Risk in the Electronics Supply Chain from Soup to Nuts

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Abstract

Fueled by the effects of the COVID-19 pandemic, rising tension between mainland China and Taiwan, and climate change, supply chain risk has moved to the front burner for policymakers with particular focus on the electronics sector. To support rigorous discussion of the potential for electronics supply chain disruption, we provide sector-specific annual indicators for political instability, natural disaster, industrial accident, and transportation disruption risk beginning in 2000. Through roughly 2010, most risk types increased substantially as China rapidly increased its share of global electronics production. Since 2010, aggregate risk for the sector as a whole has either held steady or declined. The risk profile varies substantially across the products that make up electronics production, with locations producing low to moderate value products in high volume characterized by higher supply chain risk. In addition to these supply shocks, demand shocks can play a prominent role in supply chain disruptions, as illustrated by the COVID-19 pandemic.

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1 Introduction

The electronics supply chain spans the globe: product design, material extraction and processing, component manufacturing, final product assembly, and distribution often take place in distinct economies for a single electronic device. Along the way, the sector is exposed to a multitude of risks. The perception that these risks have increased has motivated scrutiny of the geography of the electronics sector by policymakers. Examples of recent concerns include delayed semiconductor chip deliveries during the COVID-19 pandemic; elevated tension between Taiwan and mainland China; and the 2011 Tōhoku earthquake and tsunami in Japan. Events abroad such as these have steadily become more salient for the U.S. economy as import penetration for electronics has risen (fig. 1 on page 24). Such events are not a new phenomenon, and the relative importance of recent cases is difficult to gauge (table 1 on page 50).

Attention to such disruptions has markedly increased in recent years as measured by the prevalence of related terms and phrases in the Google ngram corpus (fig. 2 on page 25). The frequency with which ngrams related to natural disasters appeared moved up sharply after 2000, boosted by references to tsunamis, though it was still short of the levels seen in the wake of record blizzards in the late 1800s. References to geopolitical disruptions have climbed fairly steadily since roughly 1900, with a visible imprint from World War II and a surge since 2010 driven by "refugee" and "migrant." The frequency of epidemiological risk ngrams rockets up during the COVID-19 pandemic to levels far higher than the visible effects of the HIV/AIDS epidemic and the 1917 influenza epidemic.

Although these indexes suggest that risks have increased, more carefully constructed measures of risk are needed—consistent across industries, economies, and time. In fact, the frequency of disasters—events that involve an unexpected and overwhelming harmful impact on human beings—in countries that play a major role in the electronics sector has not increased substantially in the same period, a hint that text-based measures may be misleading (fig. 3 on page 26).[1]

To support rigorous discussion of the economic effects of these risks, we

[1] That said, disasters, though not more frequent, have become more extreme, raising the difficult question of which matters more for supply chain disruption, frequency or intensity. See "Climate Change 2021: The Physical Science Basis. Working Group I Contribution to the IPCC Sixth Assessment Report."

provide measures of political, natural disaster, industrial accident, and transportation disruption risk for the electronics sector and its component parts, from 2000 to the present. We rely on yearly shares by economy for production of electronic components and equipment published by Reed Electronics. For other industries in the sector, we construct shares from a variety of other sources. These shares are used to build production value-weighted risk indexes for each stage of production that vary over time as economic activity shifts between locations and as the risks found at each location change.

In addition to these (primarily) supply-side risks, we discuss demand shocks, which are an important risk as well. The rapid depreciation of inventories and capital equipment in the electronics sector motivates the industry to operate with little slack and inventory, making it vulnerable to shifts in demand, as demonstrated by the COVID-19 pandemic. Moreover, the low medium-run elasticity of supply prolongs the impact of such shocks.

There are many available discussions of risks and their mitigation in the electronics supply chain.[2] Relative to existing studies, the primary contribution of this work is measures that are consistent enough to support quantitative study of the relative importance of these risks over time.[3]

2 The Location of Electronics Production

The electronics sector manufactures equipment that uses electrical currents to process information. These information processing systems collect, store, transform, present, and transmit data, typically in digital form. Although some of the work done by these systems is performed by software, our

[2] Haramboure, Lalanne, Schwellnus and Guilhoto (2023) use the OECD inter-country input-output tables to study concentration in the semiconductor industry and linkages to upstream and downstream industries. Varas, Varadarajan, Goodrich and Yinug (2021) provide a detailed depiction of the technology and market structure of the sector and estimate creating regional, independent supply chains would require an investment of roughly $1 trillion and raise semiconductor prices by up to two-thirds. In a follow-up report, Varadarajan, Koch-Weser, Richard, Ritzgerald, Singh, Thornton, Cassanova and Isaacs (2024) discuss policy measures taken recently to affect the geography of the supply chain and the prospects for changing the distribution of each stage of production. Xiong, Wu and Yeung (2024) take a bibliometric approach to summarizing the existing literature.

[3] The ultimate test for these indicators, to be tackled in future work, will be whether they are related to firm location decisions and what the most effective approach to risk mitigation policy might be when taking account of firm behavior.

primary focus will be on hardware. (The risks inherent in intangibles production are rather different in nature and a left for future study.) We will mainly treat electronic equipment as a homogeneous good. From a manufacturing perspective, this assumption is more benign than it first appears. Treating all electronics as semiconductor chips in a box with differing forms of input/output peripherals doesn't distort reality by much. The identity of these devices boils down to differing sets of logical circuits which are largely amenable to fabrication in the same plants.[4] That said, manufacturers may favor domestic productionfor products produced on a smaller scale, for specialized applications, or containing sensitive intellectual property despite higher unit labor costs. We account for this difference by distinguishing special-purpose from general-purpose electronics and by distinguishing semiconductors from other electronic components.[5]

While the linchpin of (solid state) electronic equipment manufacturing—and a central focus of recent industrial policy—is the fabrication of semiconductor chips, the supply chain passes through at least a dozen distinct industries (fig. 4 on page 27).[6] Upstream from chip production are the mining and processing of needed minerals, production of material inputs such as silicon wafers, manufacturing of the sophisticated equipment used in chip fabrication and testing, research and development, and design. Downstream from chip production, they are combined with other inputs—e.g. circuit boards, batteries, cases—to produce final electronics.

Each of these stages is a distinct industry and we analyze their geographic distributions separately.[7] Some electronics industries are more labor inten-

[4]Indeed, Taiwan Semiconductor Manufacturing Corporation, the global leader in advanced chip manufacturing, relies heavily on this fact for its success.

[5]Consistent with this claim, the unit value of U.S. computer exports implied by trade data is typically 3-4 times the unit value of imports, though the ratio has fallen since 2020. For a discussion of the heavy concentration of U.S. electronics manufacturing on medical, military, and aerospace equipment see Byrne (2015).

[6]At the time of writing, most electronic information processing used semiconducting materials, usually silicon, which can be manipulated to serve as either a conductor or insulator. This semiconducting property is exploited to create the on/off switches that serve as building blocks for physical representation of logical systems. In the main, we are discussing these "solid-state electronics," though predecessor technologies have not completely disappeared.

[7]A distinct production process is the *differentia specifica* of an industry. The 2017 NAICS manual states that "economic units that have similar production processes are classified in the same industry, and the lines between industries demarcate, to the extent practicable, differences in production processes." Establishments with the same produc-

sive, like chip testing and final assembly of equipment, some are physical capital intensive, like wafer fabrication, and some rely heavily on the services of intangible capital, like chip design and R&D. These differences in input intensity combined with incomplete global factor markets motivate global production sharing. The relatively high value-to-weight ratio for electronics catalyzes that process by lowering the (quality-adjusted) cost of transportation between plant locations. Other factors affecting location include proximity to final goods markets, proximity to adjacent industries in the supply chain, intellectual property protection, headquarters location, and, of course, risk management. After looking at the sector as a whole, we sketch the geographic distribution of each of the component industries in turn.

The Sector as a Whole A high level depiction of the current geographic composition of global production and sales of final electronics—i.e. equipment ready for immediate use in the business or household sector—is shown in tables 2 and 3 on page 51 and on page 52. Both have changed markedly over time.

Key features of the composition of production over the 1985-2020 period are (1) a massive decline in the U.S. share from roughly half to about 15 percent that was largely complete by 2010, (2) a massive increase in the share of mainland China from essentially zero to nearly half which primarily took place after 2000, (3) Japanese share peaking at about one-quarter in the late 1980s then falling to a few percent by 2020, (4) a gradual decline in the share of European economies from already small (single-digit) levels in 1985, and (5) a fairly stable share for a set of smaller Asian economies—South Korea, Singapore, Vietnam, Taiwan, Malaysia, and Thailand—that collectively accounted for a little over 10 percent of production over this period. The concentration of production—as measured by a Herfindahl–Hirschman index (HHI)—rose over the period of study, but perhaps surprisingly the increase was largely complete by the end of the 1990s (though the country composition continued to evolve): The HHI held steady near 2,200 from 2000 forward, a value indicating a highly concentrated industry.

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tion process—which often but not always correspond one-to-one with physical locations—are collected into industries. Firms consist of one or more establishments under common management that need not be in the same industry; thus speaking of a firm as being part of an industry is often problematic in economic measurement. For more discussion of firm composition in the electronics sector see appendix **??**.

The distribution of the sales of final electronics across economies is moderately different from the production distribution. Directionally, trends are similar, with falling share for the United States, Japan, and Europe and rising share for China and small Asian economies; but these trends are more muted than they are in production. Whereas China accounts for roughly half of all electronics production in 2022, they account for only about one-quarter of sales. U.S. market share is also roughly one-quarter, about twice as high as the U.S. production share. The market is rather less concentrated than the industry: the HHI starts at 2,107 in 1985 and *falls* to 1,472 by 2022, a value consistent with moderate concentration.[8]

The difference between these two geographic distributions is a coarse indicator of the dispersion in the supply chain. The "earth mover" cost—the amount of probability mass one would need to move to make the distributions the same—is an indicator of this difference (fig. 16 on page 39). This measure varied between 9 and 11 percent from 1985 to 2001, roughly doubled by 2007 to 20 percent, then rose more slowly, peaking at 25 percent in 2014, before drifting down to 21 percent in 2022. Thus, from a high-level perspective, the footprint of production and sales in the electronics sector overlap fairly heavily. Pushing one step further into the supply chain, the earth-mover cost between (labor-intensive) final assembly of electronic equipment and the (capital-intensive) production of semiconductors is appreciably higher than between assembly and sales and has risen over time as well. In contrast, the distance between assembly and other (non-chip) components is more modest and has been stable over time. Examining each stage of production separately reveals far more geographic dispersion within the sector, a task we turn to next.

2.1 Materials

Electronics manufacturing makes regular use of an extraordinary diversity of materials, including 65 of the 118 known chemical elements in the periodic table, along with stable materials produced from petrochemicals such as plastics.[9] The minerals used to manufacture pure chemicals are extracted from terrestrial deposits and, in some cases, from the air, in a form chemically or physically mixed with other elements. These are purified in a

[8]The U.S. Department of Justice considers HHIs between 1,000 and 1,800 to indicate moderate concentration.

[9]See "How Cellphones Connect Us All," *Smithsonian Magazine*, July 12, 2023.

variety of ways—e.g. burning, agitation, chemical baths—to ensure consistent mechanical, electrical, chemical, and other behavior. These materials are used either in their pure form or with impurities deliberately introduced to modify their properties in predictable ways. They are the building blocks of electronic products and also serve as catalysts and environmental controls.

The role of each material in supply chain risk—the likelihood their supply will be disrupted—is affected by several factors. Among these are the number of countries with reserves of the raw materials, the cost of extraction (both variable costs and, in the case of reserves with no ongoing extraction or processing operations, fixed costs), and the prevalence in each country of various risk factors for disruption. We focus the discussion on materials with noteworthy risk profiles. That is, we set aside materials where abundant reserves are present in countries with stable friendly relations with the United States in a form readily available for extraction and processing (i.e. there is an existing industry).[10] We divide the remaining (risky) materials into three groups: Silicon, rare earth elements, and a residual category.

2.1.1 Silicon from Quartz to Wafers

The most commonly used semiconducting material in electronics is silicon, used in the form of circular wafers that are modified in various ways to produce circuitry. Although silicates account for roughly one-quarter of the earth's crust, high-purity reserves, found in the form of quartz, are uncommon. Almost all high-purity quartz (HPQ) comes from mines in Spruce Pine, North Carolina; small amounts are produced in China, Norway, and Australia. Deposits of lower purity, such as sand, require substantially more expense to process to high purity and account for a small share of industrial silicon.

The mined crystal undergoes several steps to transform it into the raw wafers that are used in chip production; these steps are typically spread across plants in multiple locations. After crushing and grinding the HPQ,

[10]Specifically, we ignore cases where substantial production takes place in Canada, Japan, Australia, Western European countries, or the United States. Many of these are the commonly available "base metals," such as copper and aluminum, materials produced from the atmosphere, such as oxygen and nitrogen, and materials produced as a byproduct of the processing of base metals, such as gallium, produced as a byproduct of zinc and aluminum processing, or a byproduct of other industries, such as sulfur, produced as a byproduct of petroleum refining.

several different techniques are used, each to remove different impurities: magnetic separation (iron); flotation (mica); acid leaching; and washing. This processing, as well as drying and sizing, is performed in plants in the United States, Norway, China, and Russia. The purified, sized HPQ is then used to produce crucibles at a distinct location.

