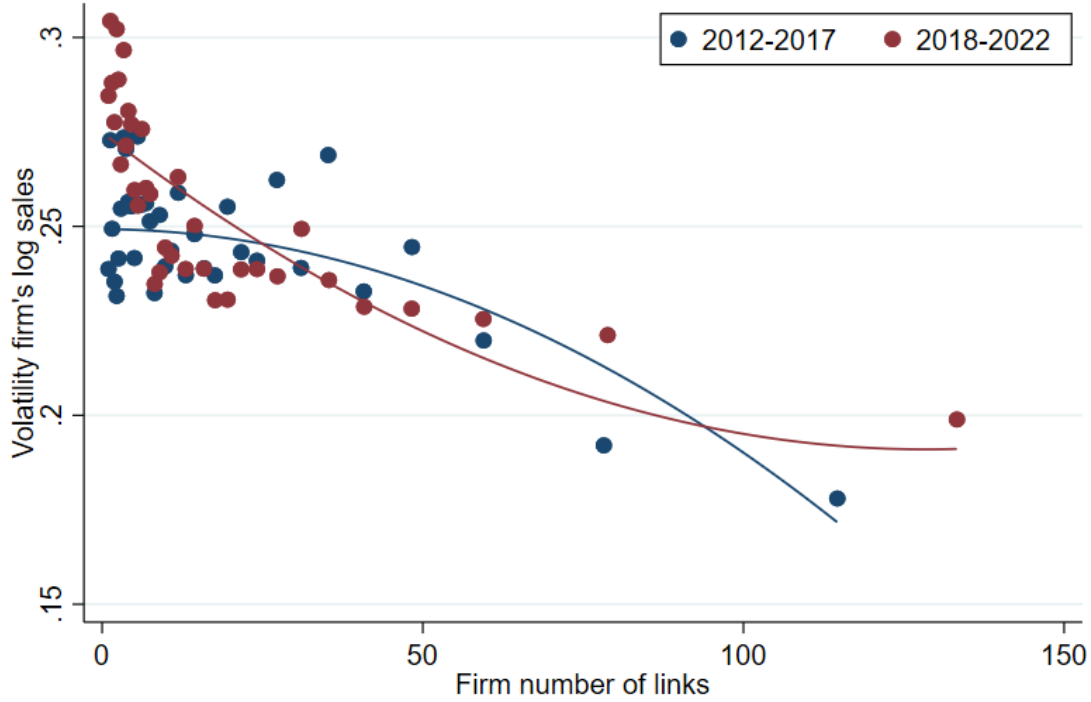
International interconnectedness may have benefits for firms' economic performance

Firm log sales



Binned scatterplot and quadratic fit of firm number of links on log sales.
Number of firms: 42240. Customer, supplier, competitor and partnership links included.

Volatility of firm's log sales



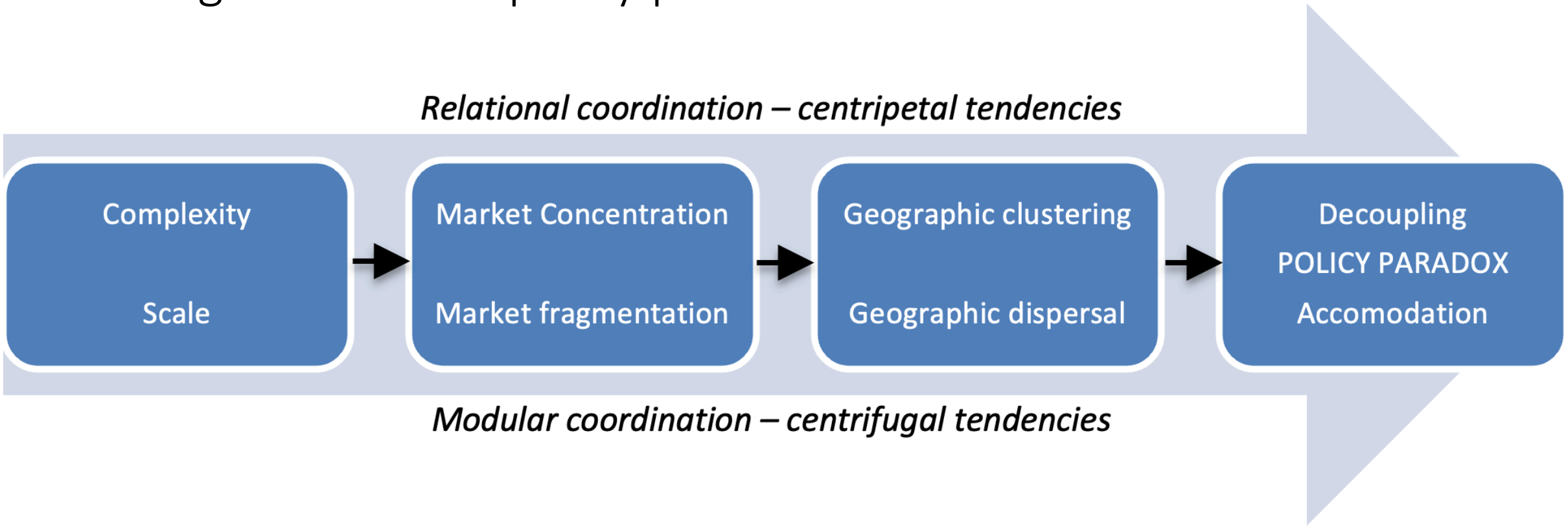
Binned scatterplot and quadratic fit of sales volatility on firm's average number of links. Customer, supplier, competitor and partnership links included. Variables trimmed at 1st and 99th perc.

Participation in MMEs (relational and dispersed GVCs) may create benefits through:

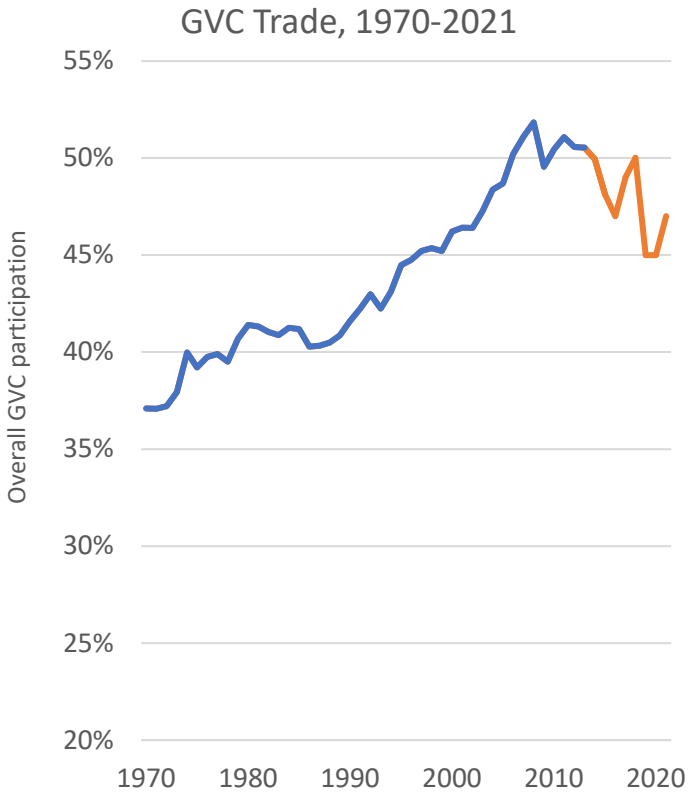
- Greater productivity, greater ability to diversify risk
- Ability to increase scale, specialize, and innovate at unprecedented rates
- Multiple pathways for value added capture and technology upgrading

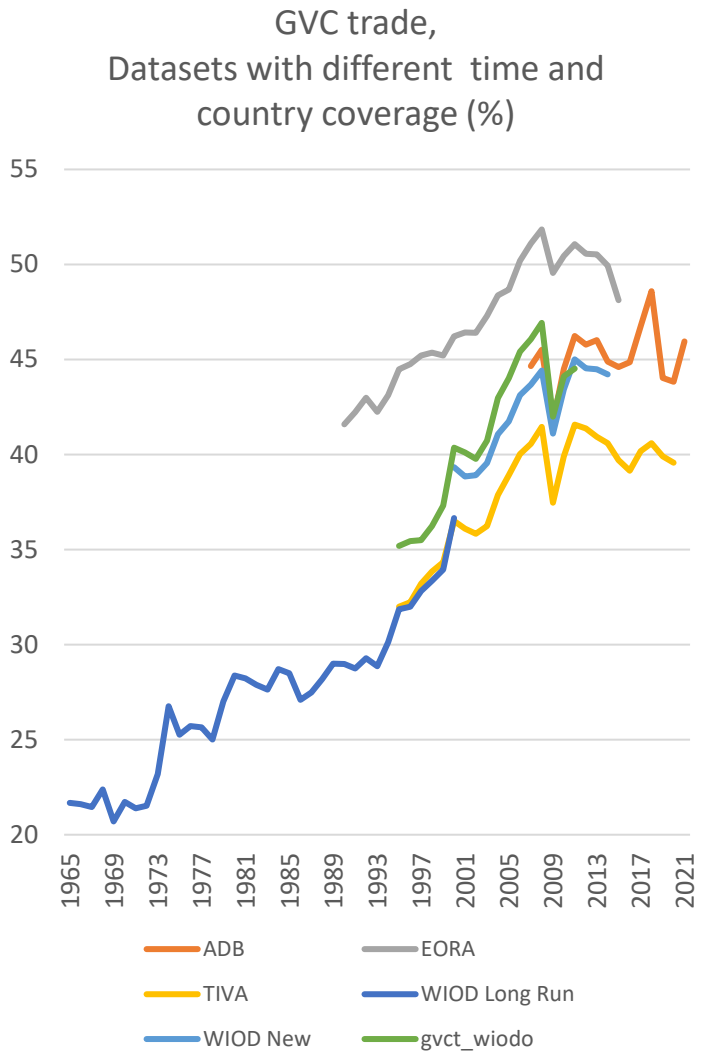
But there is a danger of dependency

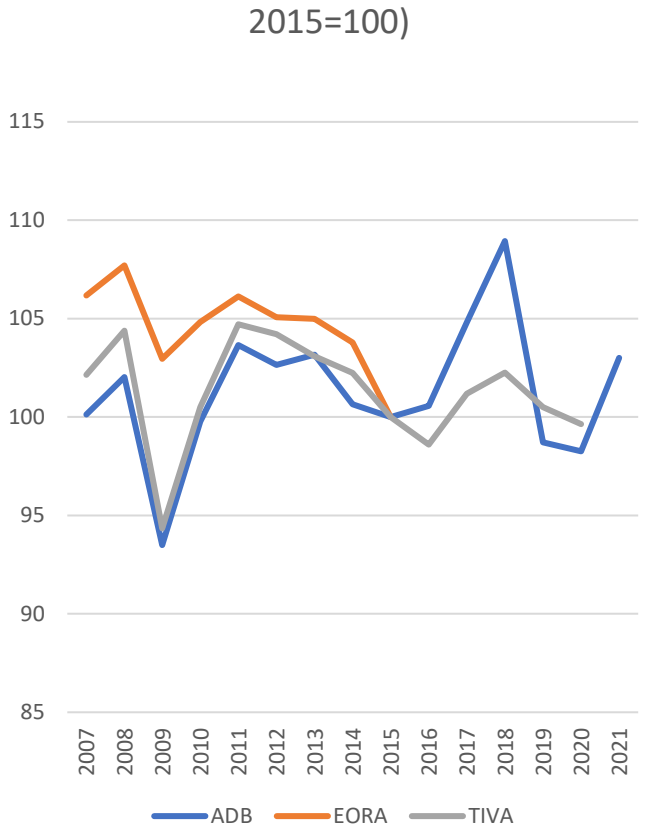
Hence, each of the three paradoxes found in MME can be associated with centripetal tendencies (relational) and centrifugal tendencies (modular) in ecosystem coordination, leading to a fourth “policy paradox”



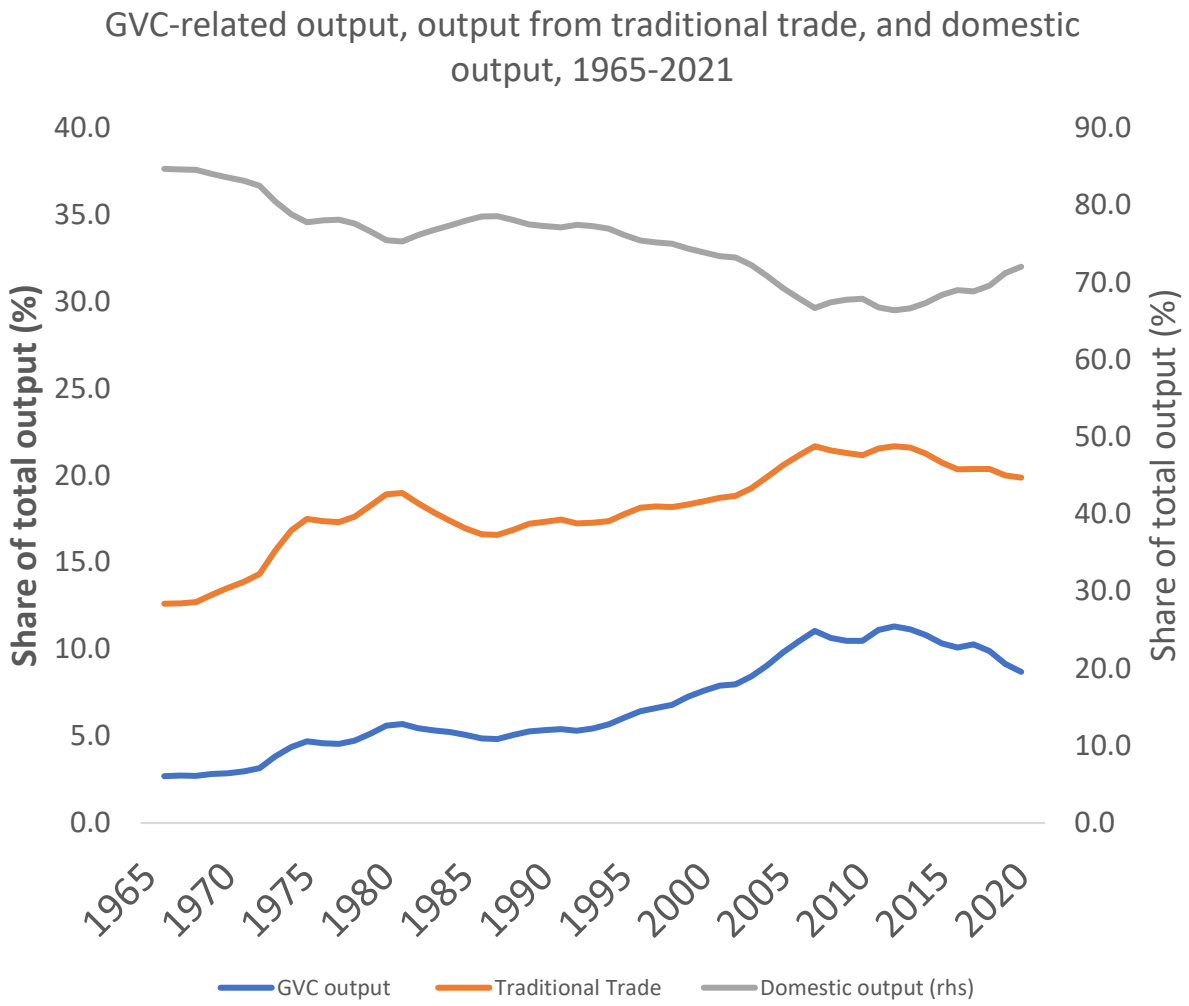
And it may contribute to explain GVC trade ups and downs since the mid 2010s…