In these crucibles, high-purity silicon is formed into ingots. The high-purity silicon used in the process is also manufactured from HPQ, using a different process. Each of several steps increases the purity of the silicon: reduction with carbon; chlorination; distillation; and reduction with hydrogen, yielding polycrystalline silicon. This processing takes place at plants in the United States, China, and Japan. Finally, polycrystalline silicon rods are processed in the crucibles to produce ingots in Japan, Germany, and the United States. These crucibles are sliced into wafers with diamond saws and polished to achieve a uniform surface and thickness. The production locations for major wafer manufacturers are shown in table 6 on page 55.

Because there is abundant wafer production capacity in friendly countries, the vulnerability of raw wafer supplies to disruption is modest. However, HPQ mining, although located in the United States, is an important source of risk because of the high dependence on a single location. Mining in Spruce Pine, North Carolina was halted by Hurricane Helene in 2024.

2.1.2 Rare Earth Elements

Rare earth elements are useful in electronics production because of their magnetic and optical properties.[11] The rare earth elements are not rare in the earth's crust *per se*, but are rarely found in concentrations that allow for inexpensive extraction. Moreover, they typically appear in combination—in monazite, xenotime, bastnasite, and other forms—and resist attempts to separate them from one another. China, currently the dominant economy in the industry, entered the market in the 1980s and rapidly took market share from the United States, Australia, and smaller players; China's share peaked at 98% in the mid-2000s (fig. 6 on page 29). After tensions between Japan and China in 2010 over disputed islands that allegedly led to China restricting rare-earth exports, the United States, Australia, and several other

[11]The rare earth elements include scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. All of these except scandium, lanthanum, and europium are used in electronics production.

economies increased production, but roughly two-thirds of rare earth production and processing still take place in China, sufficient to pose a serious risk of disruption to the supply chain.

In addition, the processing of the extracted minerals to produce industrial grade materials takes place almost entirely in China. Efforts to increase processing elsewhere have faced resistance because of the toxic chemicals produced by the process.

2.1.3 Other Minerals

[Under development] In 2023 and 2024, China restricted the exports of gallium and germanium in response to efforts by the United States to stop the exports of the most advanced semiconductor manufacturing equipment to China (Baskaran and Schwartz, 2024). These elements are essential to production of leading-edge semiconductors for communications applications in high-stress environments, such as for military and aerospace applications. Because the raw materials used for isolation of these elements are a byproduct of aluminum and zinc production, they are not particularly difficult to obtain. However, the process used produces highly toxic waste. Consequently, many economies resist efforts to perform the processing domestically and the industry is located almost entirely in China.

2.2 Equipment

The manufacturing of specialized equipment used in the fabrication of electronic devices on silicon wafers plays a central role in the pace of technical advancement, which consists primarily in creation of electronics on a smaller and smaller scale, which lowers the (quality-adjusted) cost of production, lowers power consumption (for performance of a given task), and raises task execution speed. Most notably, advances in the equipment that performs the photolithography—deposition of films on the wafer surface to produce the circuit—govern the level of miniaturization achievable. Consequently, the dominance of Japan, the United States, and, especially, the Netherlands in lithography is a strategic advantage in the continual push for greater performance.

Importantly, lithography is just one of a dozen distinct equipment types needed for the chip production process (table 7 on page 56). There are major manufacturers of all but one of these types (dicing equipment) in the United

States and many companies with headquarters in closely allied countries. China, in contrast, has companies with domestic headquarters that produce only one of the equipment types.

2.3 Design and Mask Production

The blueprint for the circuitry that gives semiconductors their functional identity comes in the form of "masks" that direct the lithography equipment to modify the surface of the wafer. Masks are glass or quartz substrates with a pattern of opaque material representing one step in the creation of a circuit in a series of layers. The mask guides radiation onto the wafer, creating miniature transistors and other features.

Electronic design automation (EDA) software, a form of computer-aided design (CAD), is used to translate product concepts into circuit designs. Four of the five major EDA companies have headquarters in the United States and one is headquartered in Japan.

Once feasibility is established for an integrated circuit, a custom set of masks is created, a process that can cost tens of millions of dollars if the most advanced technology available is employed. Mask creation is done in-house by some semiconductor companies and outsourced by others. Mask manufacturers are located in the United States, Taiwan, and especially Japan—part of a long tradition of optical technology leadership in that economy.

2.4 Chip Fabrication

Circuitry is created on raw, typically silicon, wafers of semiconducting material in ultra-clean fabrication facilities (fabs). Semiconductor manufacturing equipment is used with masks to perform the dozens of steps needed to gradually build electronic devices on raw wafers. At the fab, technical advance involves the design and engineering of the production line, calibration of the equipment, and continual refinement of the process to raise the yield—number of usable chips per wafer—for particular technologies and specific chip designs.

Historically, the semiconductor fabrication industry has been dominated by a handful of countries (fig. 7 on page 30). Measured in terms of the number of (8-inch equivalent) wafers processed, Japan was by far the largest semiconductor producer in 1996. Since then, Taiwan, South Korea, and China have pushed into the market, reducing the share for Japan. The United

States, European countries, and Singapore have had smaller but noteworthy market shares.

Importantly, country share is affected by the choice of whether to measure capacity in wafers produced or in transistors. Transistor production is a fairly reliable indicator of quality-adjusted output. Adjusting for quality by counting transistors rather than wafers, the current shares for Taiwan and South Korea nearly double and mainland China's share shrinks dramatically. In terms of transistors, the U.S. market share is little different than its market share in terms of wafers because the U.S. industry produces using a range of technologies, including leading edge production for MPUs and the trailing technology generations used for many military and aerospace applications.

Relatedly, the semiconductor industries in South Korea and Taiwan have employed more advanced technology on average than the global industry as a whole in recent years. China and Japan, in contrast, focus on nodes that trail the leading edge (fig. 5 on page 28). The United States, Taiwan, and Korea have fought over the leading edge in recent years, led by their national champions, Intel, TSMC (Taiwan Semiconductor Manufacturing Corporation) and Samsung, respectively. Japan and Singapore had kept up with the leaders through the early 2000s but have since fallen behind. China, hampered by trade restrictions that preclude acquisition of leading-edge manufacturing equipment and difficulty attracting talent, has been well behind the peloton throughout this period and has fallen even further behind in recent years.

2.5 Chip Testing and Assembly

Completed (fabbed) wafers contain multiple copies of the same chip design. These chips are tested for performance, separated, and packaged. This test and assembly stage typically takes place in a different location from the fab, often in a country with lower labor costs as the process is more labor intensive. Integrated device manufacturers (IDMs), like Intel, often have dedicated facilities for this purpose. Others, particularly fabless companies, often use contractors.

Of the seven largest companies in the contracting industry (Amkor Technology, Advanced Semiconductor Engineering, ChipMOS Technologies, JCET Group, King Yuan Electronics, Powertech Technology, and Siliconware Precision Industries), five are headquartered in Taiwan and based on what one can glean from financial reports, they primarily employ facilities in their home country. JCET Group, headquartered in mainland China, primarily

operates there, and Amkor Technology, a U.S. company, has facilities in multiple countries. Allocating Amkor Technology's facilities according to their reported size and using annual revenues, roughly 81 percent of the contract test and assembly work takes place in Taiwan, 7 percent in Korea, 5 percent in China, and the remainder scattered across other countries.

Identifying the locations of the test and assembly facilities of IDMs is difficult as financial reporting rules do not require them to reveal this information at the country level. However, the exports of semiconductors from countries that do not have domestic fabs provide a window into this activity. Malaysia is the most prominent example of such a country, with the Philippines, Vietnam, and Thailand also playing a noticeable role. There has been a pronounced increase in semiconductor exports from Malaysia since 2016. The timing suggests that test and assembly activity may have been shifted from mainland China to Malaysia in response to the rising trade policy tension between the United States and China.

2.6 Other Components

The geography of production for other components—printed circuit boards, screens, batteries, casings, antennae, microphones, speakers, cameras, etc.—varies by product. Table 8 shows the location of selected manufacturers of these components. Contract assembly companies also produce some of these components on site. These non-semiconductor components are essential to electronics output and disruption to their production can slow equipment assembly. For example, lead times for power supplies, conditioners, and batteries shot up during the COVID-19 pandemic, peaking at twice their pre-pandemic level.[12]

2.7 Product Assembly

Product assembly is typically performed by contract manufacturers known as electronics manufacturing service (EMS) firms or original design manufacturers (ODM). The original equipment manufacturer (OEM) specializes in management, design, and marketing and takes responsibility for product quality. ODMs are distinguished from EMSs by their performance of design work as well, according to the high-level conceptual description of the

[12]Based on proprietary data from The Electronics Industry Association (ECIA).

product provided by the OEM (Thun, Taglioni, Sturgeon and Dallas, 2022). This fragmentation emerged in the electronics industry in the 1970s and accelerated markedly in the 1990s as companies like IBM and HP spun off their facilities. The contract manufacturing market is dominated by companies in Taiwan for products produced in high volume. Lower volume, more specialized production is often done by smaller U.S. firms.

Regardless of the location of management, the location of assembly can be measured by country shipments of final electronics. As mentioned above, the geographic composition of these shipments has shifted dramatically toward mainland China since 2000.

Unlike the equipment used in semiconductor fabs, the equipment used in the assembly process is available from a large number of manufacturers with diverse locations. Among the types of equipment needed are machines for solder paste printing, pick and place, reflow soldering, automated inspection, glue dispensing, and testing as well as conveyor systems, assembly fixtures, and jigs.

2.8 Intangibles

In addition to the EDA software used in the design process and the designs themselves, discussed above, intangible capital includes research and development. The noteworthy change in the distribution of major IT hardware company R&D across countries in recent years is a rise in the share performed by companies with Chinese headquarters from essentially nil to 20 percent at the expense of the R&D shares of European and Japanese companies (fig. 9 on page 32). The shares for Taiwan and South Korea have moved up modestly. The share accounted for by U.S. companies has moved down 5 percentage points to 42 percent in 2022.

In addition to conducting research in labs, semiconductor companies often devote fabs to research into new fabrication technologies and development of the process that allows those technologies to be employed at scale. The distribution of these corporate R&D fabs differs markedly from the distribution of production fabs. In particular, the Asian locations accounting for roughly 60 percent of global wafer capacity in 2021—China, Taiwan, Singapore, and South Korea—accounted for less than 20 percent of the corporate R&D fabrication plants, though this share has increased in recent years (fig. 8 on page 31). The United States, which accounted for only 12 percent of global wafer starts in 2021, accounted for more than 40 percent of R&D fabs, and

Japan and Europe accounted for another 40 percent.

Academic and government fabs are an important part of R&D for the industry as well, with a particular focus on basic research. Here the role of Asia is also disproportionately small: China, Taiwan, Singapore, South Korea, and Japan collectively are the location for roughly one in five of these fabs. The United States is the most prominent location, and Europe, despite having relatively little production capacity, is an important location as well.

Taking stock The extensive detail provided above illustrates that the component industries of the electronics supply chain each have distinct geographic profiles. Painting this complicated picture with a broad brush, substantial shares of many of the industries in the sector are located in the United States, China, Taiwan, and Japan; South Korea, Europe, and Southeast Asian economies are noteworthy locations for some of the industries as well (fig. 10 on page 33). There are a few choke points, notably rare earth processing, leading edge lithography equipment manufacturing, and leading edge chip fabrication. Interestingly, these are split between China, the United States and its partners, and Taiwan. That said, most of the activities in the sector are spread across multiple economies.

3 Quantifying Supply-Side Risk

We focus on four types of risk: political instability, natural disaster, industrial accident, and transportation accident. For each, we aggregate country-level indexes from the sources described below. First, we aggregate the direct risk corresponding to trading partners, weighting them by their share of U.S. imports. Next, we consider the global supply chain as a whole, weighting risks for each country by its contribution to global value added for different stages of production.

3.1 Risk Indicators

Political Instability We use the World Bank World Governance Indicators (WGI), which are described as follows: "The WGI are composite governance indicators based on over 30 underlying data sources. These data sources are rescaled and combined to create the six aggregate indicators using a statistical methodology known as an Unobserved Components Model

(UCM)." There are six individual indexes: voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. Scores are provided in terms of location within the cross-country distribution (consequently, global trends affecting all countries are not reflected in these indexes). We use the geometric mean of the six indicators. (No composite index is provided by WGI.) Country component indexes tend to move sympathetically with one another, so this equal-weight aggregation discards little information and is suitable for the coarse question of interest in this paper.

In almost all cases, except Singapore, the average composite WGI is substantially lower for labor-intensive economies than for capital-intensive ones. Mainland China has the lowest average index among low-wage countries (table 11 on page 59). Among high-wage countries, the United States has the second highest average composite index, about one-third of a standard deviation below Canada and a touch above Japan and an average of European countries.

Time-series variation is modest. To illustrate, the component indexes for the United States, China, and Taiwan show little movement in most cases (fig. 11 on page 34). One exception is the U.S. "political stability, no violence" indicator, which dropped after the September 11, 2001 terrorist attack and has remained low since then. Another is the indicator for "government effectiveness" in China, which has moved up noticeably. Broadly speaking, the indicators for Taiwan have moved up modestly, reaching roughly the level of the typical U.S. indicator by the end of the period.