And reorientation away from GVC-and trade-related output



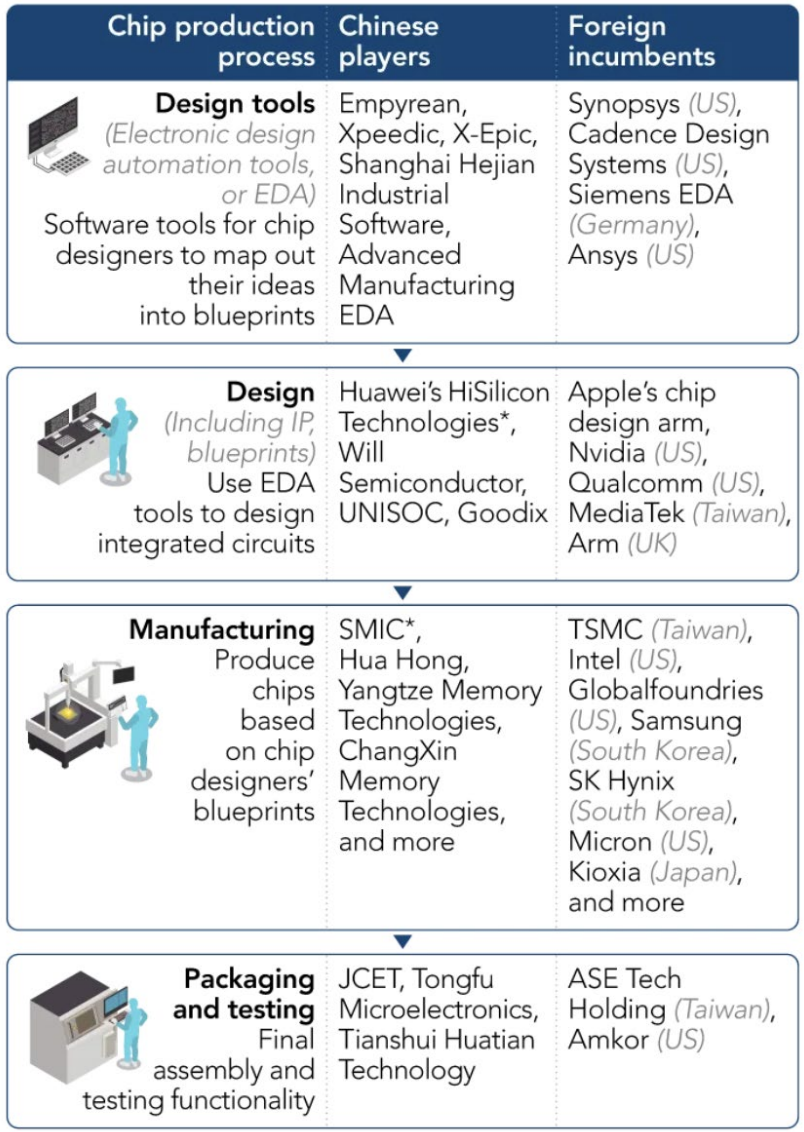
Five policy goals that countries are experimenting with, to cope with the decoupling-accommodation policy paradox

- Self-sufficiency
- Targeted industrial policy
- Influencing (interconnect) standards
- Win friends, influence countries
- Decouple from a major emerging competitor

Self-sufficiency

National policies: China's strive towards self-sufficiency

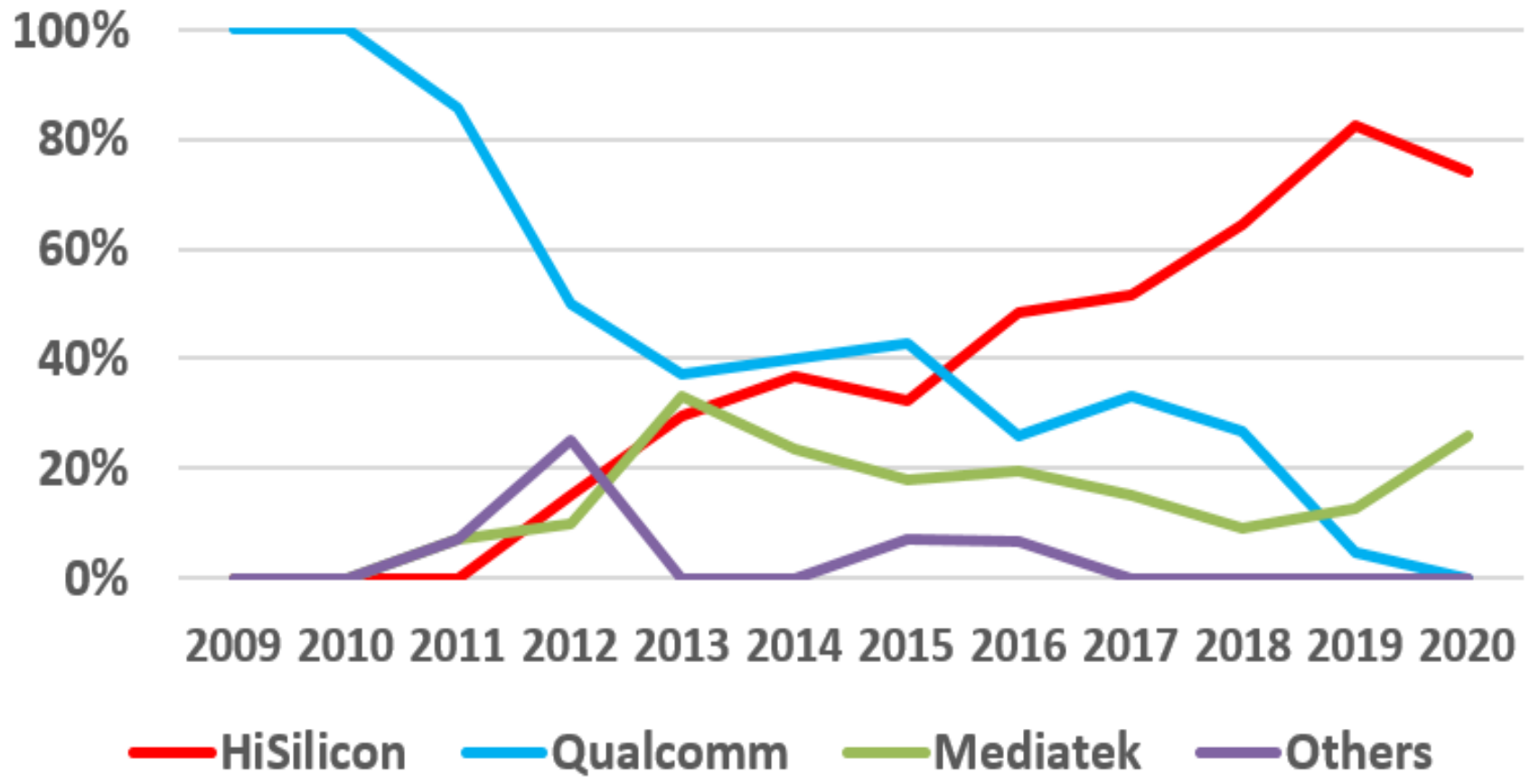
- China's push for the adaption of indigenous technologies and phasing out reliance on foreign technologies.
- New approaches to financing new economic policies to incentivize investment in domestic capabilities (e.g. STAR market, tax incentives).



Chip production process	Chinese players	Foreign incumbents
Design tools *(Electronic design automation tools, or EDA)* Software tools for chip designers to map out their ideas into blueprints	Empyrean, Xpeedic, X-Epic, Shanghai Hejian Industrial Software, Advanced Manufacturing EDA	Synopsys *(US)*, Cadence Design Systems *(US)*, Siemens EDA *(Germany)*, Ansys *(US)*
Design *(Including IP, blueprints)* Use EDA tools to design integrated circuits	Huawei's HiSilicon Technologies*, Will Semiconductor, UNISOC, Goodix	Apple's chip design arm, Nvidia *(US)*, Qualcomm *(US)*, MediaTek *(Taiwan)*, Arm *(UK)*
Manufacturing Produce chips based on chip designers' blueprints	SMIC*, Hua Hong, Yangtze Memory Technologies, ChangXin Memory Technologies, and more	TSMC *(Taiwan)*, Intel *(US)*, Globalfoundries *(US)*, Samsung *(South Korea)*, SK Hynix *(South Korea)*, Micron *(US)*, Kioxia *(Japan)*, and more
Packaging and testing Final assembly and testing functionality	JCET, Tongfu Microelectronics, Tianshui Huatian Technology	ASE Tech Holding *(Taiwan)*, Amkor *(US)*