Natural Disasters We use the Emergency Events Database (EM-DAT) published by the Centre for Research on the Epidemiology of Disasters (CRED) at the University of Louvain, Belgium, which is described as follows: "The EM-DAT database records mass disasters as well as their health and economic impacts at a country level. The database contains core data on the occurrence and effects of 26,000 disasters worldwide from 1900 to the present. However, the data are not recommended for time-series analysis prior to 2000 due to technology-related changes in the availability of disaster information. The database is compiled from various sources of information, including UN agencies, non-governmental organizations, insurance companies, research institutes, and press agencies"

The types of natural disasters included are biological, climatological, geo-

physical, hydrological, and meteorological. By far, the most prevalent natural disasters are storms and floods, each accounting for roughly one-third of the events recorded. The remaining disasters are earthquakes (8%), extreme temperatures (6%), mass movement (5%), wildfires (4%), epidemics (3%), drought (3%), and miscellaneous other events.

Importantly, at the time of writing, the COVID-19 pandemic was not yet reflected in the data.

Scaling this indicator to account for the impact of disasters is a challenge. Measures of intensity are available, but only for a portion of disasters.[13] Only half of tropical cyclones have a reported maxiumum windspeed for example. We use the number of individuals affected by each disaster, reasoning that the effect on economic activity may well be proportional to the effect on the local population, aggregate across disasters within each country and take the five-year trailing average as our indicator of the risk of disasters in the near term.[14]

The disaster impact indicator varies widely across economies (table 12 on page 60). The share of the population affected by disasters in China is roughly four times the share in the United States. And, in the typical (median) year, little of the U.S. population is affected whereas the high median share in China indicates that disasters affect a high share of that population consistently. Other low-wage economies tend to have high disaster prevalence as well, though lower than in China in most cases (fig. 15 on page 38). Other high-wage economies have lower disaster prevalence than the United States in most cases, Taiwan and Japan being exceptions (fig. 14 on page 37). Perhaps surprisingly, there is no clear upward trend in the number of individuals affected by disasters since 2000, an indication that the evolution of disaster risk in recent years is more complicated than one might assume (fig. 12 on page 35).

Industrial EM-DAT also provides a record of industrial accidents, most of which are structural collapse, fire, or explosion. We use the five-year average count of disasters scaled by manufacturing employment as our indicator.

[13] 71 percent of disaster observations provide the number of individuals affected. In future versions of this paper, we will explore imputing the others with EM-DAT information on location, type of disaster, and other magnitude measures like area affected and windspeed.

[14] This approach has the appeal of mitigating the fact that the distribution of disasters need not match the distribution of economic activity.

The number of industrial disasters rose sharply in China as manufacturing expanded, but scaled by manufacturing employment, it displays a steady downtrend. Relative to the United States it is roughly similar in recent years. In fact most competitor low-wage countries also have similar disaster rates to the United States.

Transportation EM-DAT provides data on transportation disasters as well, including for air, rail, road, and water transport. Road transport accidents account for over half of the disasters (54%), water transport for 29%, air for 11%, and rail for 6%. Scaled by population, transport disasters have declined in most countries since 2000.

In addition to the risk within economies, there is the risk borne while the goods are in transit between them. With each addition of a location to the production process, this risk increases. As noted above, international trade within the supply chain necessarily increases with the difference in distributions between successive stages in the chain, so the earth-mover cost serves as an indicator of international transport risk (fig. 16 on page 39). This indicator serves as a lower bound since in principle movement across countries within stages may occur. For example, within the component stage the production of silicon wafers from quartz takes place in several stages as described above, which may be spread across multiple countries.

At least two forms of risk are inherent in the international transport process. Hazards presented by ocean shipping in the form of piracy and cargo loss in accidents have declined in recent years, reducing distribution risk for that mode of transport (fig. 17 on page 40). Similar data were not yet located for air transport, which presumably has a rather different risk profile (e.g. little hijacking occurs). Because of the high value-to-weight ratio of electronics and their rapid depreciation, air transport, more costly per ounce but quicker, is the dominant mode of international transport for electronics (fig. 18 on page 41).

3.2 Aggregating Risk

3.2.1 Direct Exposure through Trading Partners

The direct impact of trading partners on the risks discussed here is shown in fig. 19 on page 42.

Political instability risk aggregated across trading partners using share of electronics imports has shown a marked decline, falling from roughly 0.9 standard deviations better than the average country to parity with the average country. This is the effect of changes in the mix of trading partners, rather than degradation of governance within partners: Holding trade shares fixed at their 1995 levels, the aggregate governance indicator improves slightly. As trade has shifted, primarily toward China, aggregate trading partner governance has worsened for U.S. merchandise imports, generally, but by less than for electronics. And, the aggregate of the world governance index indicators for the United States has moved down as well, but remains far above the typical trading partner. Consequently, rising import penetration raises risk relative to domestic production.

Natural disaster risk, measured as the weighted average of the share of population in trading partners affected by disasters, moves up sharply beginning in 2000, then declines by roughly the same amount. The primary explanation for the increase is a shift toward China, where risks are higher. As can be seen in the chart, in the absence of that shift, the risk index would have moved roughly sideways. Then from 2010 forward, the effect of flood management efforts in China drastically reduced the share of the population affected, bringing the aggregate down. Meanwhile, the U.S. index pops up due to a record blizzard, rather than a broad-based change.

The trade-weighted per capita prevalence of industrial accidents has fallen substantially since 2010 as China's record has improved, after moving up slightly from 2000 to 2010 driven by offshoring to China. The U.S. record of industrial accidents has improved over time on balance as well, but is worse than the average trade partner in the most recent reading.

The transportation safety record among trading partners is far worse, on average, than the United States, though it has shown a market improvement over time.

3.2.2 Risk in the Full Supply Chain

We next consider the risk of disruption in the supply chain as a whole. This is a rather different exercise than tracing links back through the supply chain for specific imports.[15] We ask the simpler question of how the likeli-

[15]See "An Anatomy of U.S. Establishments' Trade Linkages in Global Value Chains" and "Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tōhoku Earthquake" for examples of work using that approach.

hood of adverse events in the global electronics sector has changed over time as the geographic distribution of activity has changed without restricting attention to goods eventually imported to the United States.[16] To answer our question, We create simple aggregates of country-level indexes using weights provided in the previous section, distinguishing between final assembly and component production. *Future versions of the paper will examine risk in the other industries in the sector.*

Political Instability For the sector as a whole, governance risk *relative to risk worldwide* has increased significantly since 2000, moving from one standard deviation less risky to 0.4 standard deviation less risky. The primary source of this risk is variation across countries rather than changing risk within countries over time. In fact, the shift within countries has a modest damping effect on the increase in governance risk in the sector; because risk in China has diminished and risk in the United States has increased, the shift of production toward China has damped the increase in sector risk.

Within the sector, governance risk in the location of final assembly of electronics is has risen far more than is the case for components, a result of a more pronounced increase of China's share of global production for final assembly (up 39 percent) than for components (up 22 percent). Component production has also shifted toward South Korea and Taiwan, which have relatively less governance risk than China. Final assembly of high-volume electronics—computing, communications, and consumer equipment—takes place in far riskier locations, on average, and that risk has risen by far more than is the case for low-volume production of special-purpose electronics—industrial, medical, and control & instrumentation equipment.

Natural Disasters For the sector as a whole, natural disaster risk, measured as the share of the population affected in the preceding 5 years, rose steadily from 2000 to 2011, increasing more than four-fold, then moved down, ending the period in 2020 at a level approaching twice that of 2000. Two factors explain the bulk of the contour. In the period of rising risk, the share

[16]Such disruptions may have a direct effect on U.S. downstream production through supplier relationships or on sales of final goods produced in a chain passing through the disruption location. With this approach, however, we cannot be sure such a supplier or distributor link with the U.S. economy is present for any particular shock. Knock-on effects through macroeconomic effects may well be present even in the absence of such links, of course, to the extent that price-setting is global.

of electronics production taking place in China, where natural disaster risk is far higher than in the United States and Japan, rises from roughly 10 percent to 45 percent. China's production share rises 10 percentage points further at the expense of Japan and European producers from 2010 to 2015 and is stable from that year forward. Even so, aggregate risk moves down as the risk indicator for China moves down markedly. Chinese infrastructure projects for flood management provide the likely explanation.[17] Even during a period of rising disaster frequency, the share of the population affected moved down in China. Indeed, in recent years, natural disaster risk has been *lower* in China than in the United States as U.S. risk popped up as a result of a category 5 blizzard in 2016.

Mirroring the pattern for political risk, within the sector, natural disaster risk is higher for high-volume electronics assembly than special-purpose electronics assembly, and lower for semiconductor chips than for non-chip components, in the main. The contour for the high-volume electronics and lower-quality components moves sympathetically with the sector as a whole while the low-volume and higher-quality portions echo the contour of risk in the United States.

Industrial Accident Risk of industrial accident for final assembly of electronics climbs in the mid 2000s before falling steadily to the end of the period studied. Risk in component production exceeds final assembly briefly in the early 2000s, then is consistently lower going forward. As general-purpose electronics account for a far larger share of electronics assembly, they naturally have a similar contour to the aggregate. In contrast, special-purpose electronics—more likely to be produced in the United States, have a far lower risk of industrial accident. For most of the period studied, industrial accident risk for semiconductor production locations is far lower than for non-chip components.

Transportation Disruption In contrast to the other risk types, transportation disruption risk differs very little across product types. Risk of this type moves downward steadily through roughly 2010, then largely moves

[17] These efforts include the *Huai River basin flood management project*, the *South-North Water Transfer Project*, that moves water from the Yangtze River basin to the Yellow River basin, and the *sponge city program*, which reportedly collect 70 percent of floodwater in participating areas. See "How China is adapting to increasingly frequent flooding."

sideways, with the exception of semiconductors, for which the risk rises.[18]

4 Demand-Side Risk and the COVID-19 Pandemic

As noted previously, the COVID-19 pandemic is not yet reflected in the EM-DAT data on natural disasters. It surely represents a significant supply shock by the natural disaster measure constructed here. (Indeed, the approach we use may not suit the event particularly well, in that the number affected—several hundred million—will dwarf all other recent disasters.) Restrictions on labor supply in the sector were noteworthy, particularly in final product assembly and other labor-intensive industries. More capital-intensive industries were little affected; semiconductor fabs managed to continue operations in most cases, though a separate natural disaster—a drought in Taiwan—did disrupt production in the same time period. However, the knock-on effect of the drop in air travel was to reduce air cargo capacity (a substantial share of which is carried on passenger flights), so semiconductor deliveries were delayed and air freight prices rose more than 50 percent (fig. 24 on page 47).

That said, the demand effects of the pandemic appear to have played a larger role in supply chain disruptions. Using U.S. household spending to illustrate, the share of personal consumption accounted for by electronics popped up one-quarter percentage point (fig. 25). The effect of this shock was two-fold.

First, because inventories and capital equipment depreciate very rapidly in the electronics sector broadly and for semiconductors especially, manufacturers maintain very high capacity utilization and (fig. 23 on page 46). Consequently, there was little slack in the system to accommodate the surge in demand. Delivery times more than doubled, on average, and for some chip types, rose five-fold, from 10 to 50 days (fig. 26 on page 49).

Second, the composition of demand for electronics changed dramatically. The share of global semiconductor output used in data processing electronics

[18]There is also risk within countries as goods travel from ports to market. Aggregating country-level natural disaster risks using sales, rather than production yields an indicator of in-country distribution risk that is a muted version of the production risk indicator, rising to 2011, though far less, then moving down, on balance, though temporarily boosted by the 2016 jump in the U.S. index.

moved up unexpectedly by 4 percentage points in 2020, to 32 percent, at the expense of communications, consumer, and automotive electronics.[19] Contract semiconductor manufacturers ("foundries") allocate capacity based on contracts negotiated well in advance, and the process of ramping up production for a particular chip is time-consuming, the industry moved sluggishly to accommodate this unexpected product mix. In contrast, the *anticipated* mix shift toward automotive electronics, from 11 percent in 2020 to 17 percent in 2023 has not caused similar supply chain problems.

An important aggravating factor for the pandemic supply chain disruption was the very low supply elasticity in the semiconductor industry. New plants take several years to construct. Anticipating that the surge in demand would abate when the pandemic ended, manufacturers had little incentive to build new plants and install new equipment.

5 Conclusion

From 2000 to the present, the geography of the electronics supply chain has shifted dramatically. Final assembly has moved from the United States and Japan to China, with the exception of some special-purpose electronics. Taiwan, South Korea, and China have increased their share of component production at the expense of Japan and the United States. Other Asian and European economies remain small players in these core industries. Upstream, minerals extraction and processing, semiconductor manufacturing equipment production, other component manufacturing, and intangible activity all have distinct and evolving geographies.

Each economy has a distinct risk profile. Natural disasters and industrial accidents have historically been a far greater risk in China than the United States, and the risk of political instability has been higher as well; in recent years, however, China has made progress on closing that gap. On balance, these forces led to a rise in risk as production shifted to China, followed by a fall as risks in China declined. As measured by the indexes constructed from production-weighted country risk, aggregate risk in the electronics supply chain has moved down, on balance, since 2000, in the case of political instability, industrial accident and transport accident. Natural disaster risk

[19] See "State of the Semiconductor Industry," published by Semiconductor Industry Association, various years.

has moved down substantially since peaking in 2010 but remains 50 percent higher than in 2000.

In an era of heightened concern about a variety of risks to the electronics supply chain, dominated by the COVID-19 semiconductor shortage experience, it is essential to good decision-making to rely on impartial measures of the risk environment. We looked at four kinds of risk—political instability, natural disaster, industrial accident, and transportation disruption. Our focus has been on quotidian risks—the occasional blizzard, cyclone, or bout of civil unrest—not on the historic disruption seen during the pandemic. In short, as measured by these indicators, the supply chain is not characterized by markedly higher risk of these regularly occurring disasters and accidents in recent years relative to the early 2000s except in the case of natural disaster.

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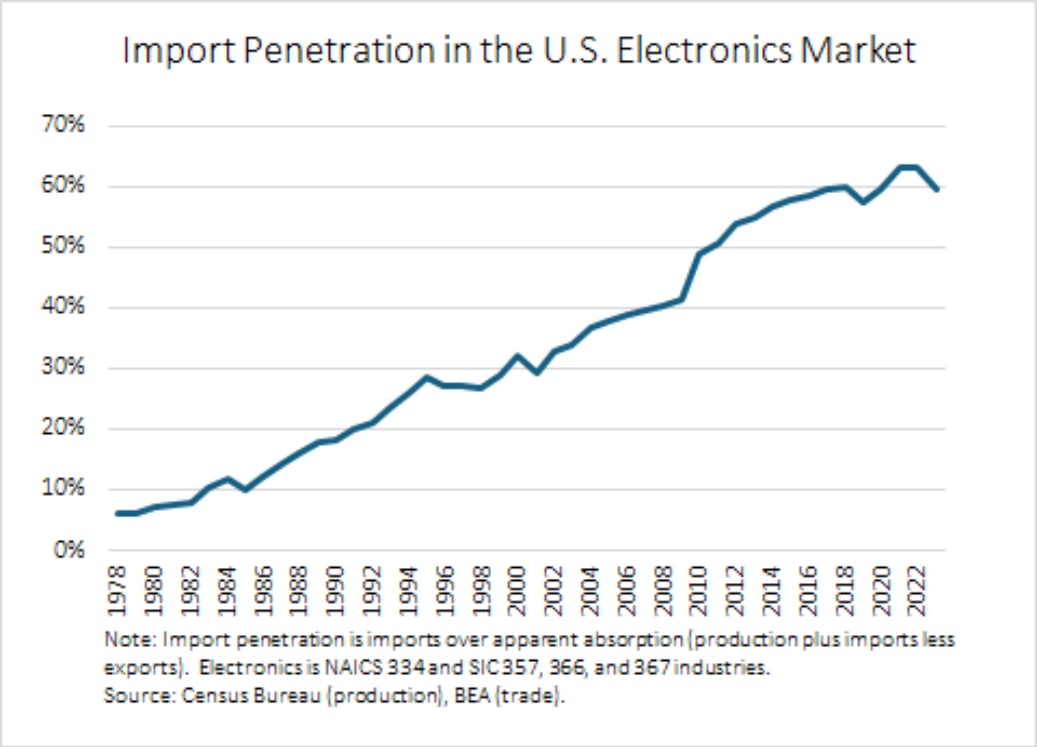
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Figure 1



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Figure 2

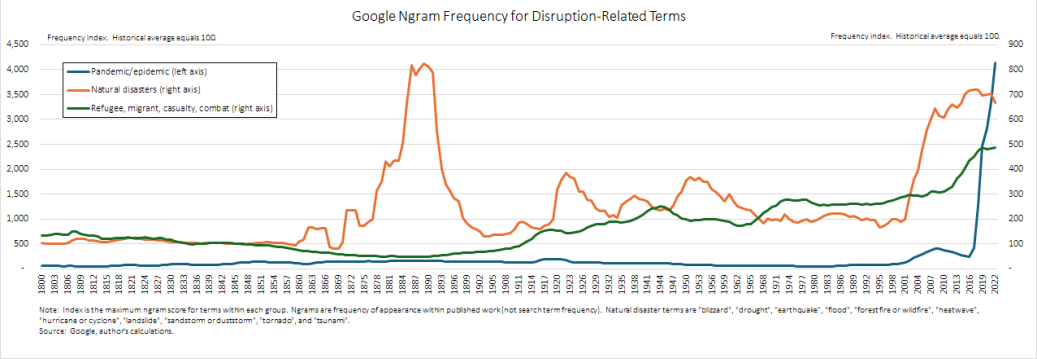
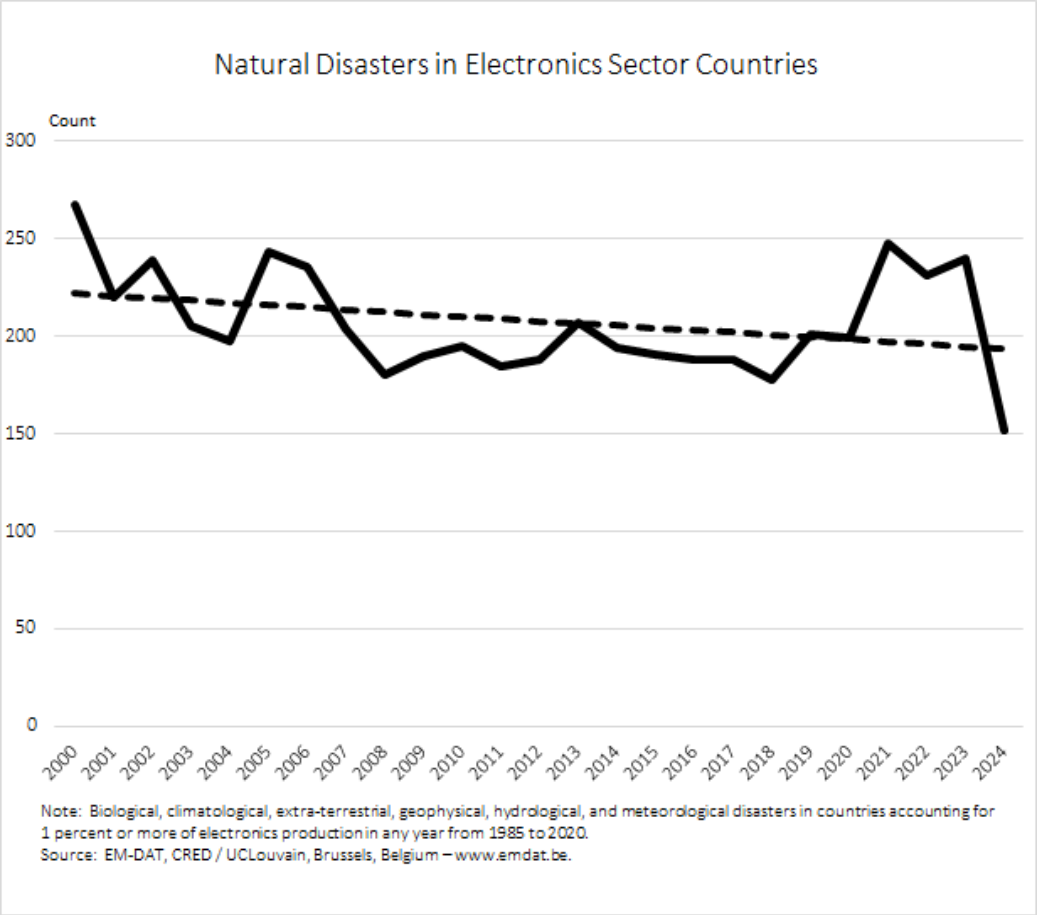
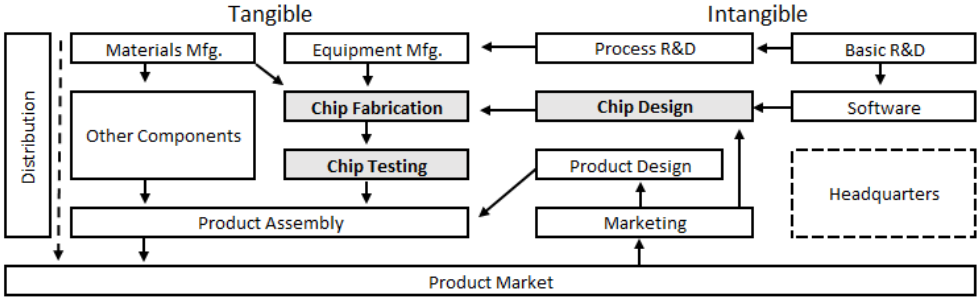


Figure 3: Hold for caption



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Figure 4: Stylized Electronics Sector Supply Chain

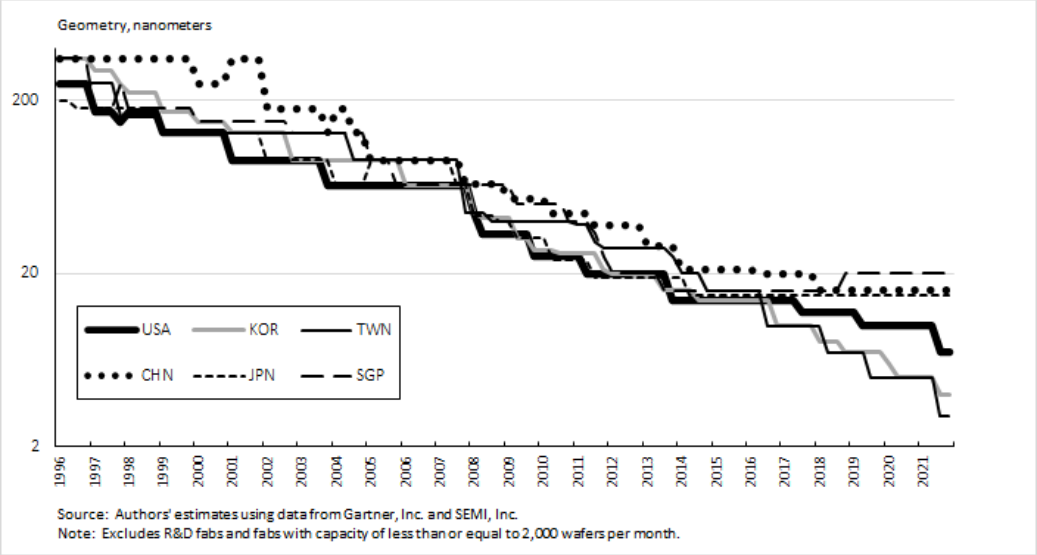


Source: Byrne and Green (2023).

Note: Headquarters includes functions such as strategy, policy, marketing, back office, communications, and finance.

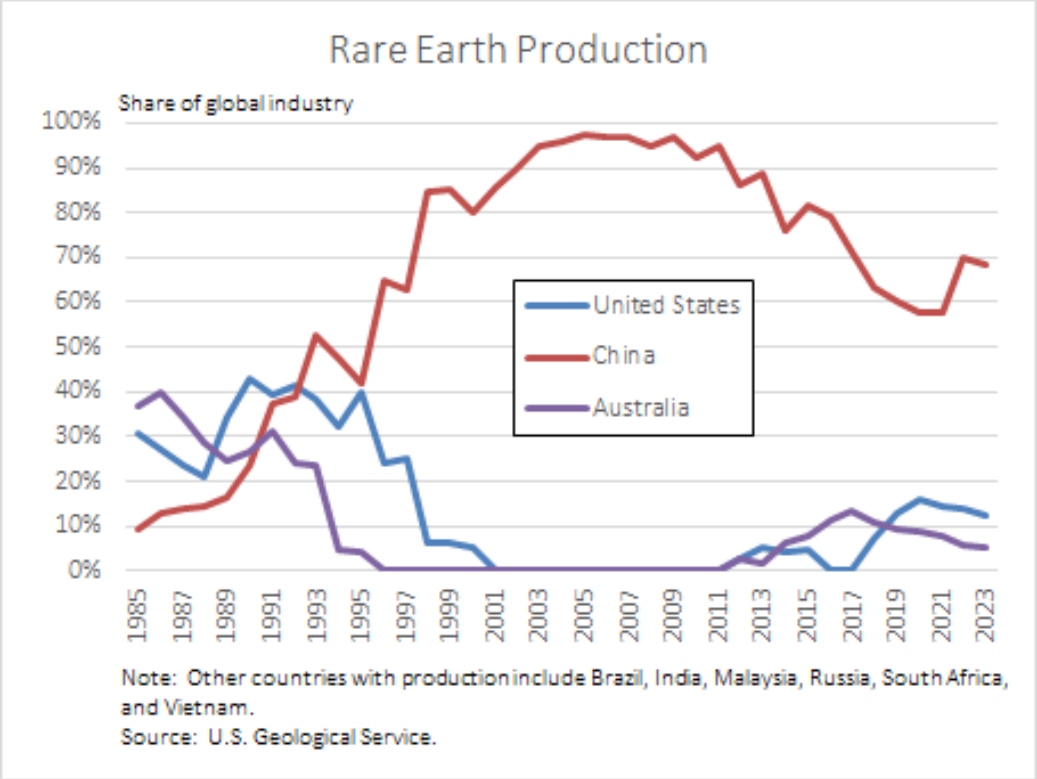
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Figure 5: Most advanced technology in volume chip fabrication by country.