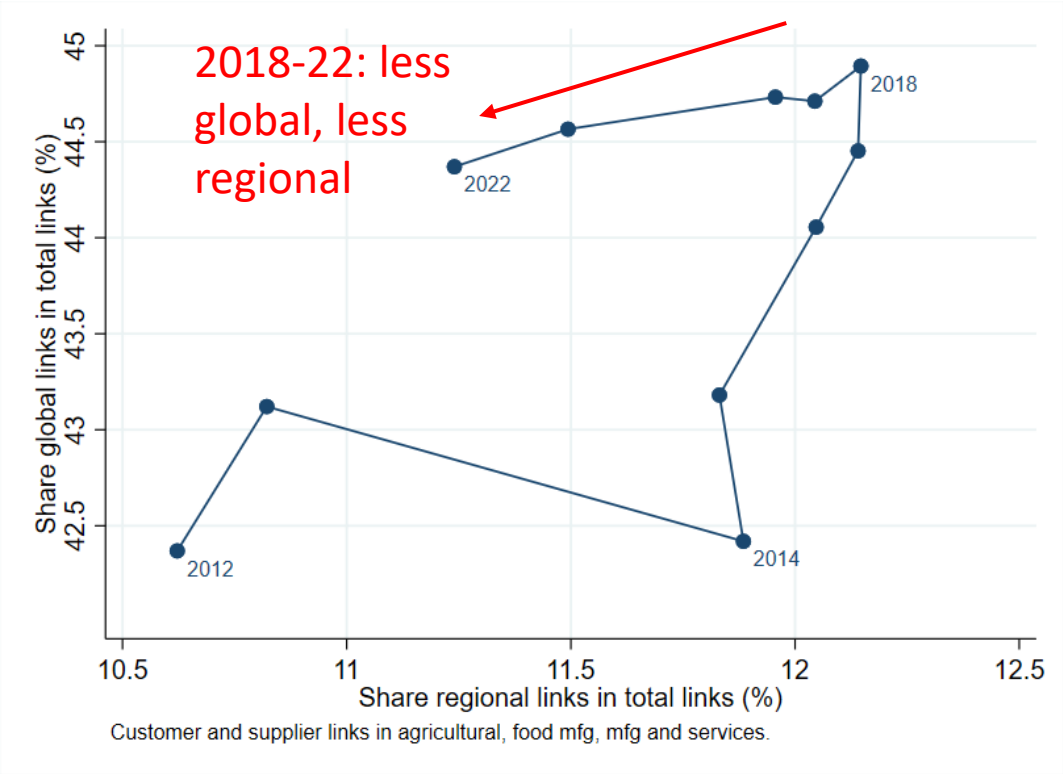
Source: Nikkei Asia

Firm policies: Huawei shift towards self-sufficiency in sourcing of application processors (HiSilicon)

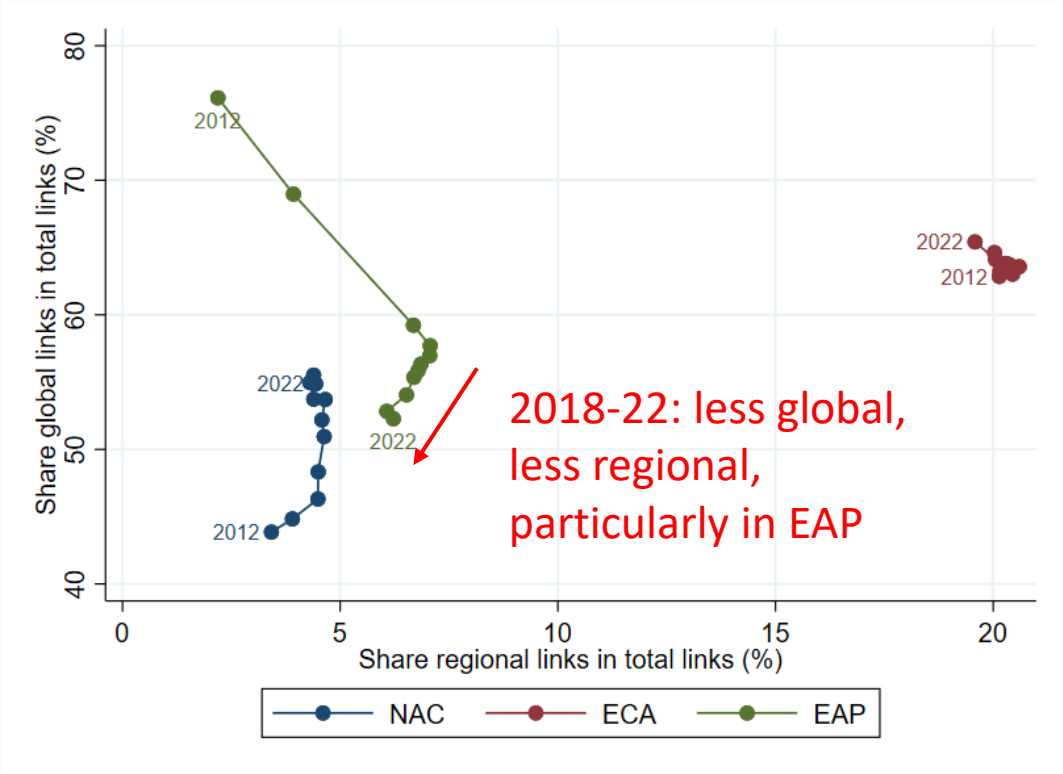


In our dataset we observe that supply chain links pivoted away from international partners since 2018: is this associated to self-sufficiency goals?