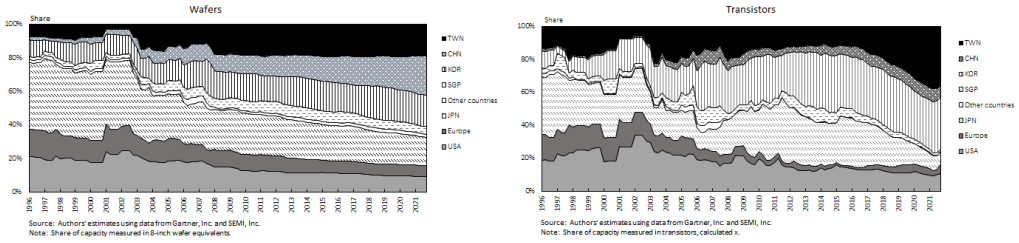
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Figure 6: Rare Earth Production



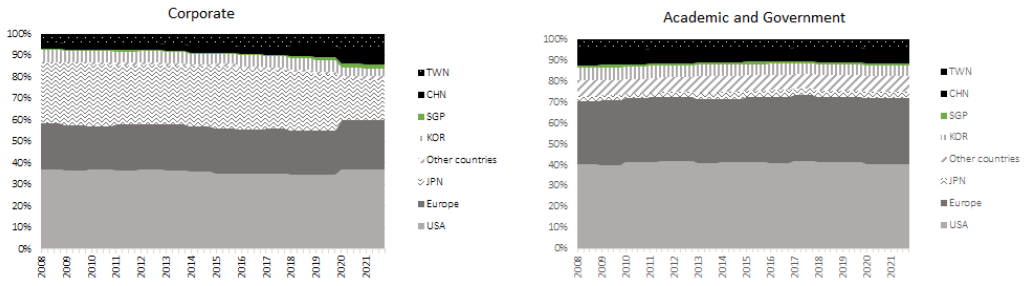
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Figure 7: Country market share, semiconductor wafer fabrication.



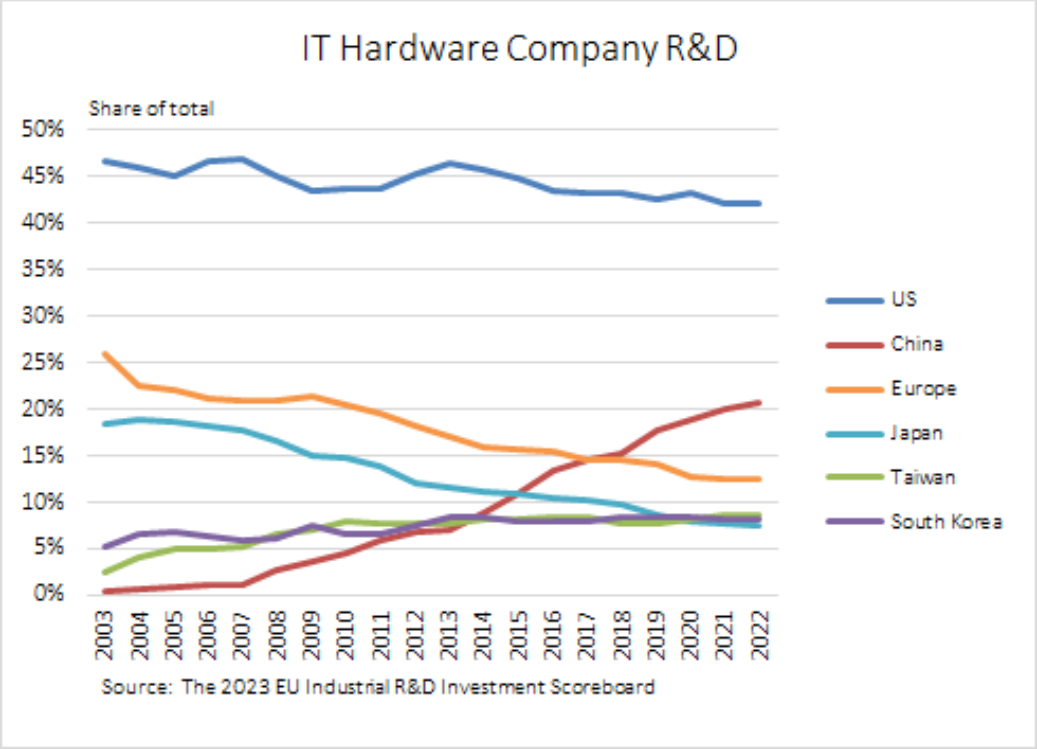
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Figure 8: R&D Semiconductor Fabs



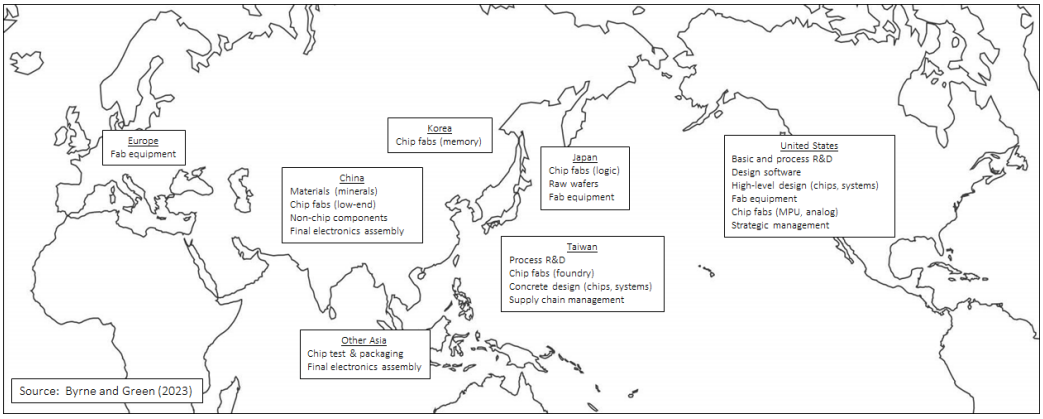
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Figure 9



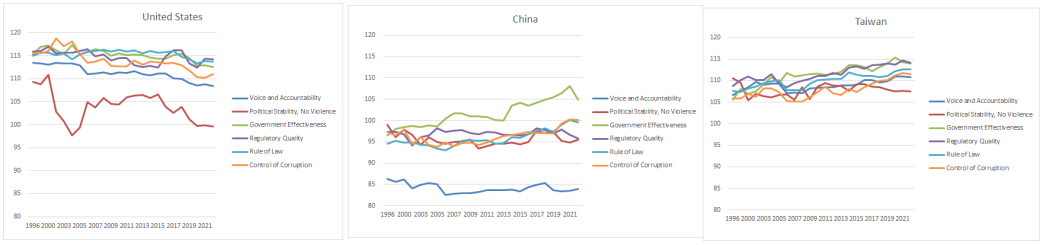
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Figure 10: Electronics Supply Chain Specialization by Country



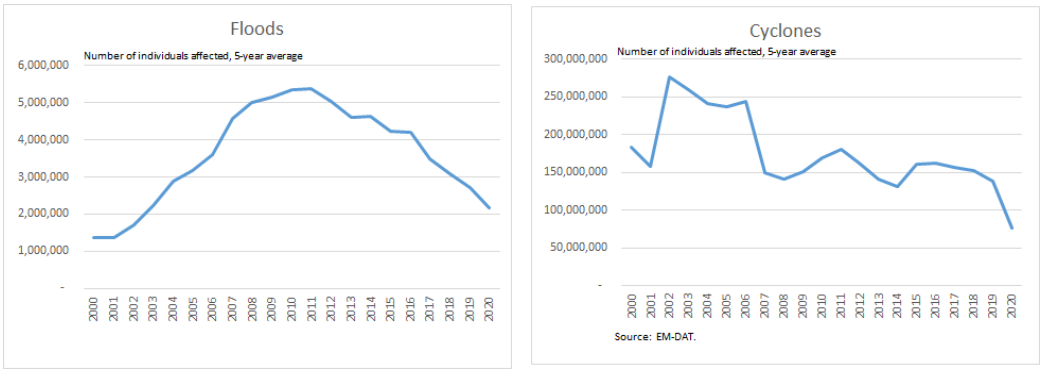
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Figure 11: World Governance Indicators: Selected Economies



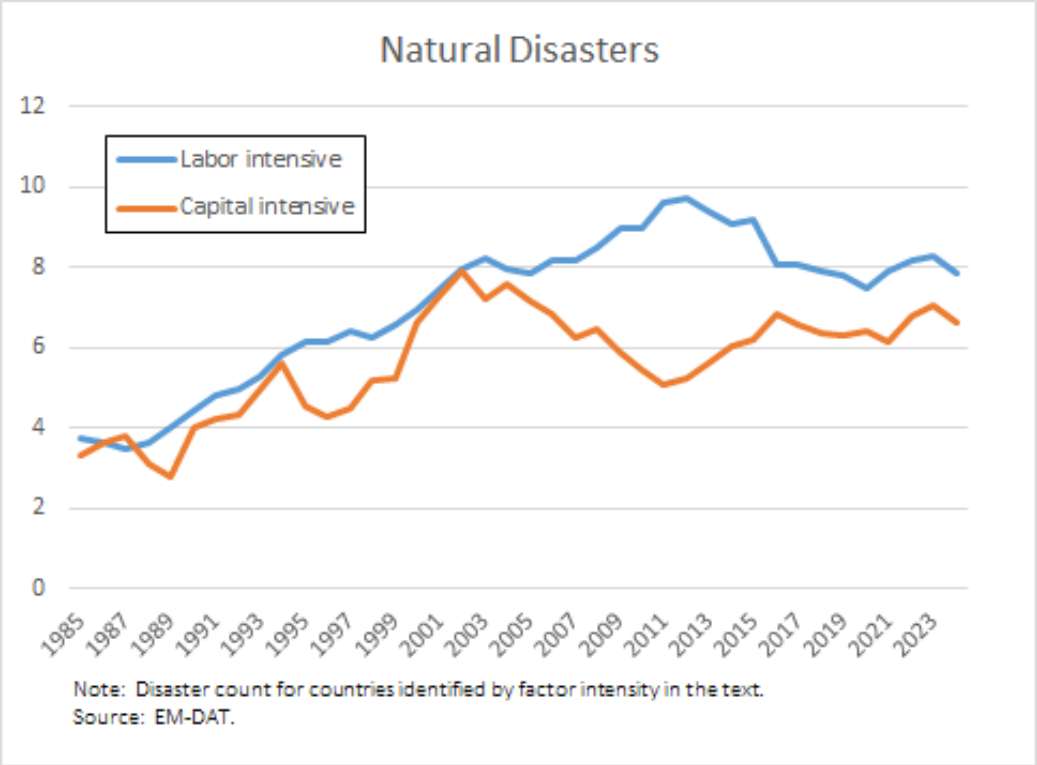
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Figure 12: Population Affected by Selected Natural Disasters



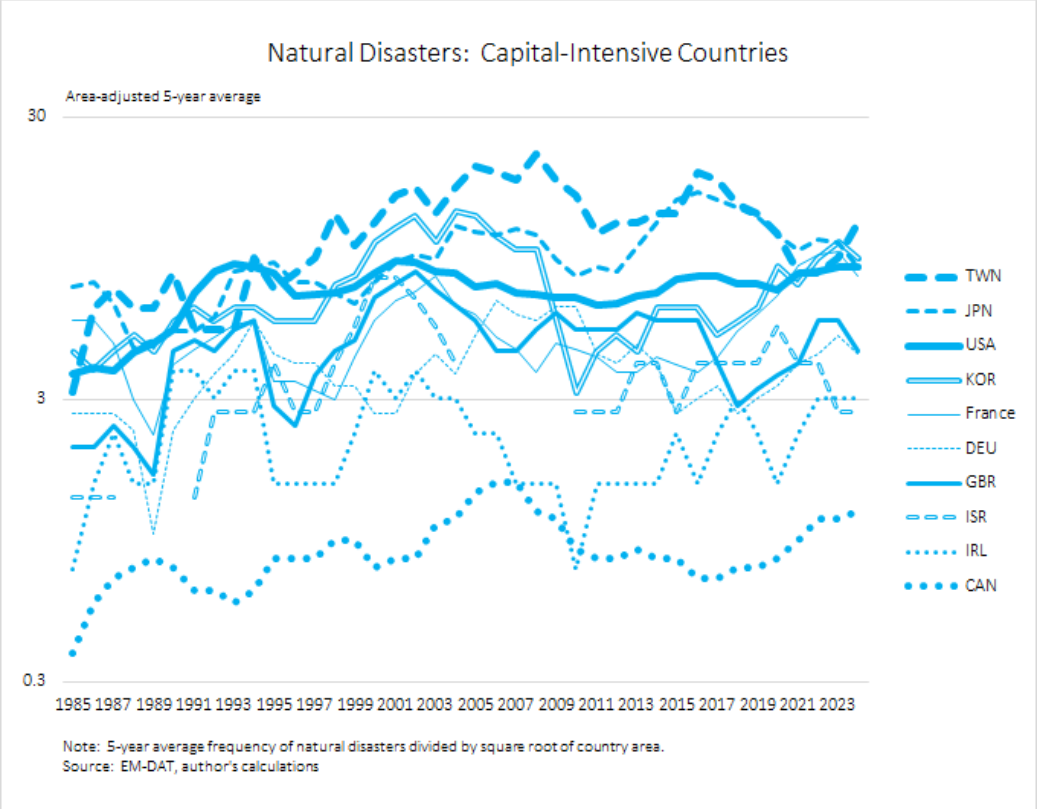
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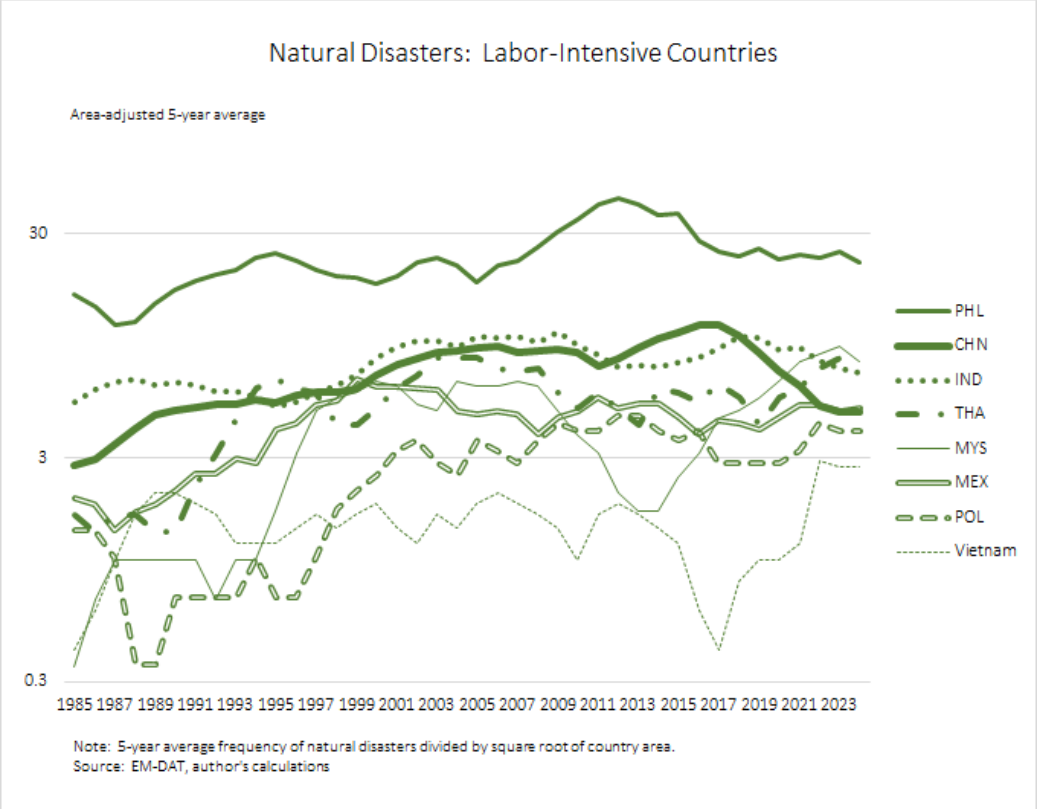
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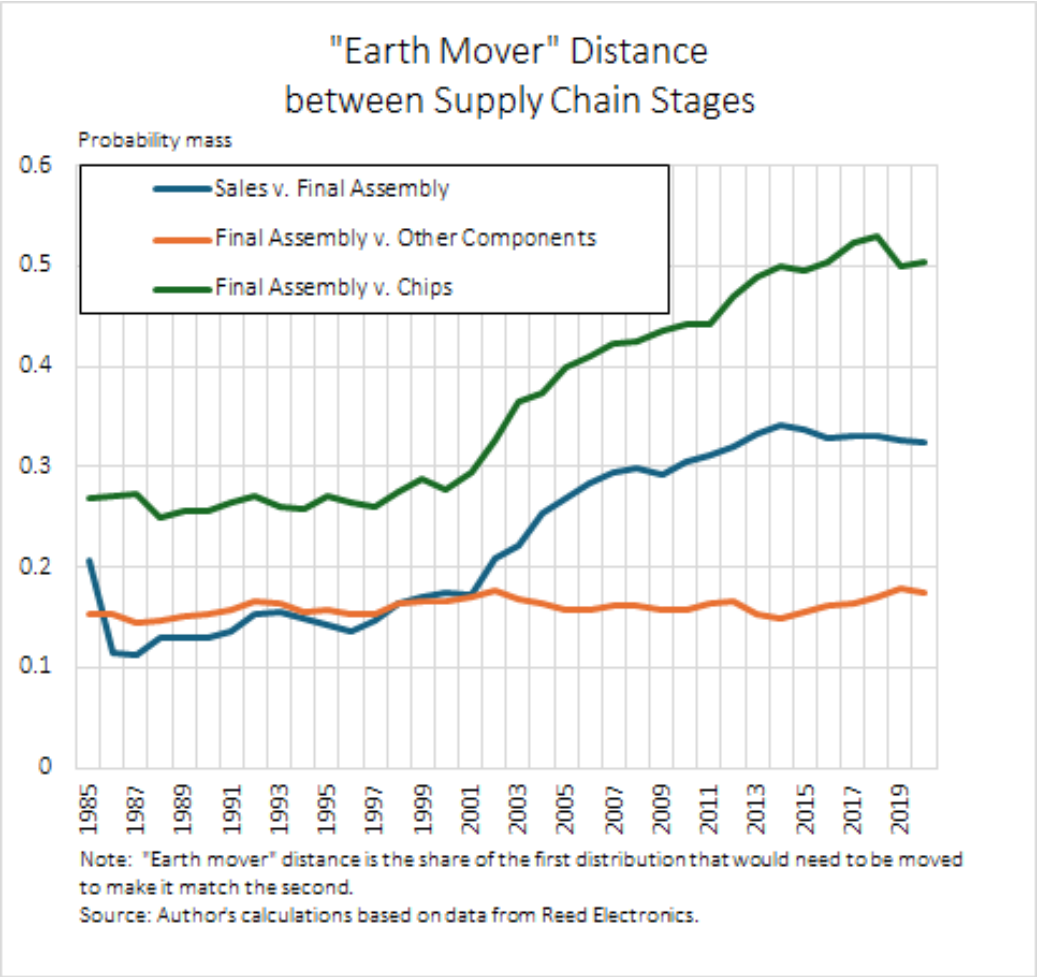
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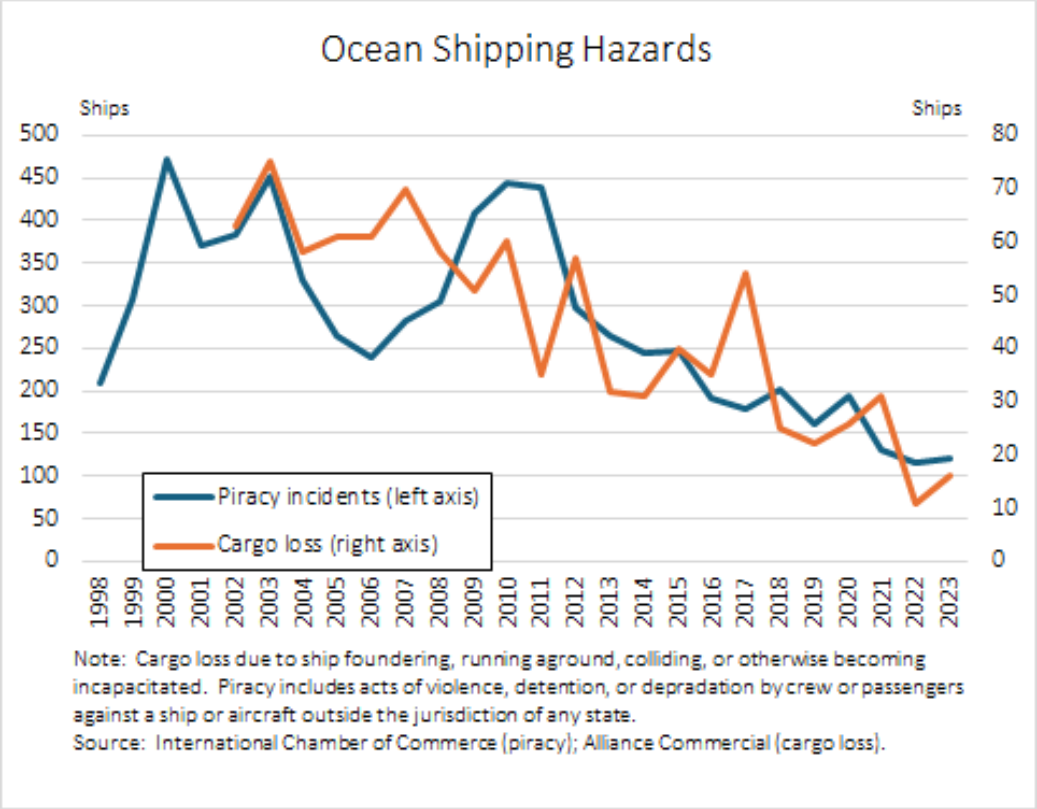
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Figure 16



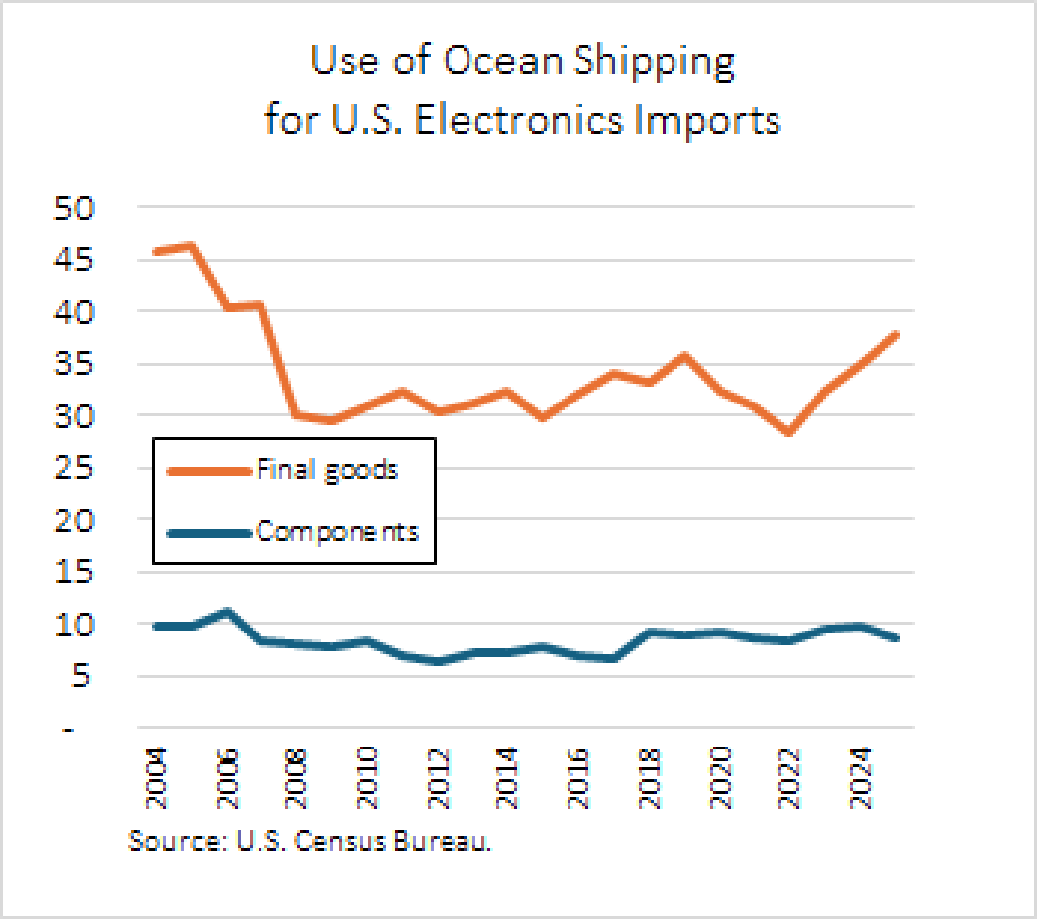
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Figure 18: Hold for caption