Overall

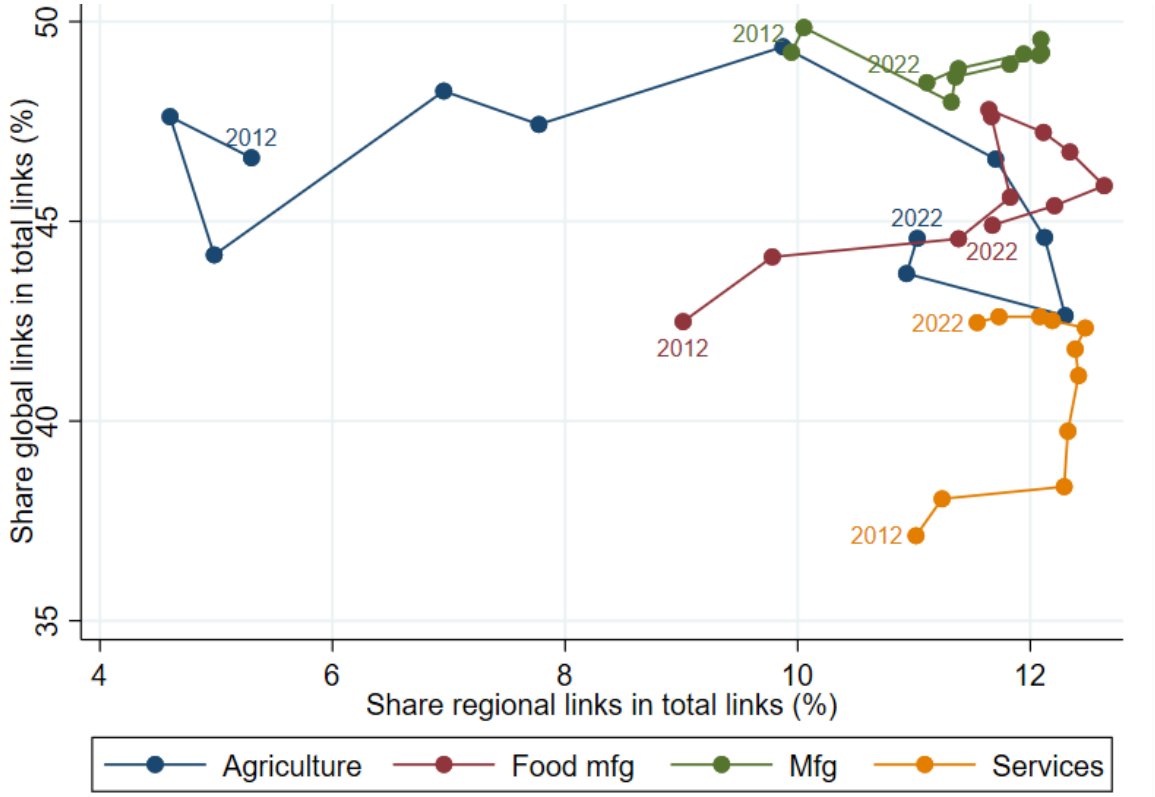


By macro-region



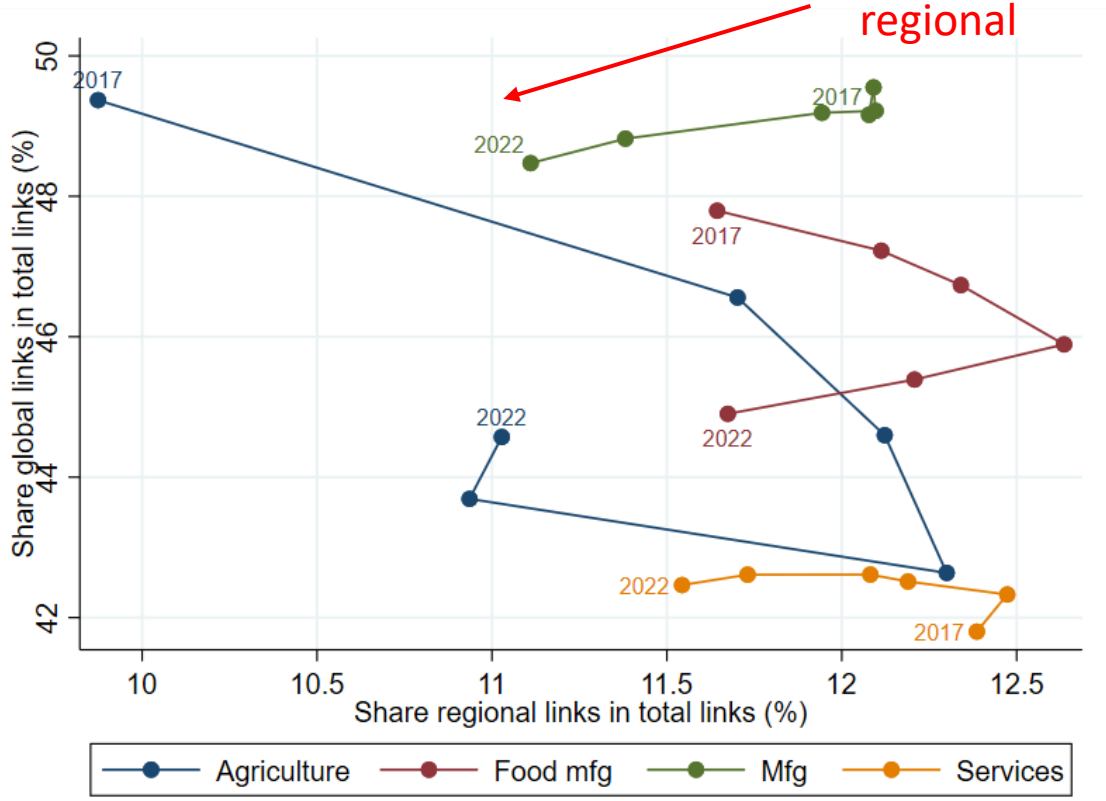
Domestic-reorientation is particularly visible in manufacturing

By sector, 2012-2022



By sector, 2017-2022

2018-22: less global, less regional



Self-reliance is great, but…two decoupling paths (full and partial import substitution) may have similar and distinct risks

Full decoupling - risks:	Partial import substitution - risks:
Very high capital costs	High capital costs
Possible systemic failure	Reshoring in one segment may crate a spate of new import dependencies
Accelerated brain drain	MME segment selected may not be the correct one
Early obsolescence of lumpy, non-market-driven investments	
Loss of export scale/revenue (walled garden), including in complements	
Loss of product and system functionality	
Interruptions in ongoing collaborative technological learning across the MME, possibly including learning from global standard-setting activities and participation in open-source projects	
Interruptions in human resource development	

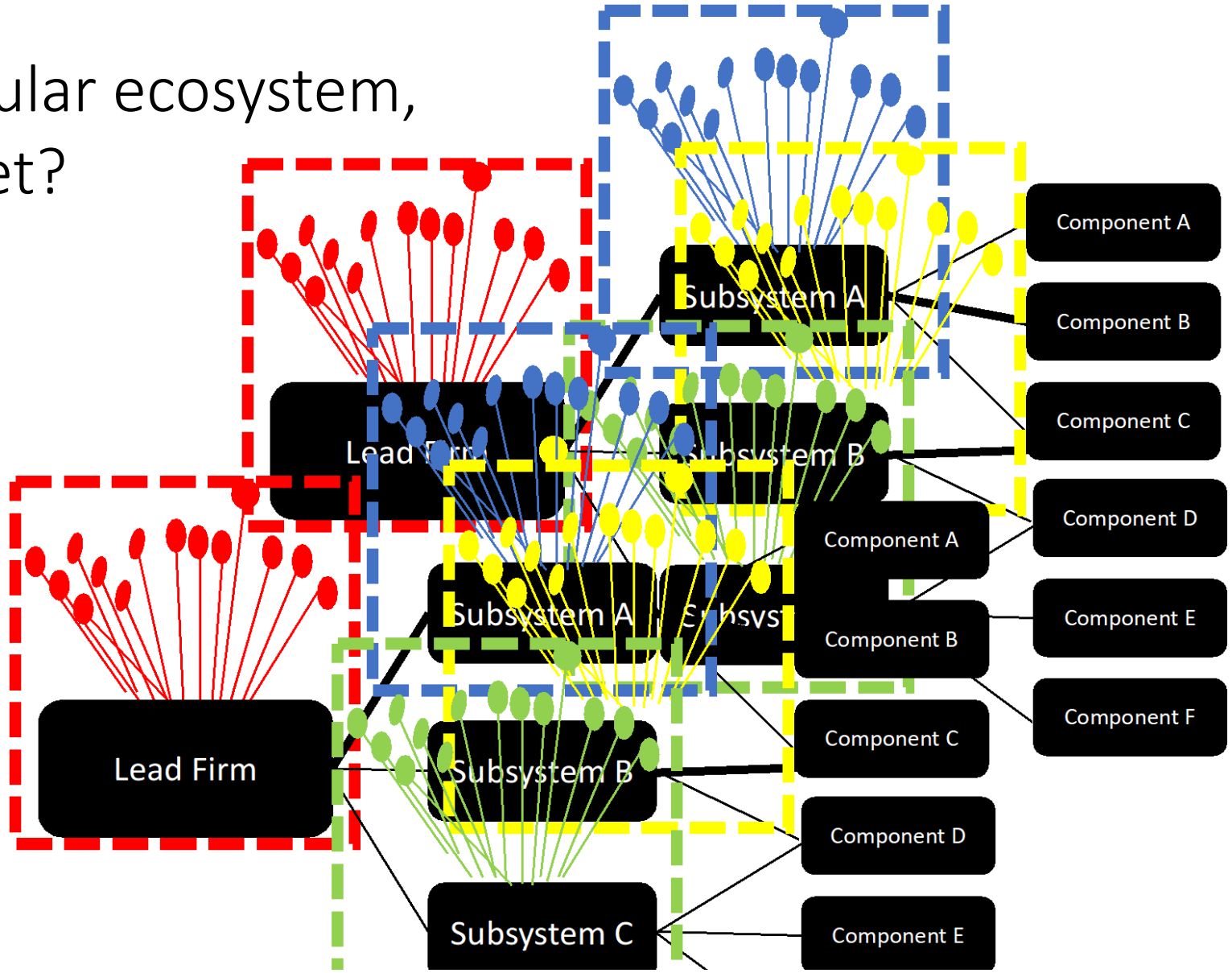
Targeted industrial policy

Possible policy goal, II – targeted industrial policy in semiconductors

Jurisdiction	Japan	European Union	United States	South Korea	China
Initiative	Unnamed "national project"	Digital Compass Plan	CHIPS for America Act (proposed)	K-Belt National Chip Plan	14th Five-Year Plan
Projected spending	unknown	$25-35 billion	$50 billion	$35-65 billion	$150 billion
Time period (from 2021)	unknown	Ten years	unknown	Three years	Ten years
Goal	Revitalize Japan's semiconductor industry	Produce 20% of world's high-end semiconductors	Revitalize US semiconductor manufacturing and R&D	Secure world leadership in semiconductors, double workforce	Achieve self-sufficiency in semiconductors
Instruments	R&D support and investment attraction from other countries (e.g., Taiwan, South Korea)	25% R&D tax credit and other incentives for manufacturing and research	40% investment tax credit and additional funding for supporting national agencies	6-44% investment tax credit and up to 50% tax credit for R&D	Income tax exemptions state financing for R&D and other initiatives