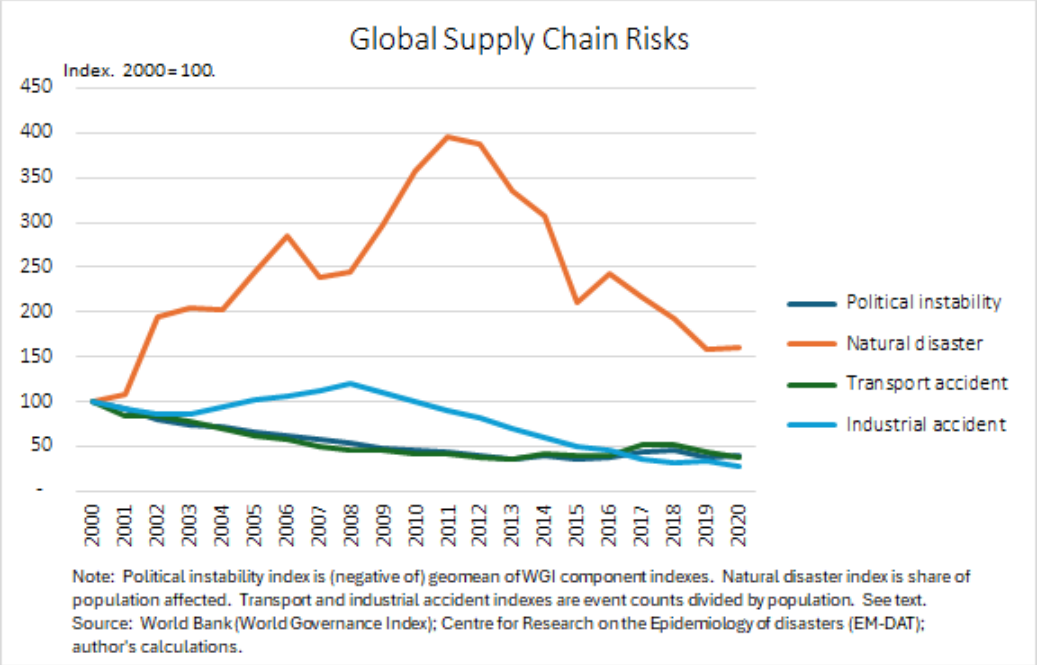
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Figure 19: Country Risk Aggregated by Import Share



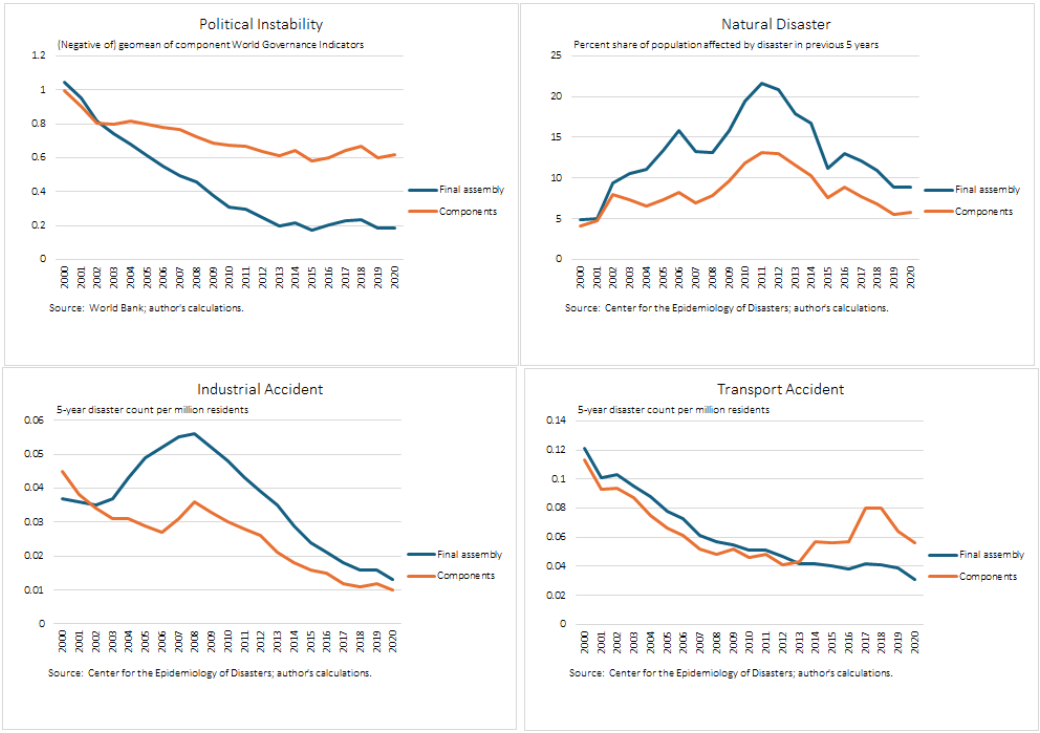
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Figure 20: Electronics Supply Chain Risk



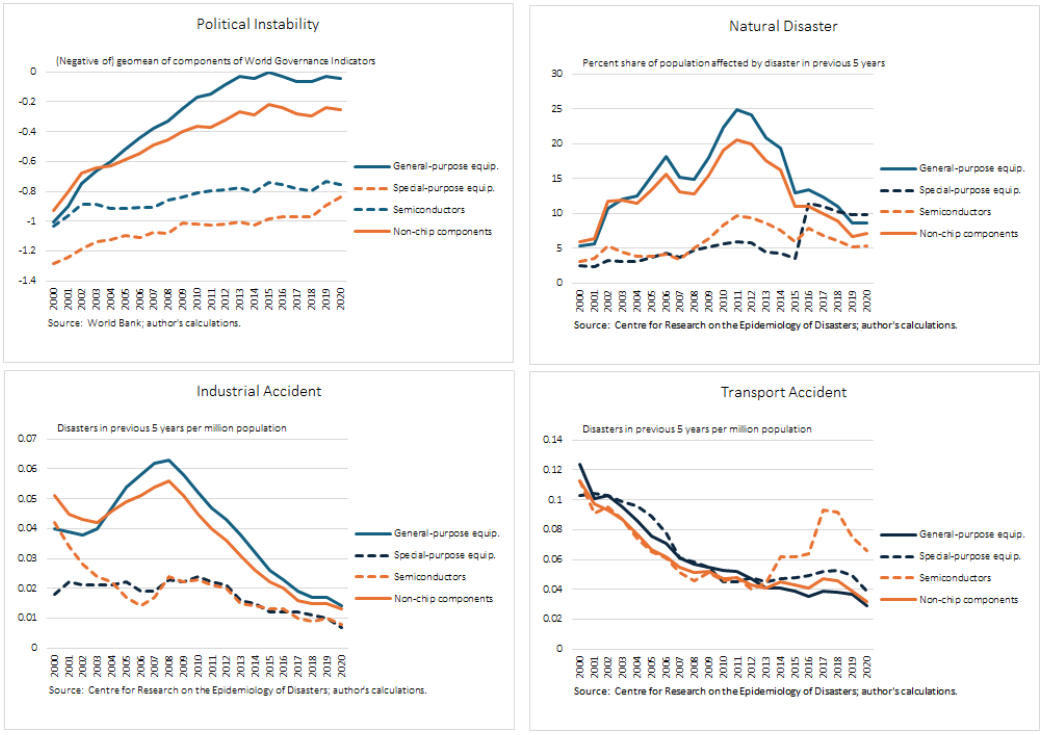
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Figure 21: Electronics Supply Chain Risk by Stage of Production



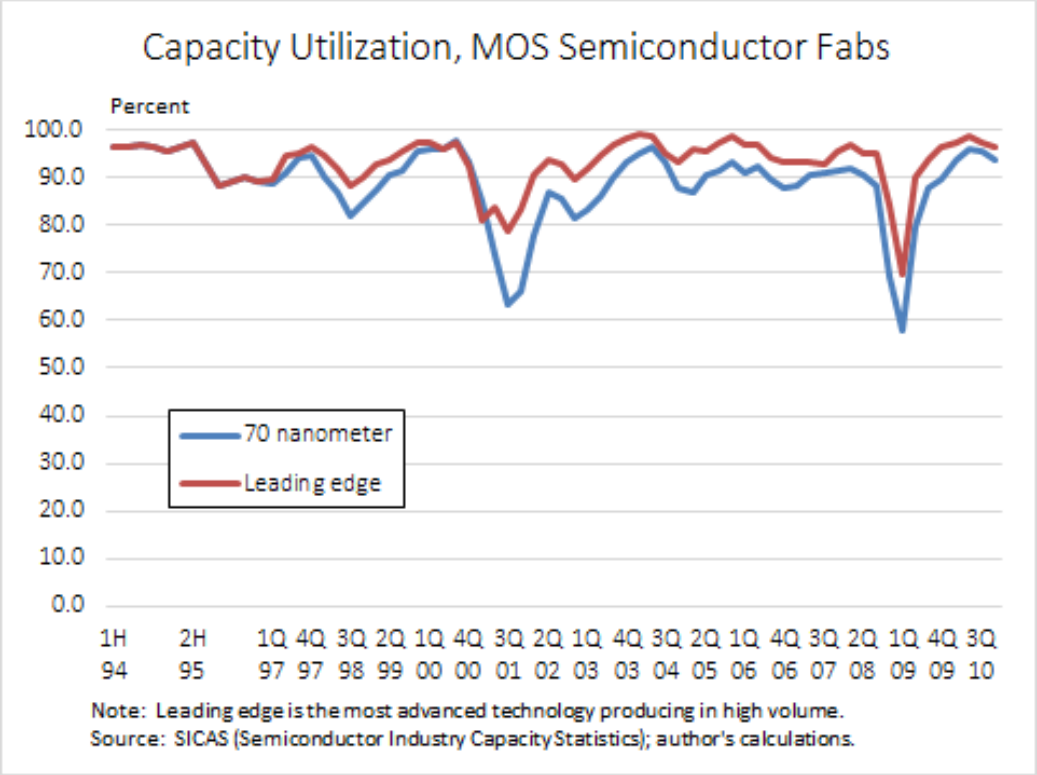
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Figure 22: Electronics Supply Chain Risk by Stage of Production grouped by Factor Intensity



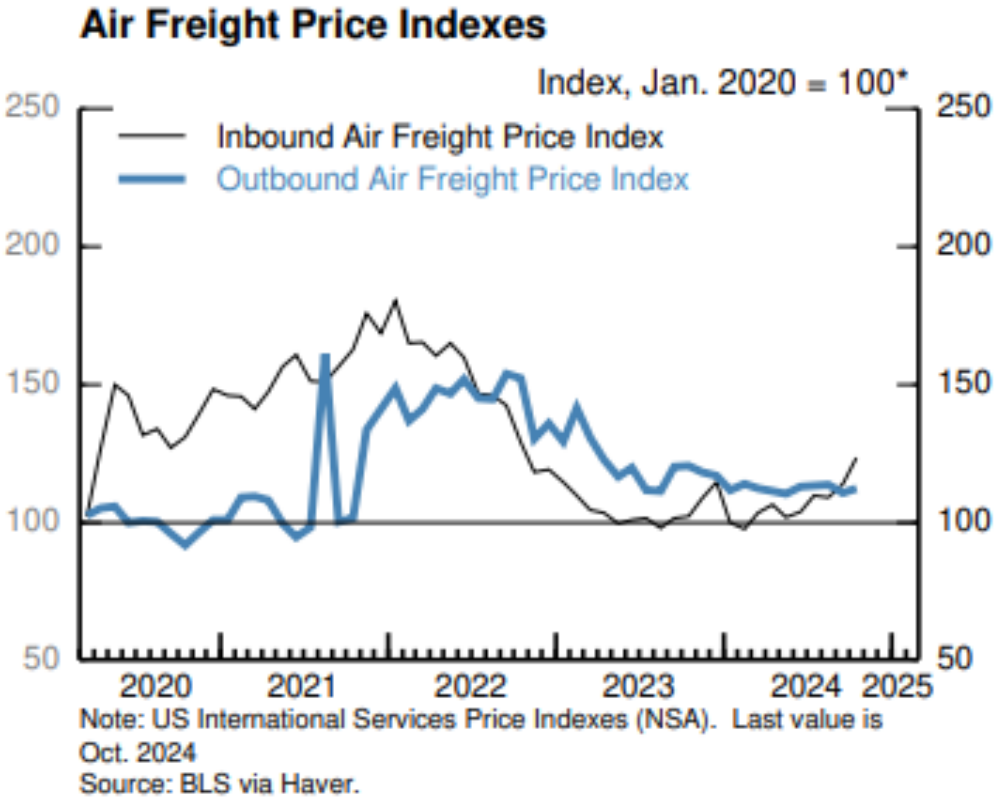
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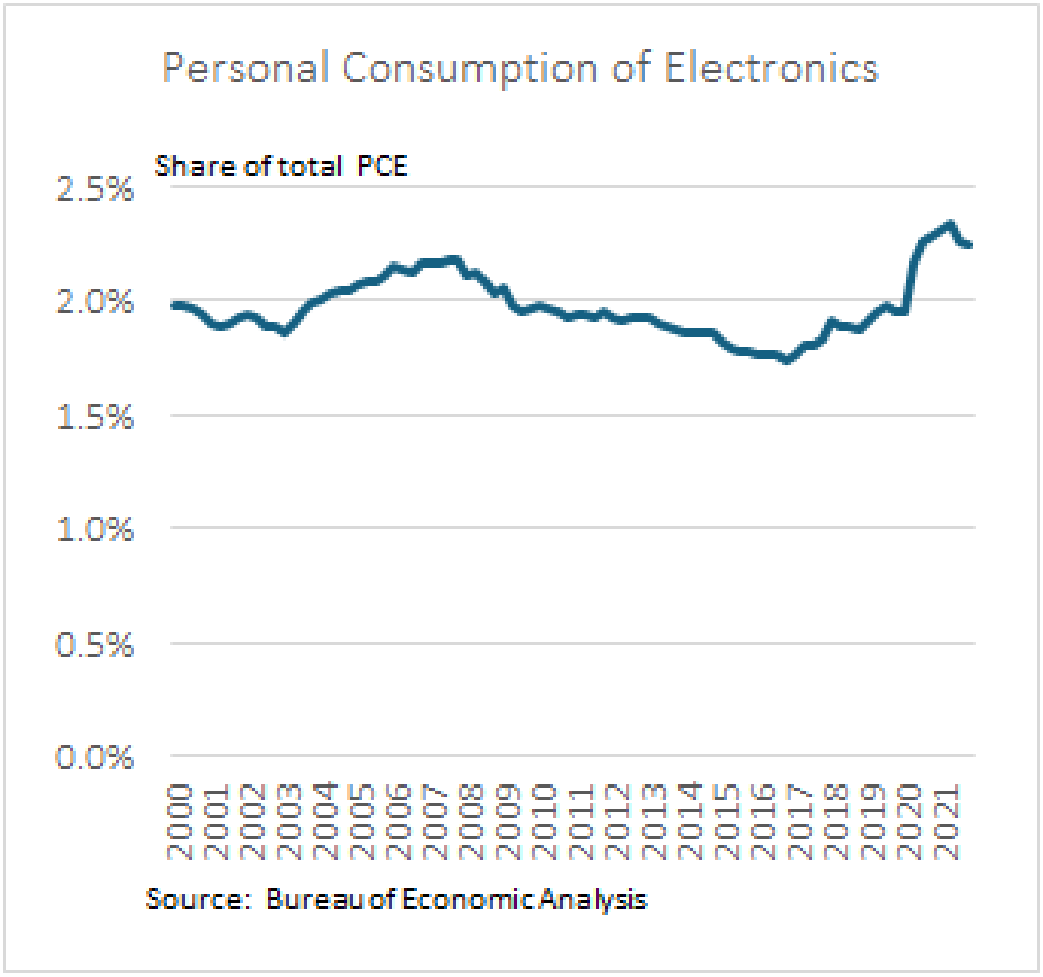
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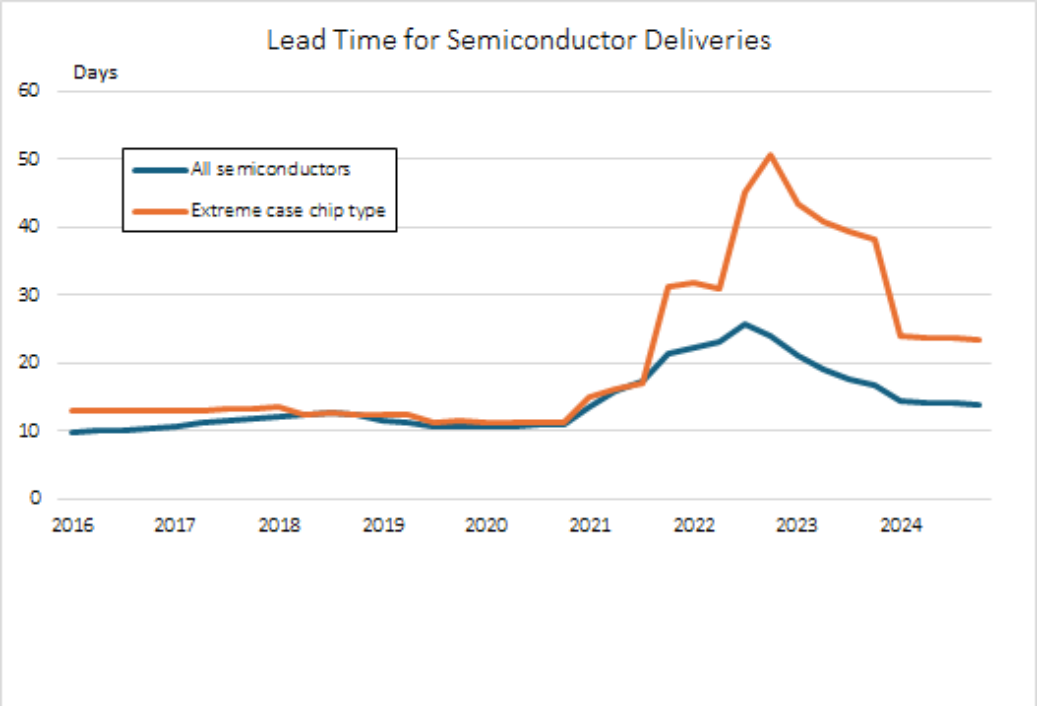
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Figure 25: Hold for caption



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Figure 26: Hold for caption



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Table 1: Selected Disruptions to the Electronics Sector

Year	Location	Type	Affected Activity
2024	N. Carolina	Flood	Quartz mining
2022–	Ukraine	War	Neon production
2020–2022	Global	Pandemic	Broad based
2011	Thailand	Flood	Hard drive production
2011	Japan	Earthquake, tsunami	Chip production
2008	China	Earthquake	Chip testing
1999	Taiwan	Earthquake	Chip production
1989	California	Earthquake	Power generation

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Table 2: Top Economies: Final Electronics Assembly

Economy	Peak	1985	1990	1995	2000	2005	2010	2015	2020
United States	48.4	**48.4**	30.7	28.4	29.3	20.3	15.5	14.5	14.8
China	44.7	0.0	1.5	2.7	6.4	22.1	34.2	44.6	**44.7**
Japan	27.1	19.6	**23.4**	22.1	15.9	10.6	8.7	4.2	4.3
Germany	7.6	6.0	**7.1**	5.4	4.4	5.3	3.7	3.4	3.1
South Korea	5.9	1.1	2.4	2.8	4.0	**5.4**	4.0	3.4	2.6
France	5.2	4.1	**5.0**	3.9	3.1	2.6	1.8	1.5	1.5
United Kingdom	5.0	4.5	**4.7**	4.3	**4.7**	2.7	1.5	1.5	1.2
Memo:									
Other countries	32.9	16.3	25.2	30.4	**32.2**	31.0	30.6	26.9	27.8
HHI	NA	**2,822**	1,635	1,426	1,276	1,130	1,571	2,286	2,305

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Table 3: Top Economies: Final Electronics Sales

Economy	Peak	1985	1990	1995	2000	2005	2010	2015	2020
United States	42.2	42.2	32.0	32.4	34.0	26.9	22.8	24.7	23.6
China	28.7	2.2	1.7	2.6	6.0	13.4	18.5	24.9	28.0
Japan	19.9	17.5	17.3	19.0	15.2	10.8	10.4	7.1	7.1
Germany	8.0	4.9	7.5	5.9	4.8	5.5	5.0	3.7	3.3
South Korea	3.1	0.9	2.0	2.9	3.1	3.1	3.0	2.9	2.8
France	5.2	3.6	5.2	3.9	3.0	3.0	2.5	1.9	1.7
United Kingdom	5.2	4.4	5.1	4.3	5.1	4.0	2.6	2.5	1.7
Memo:									
Other countries	37.3	24.2	29.2	29.0	28.8	33.4	35.2	32.3	31.8
HHI	2,301	2,107	1,557	1,532	1,527	1,126	1,068	1,353	1,459
Wasserstein	24.6	10.3	8.9	9.3	10.8	17.7	22.3	24.0	20.8

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Table 4: Top Economies: Chip Production

Economy	Peak	1985	1990	1995	2000	2005	2010	2015	2020
Japan	41.8	36.0	**37.4**	35.7	28.3	23.7	20.1	13.1	7.5
United States	35.6	**35.6**	25.6	24.7	25.5	16.8	12.9	11.9	10.1
South Korea	23.2	4.2	7.5	12.0	12.0	15.1	14.9	16.6	**18.8**
China	18.5	0.0	1.4	1.2	2.4	4.1	10.2	15.0	**18.4**
Taiwan	14.0	0.0	2.7	3.1	4.6	6.9	9.1	13.0	**14.0**
Singapore	12.5	2.7	3.7	4.7	5.9	7.8	10.3	9.3	**12.5**
Malaysia*	8.0	3.2	3.7	4.4	4.2	6.9	6.8	7.2	**7.4**
Germany	5.3	3.4	**4.2**	2.7	2.2	3.9	3.9	2.3	1.6
Memo:									
Other countries	17.7	**14.9**	13.8	11.5	**14.9**	14.8	11.8	11.6	9.8
HHI	NA	**2,636**	2,183	2,101	1,700	1,282	1,159	1,138	1,267

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Table 5: Top Economies: Other Component Production

Economy	Peak	1985	1990	1995	2000	2005	2010	2015	2020
China	48.7	0.0	2.3	4.3	8.4	22.5	34.1	46.4	**48.7**
United States	37.5	**37.5**	24.3	21.5	21.2	12.1	8.8	8.1	7.8
Japan	36.1	**31.5**	30.2	29.4	24.2	18.6	17.3	10.3	11.0
Germany	9.1	7.2	**9.1**	6.4	4.6	5.7	4.8	4.0	3.6
South Korea	5.3	2.2	4.4	**5.0**	4.3	4.7	4.4	4.2	3.8
Taiwan	5.1	0.0	3.7	4.4	**5.1**	3.9	4.0	3.9	3.7
Memo:									
Other countries	34.3	21.3	26.0	29.0	32.2	**32.5**	26.6	23.1	21.4
HHI	NA	2,500	1,670	1,481	1,228	1,126	1,636	2,402	**2,619**

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Table 6: Silicon Wafer Manufacturing Companies

Company	Headquarters	Plant Locations
Globalwafers	Taiwan	Italy, Japan, Malaysia, South Korea, Taiwan, United States
Shin-Etsu	Japan	Japan, Malaysia, Taiwan, United Kingdom, United States
Siltronic	Germany	Germany, Singapore, United States
SK Siltron	South Korea	United States
SUMCO	Japan	Indonesia, Japan, Taiwan, United States

Note: Wafer manufacturing locations only.
Source: Company websites.

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Table 7: Semiconductor Equipment Manufacturing Locations

Equipment type	Headquarters of major manufacturers
Wafer manufacturing	
Single crystal growth furnace	United States, United Kingdom
Ingot grinding	United States
Wafer slicing	United States, Germany
Wafer etching	China, Japan
Polishing	Japan, United States
Cleaning	Germany, Japan, United States
Semiconductor manufacturing	
Lithography	Japan, Netherlands, United States
Deposition	Holland, Japan, United States
Dry Etching	United States
Sputtering	France, United States
Dicing	Israel, Japan
Inspection	Israel, United States

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Table 8: Headquarters for Non-Chip Electronic Component Manufacturing Companies

Component	Headquarters of Selected Manufactuers
Printed Circuit Boards	Mainland China, Taiwan, United States
Screens	Mainland China, South Korea
Batteries	Mainland China, South Kores
Casings	Mainland China, United States
Microphones, speakers	Mainland China, United States
Cameras	Japan, United States

Table 9: Caption

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Table 10: Key Economies in the Electronics Sector, 1985-2020

Economy	Description
United States	Mid–1980s: 50% of final assembly, 35% of chips and other components; 15% of assembly and 10% of chips in 2020.
Japan	Mid–1980s: 40% of chips, 25% of assembly; falls to 5–10% of sector by 2020.
China	Mid–1980s: minor player; beginning in 2000, surges to 45% of final assembly and non-chip components by 2014; then levels off; 18% of chips in 2020, still rising.
South Korea	Mid–1980s: minor player; chip share climbs to 20% by 2020.
Taiwan	Mid–1980s: minor player; chip share surges after 2000 to 13%.
Malaysia	Mid–1980s: 3% of chips (testing & assembly), 1% of assembly; climbs to 7% of chip shipments by 2020.
Singapore	Rising second–tier chip fab location (12% in 2020); minor share of assembly.
France	Mid–1980s: 5% of final assembly, 3% of chips; falls steadily to 1–2% by 2020.
Germany	Mid–1980s: roughly 7% of sector; falls to 3% by 2020.
United Kingdom	Roughly 5% of final assembly through 2000, then falls to 1% by 2020; minor player in components.

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Table 11: Governance Index
1996-2023 Average

Low-Wage Countries	
Economy	Mean
Singapore	1.48
Malaysia	0.33
Thailand	-0.14
Mexico	-0.22
India	-0.24
The Philippines	-0.38
Vietnam	-0.49
Mainland China	-0.51
High-Wage Countries	
Economy	Mean
Canada	1.59
United States	1.25
Japan	1.21
Europe	1.19
Israel	1.08
Taiwan	0.94
South Korea	0.72

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Table 12: Natural Disaster Prevalence, 2000-2023
Share of Population Affected Annually

Economy	Mean	Median
United States	1.44	0.06
Mainland China	5.69	4.16
The Philippines	7.78	6.28
Thailand	4.98	1.64
India	3.91	1.29
Vietnam	2.02	1.74
Mexico	0.57	0.14
Malaysia	0.47	0.07
Singapore	0.01	0.00
Israel	1.08	0.00
Taiwan	0.55	0.00
Japan	0.18	0.08
Australia	0.13	0.04
South Korea	0.07	0.02
Europe	0.06	0.03
Canada	0.05	0.02