Sources: SIA and press reports

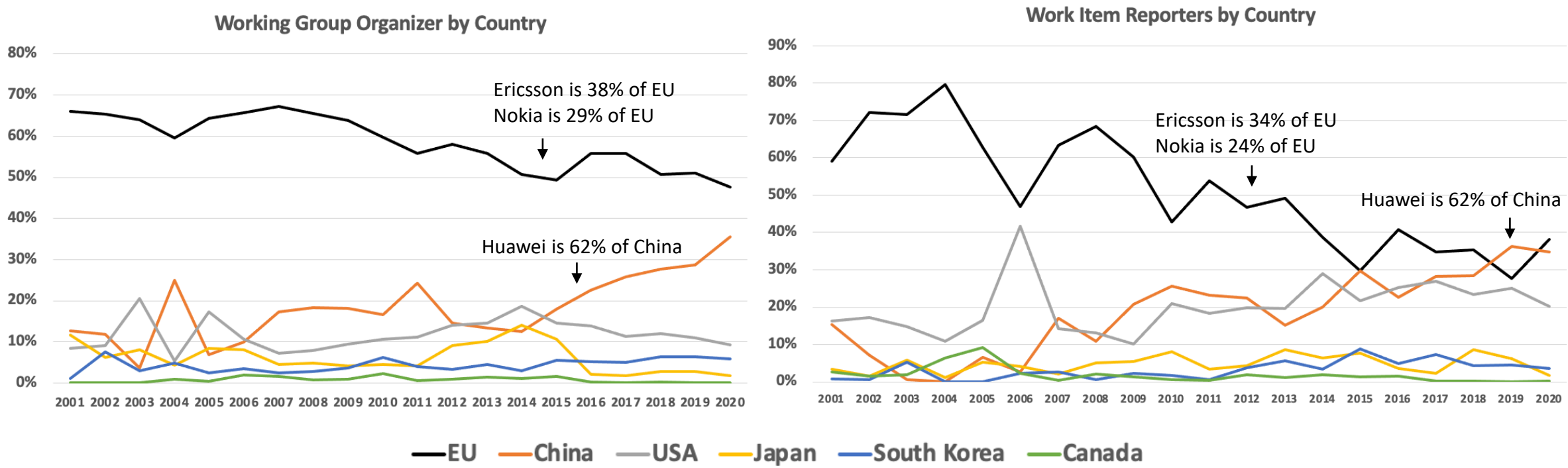
In a massive modular ecosystem, what do you target?



Influencing interconnect standards

Possible policy goal, III – influence interconnect standards

Participation in mobile telecom interconnect standard setting by country (3GPP), 2001-2020

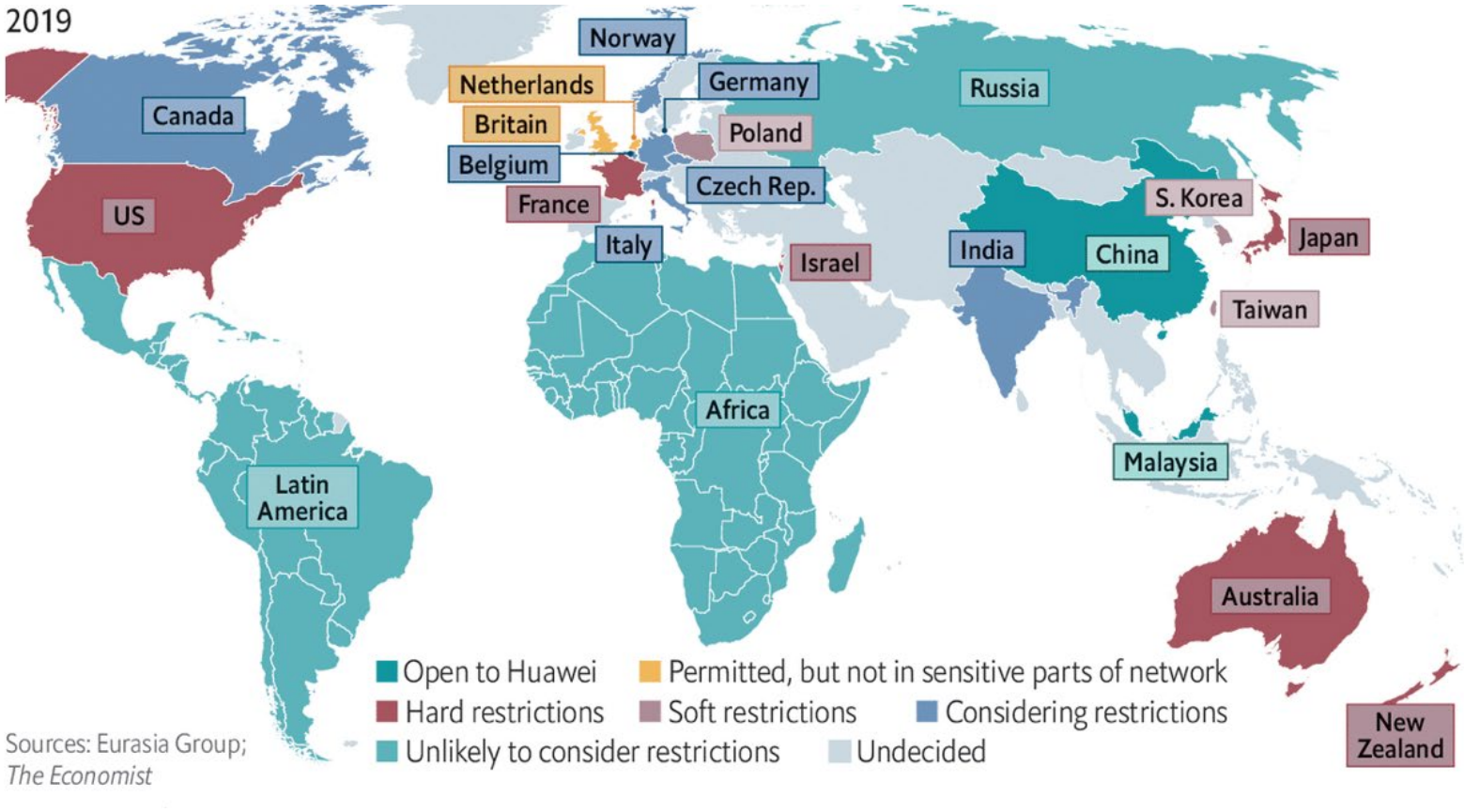


A “China Standards 2035” initiative has been announced and the U.S. is studying a response, possibly with the “Quad” partners (USA, Japan, India, and Australia).

Source: Thun, Taglioni, Sturgeon, and Dallas, 2022.

Win friends and influence countries

Possible policy goal, IV – win friends, and influence countries

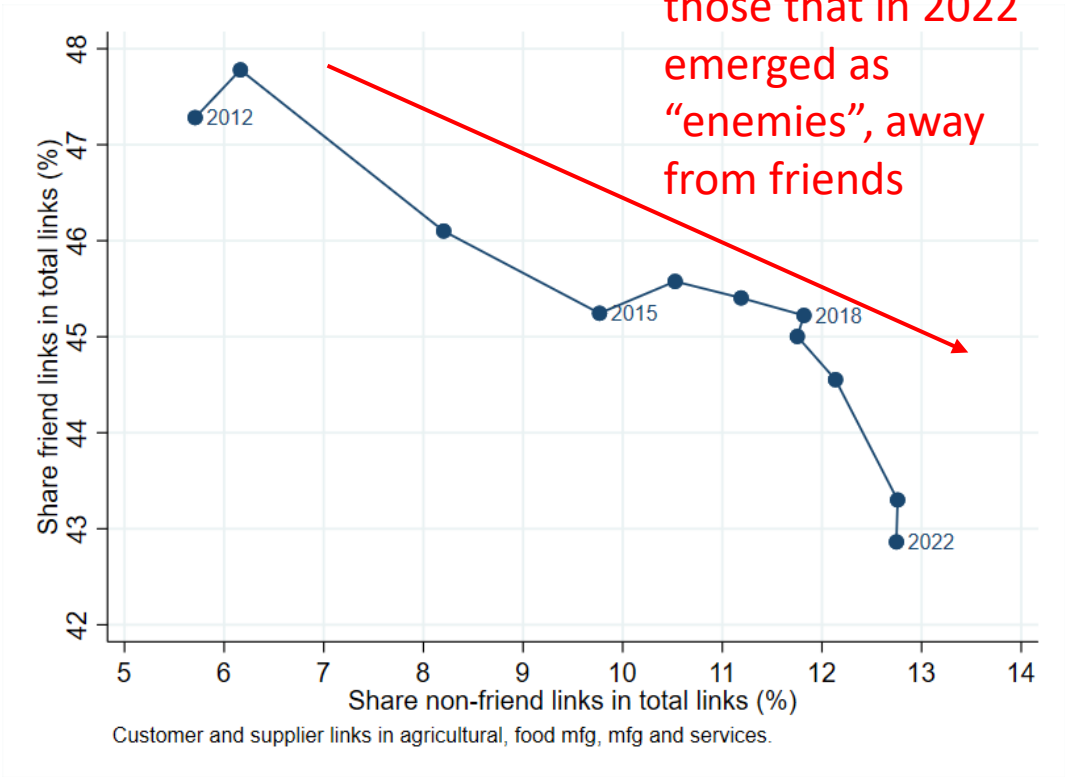


Source: The Economist, July 13, 2019

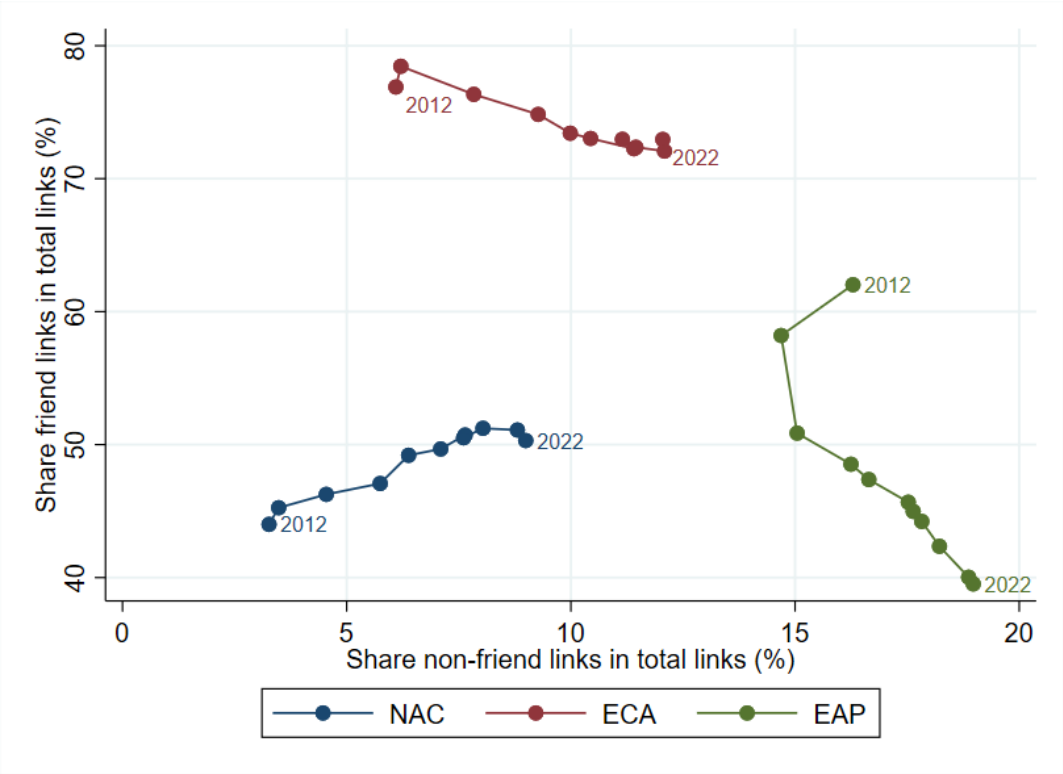
Friend-shoring: how do you determine who are your friends and your enemies?

Globally

2012-22: links pivoted towards those that in 2022 emerged as "enemies", away from friends



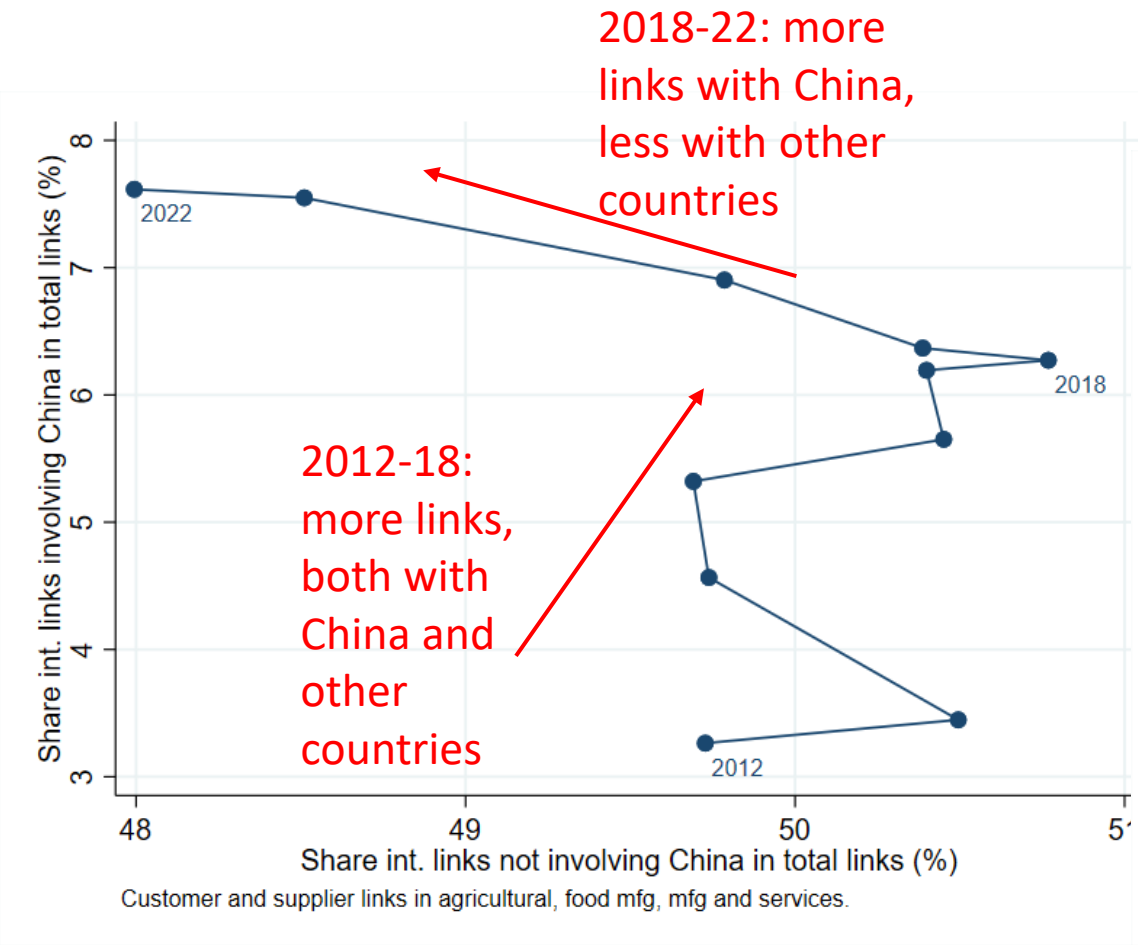
By region

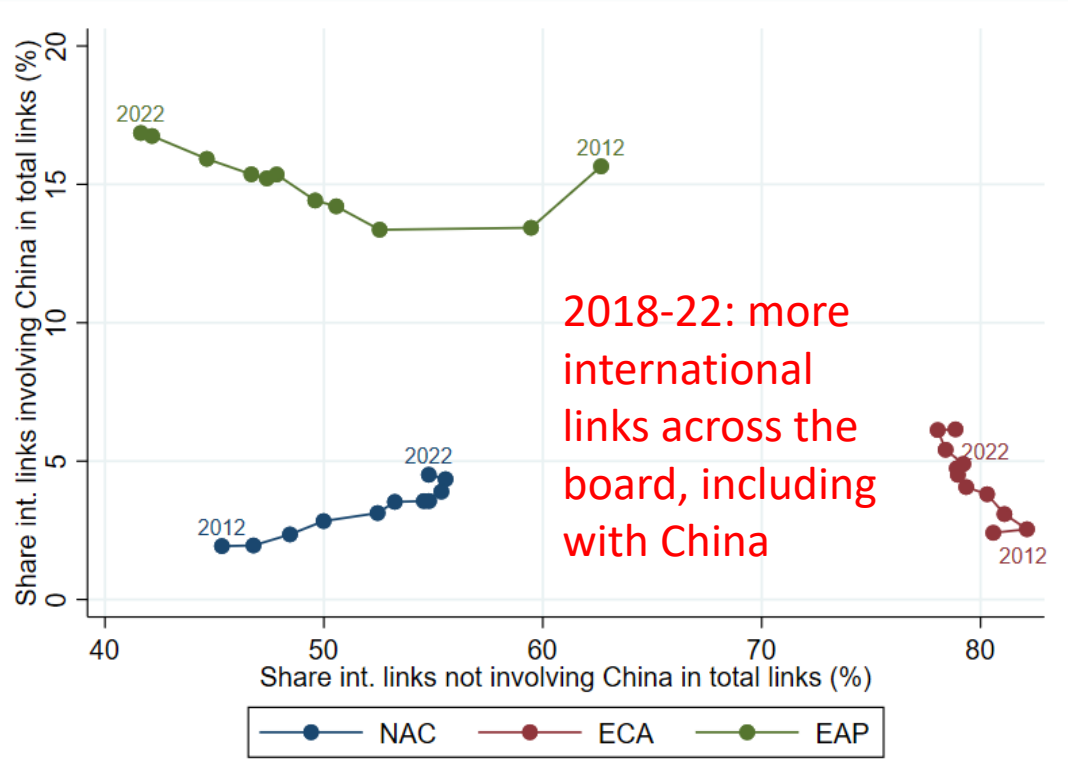


Definition of friends and enemies: alignment on voting preferences at UN security council, Russia-Ukraine War 2022

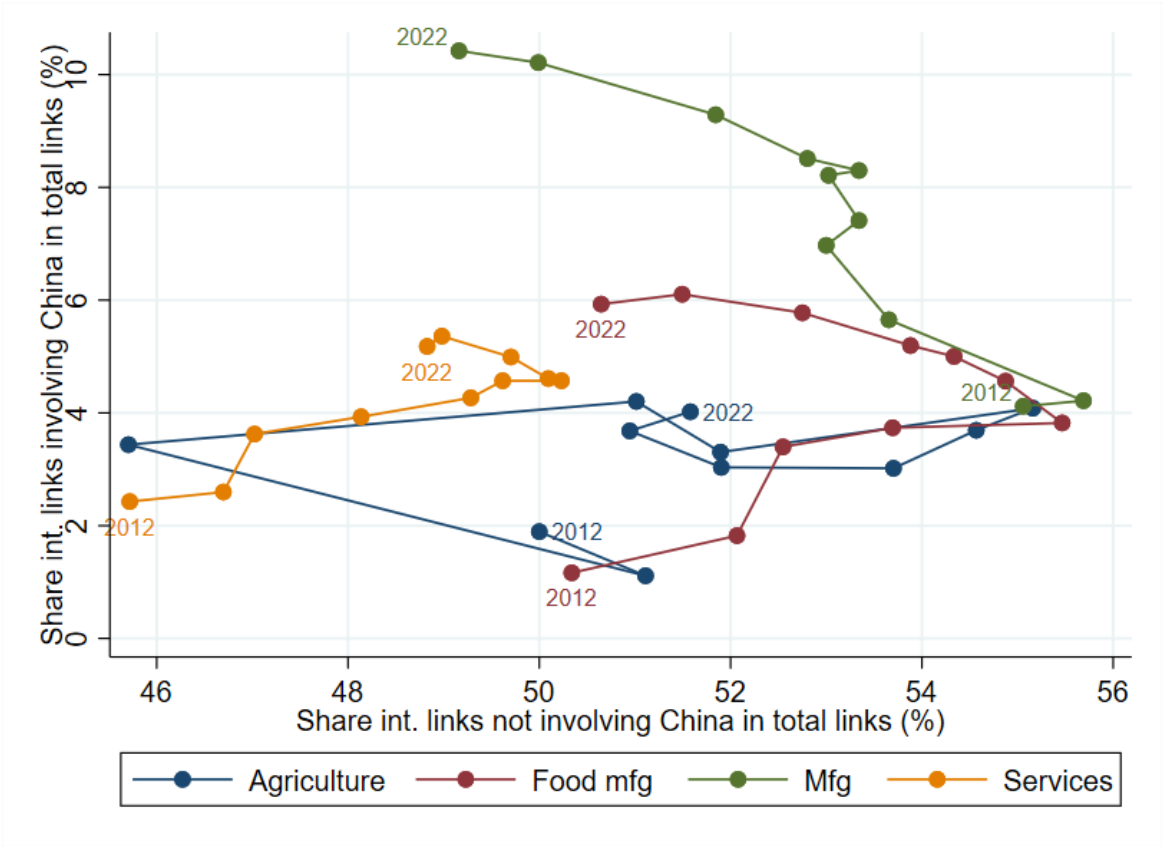
Decouple from China

Decoupling from China is only just starting to emerge in the data

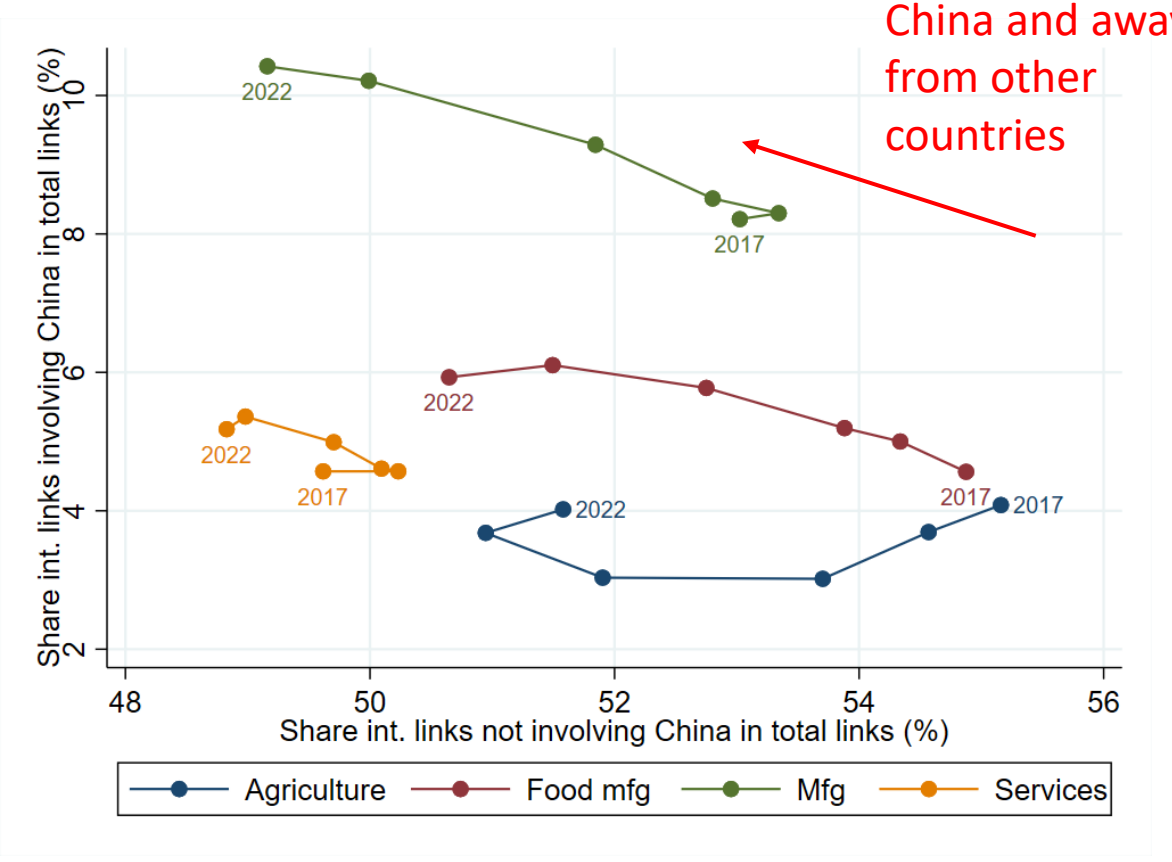




In all sectors, trend since 2017 is a reorientation of international links towards China, not away from it



2012-18: towards China and away from other countries



Possible explanations?

- Scale, manufacturing capacity, capital and human capital investments offset increase in trade costs, hence China remains a fundamental GVC partner?

In conclusion

- Across broad industries, there is evidence of three paradoxes: complexity at scale, concentration and fragmentation, and geographical dispersal and clustering.

- While there are signs of deglobalization since 2017, entrants are systematically more globally and regionally connected than exiters.

- Preliminary descriptive analysis points to a positive correlation between international connectedness and sales growth and a negative correlation between international connectedness and output volatility.

- Policy implications
  - Self-reliance, leveraging the nation-state for shaping global industrial policy, and moving away from a rule-based international integration may look politically attractive in the face of geo-political tension and supply chain disruptions, but…
  - …there will be strong incentives to rebuild an international system that accommodates sustainable interdependence
  - New and better mechanisms must emerge (sooner or later) to manage unproductive tribalism and nationalism, inefficiencies, and zero-sum thinking