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CLIMATE RISKS TO GLOBAL SUPPLY CHAINS

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Extreme weather events are increasing in both intensity and frequency as climate change progresses. Understanding their impacts on the world economy thus takes on increased importance.

While most extreme weather events are localised, their economic impacts reverberate through global supply chains (GSCs). The importance of this is widely recognised, but the potential scale of economic risks to GSCs from such 'fast onset' events is still poorly understood. In this paper we look at how past extreme weather events affected supply chains, and how the public and private sectors should prepare for and try to mitigate future shocks.

We examine three distinct forms of disruption: lower manufacturing production due to natural disasters; reduced agricultural yields caused by floods and drought conditions; and damage to infrastructure and disruption of trade routes by climate conditions.
In recent history, such events have had measurable effects, though limited by the diversified nature of global supply chains. Extreme events, such as the 2011 Thai floods or the 2022 drought affecting the Panama Canal, had measurable macroeconomic effects but remained short lived. As such events become more frequent and intense, the impact will become significantly larger and mitigation measures more important.

To prepare for the future, businesses need to invest not only in a better understanding of the risks to their supply chains, but also in mitigation measures. For governments, it will become increasingly important to set the right incentives for companies to mitigate their risks. At the international level, as the example of the 2007-2008 global rice crisis showed, uncoordinated policy responses can strongly exacerbate the effect of otherwise manageable climate-related production shortfalls. This highlights the need for globally coordinated policies.

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1 Introduction

As global temperatures rise, climate-related extreme weather events are expected to become increasingly frequent (IPCC, 2023). So too will the economic shocks emanating from them. These shocks are not confined to the regions where physical damage occurs, nor are they limited to sectors that are directly dependent on meteorological or climatic conditions[1]. In an interconnected global economy, trade is a key channel through which the effects of climate hazards are transmitted across borders and sectors.

Global supply chains (GSCs), which span multiple countries with varying levels of climate vulnerability, act as conduits for these shocks. Climate hazards such as floods, droughts, heatwaves and wildfires, which disrupt one part of the chain, can also trigger cascading effects well beyond the immediately affected area. As a result, countries with relatively low direct exposure to climate hazards can nonetheless experience significant economic disruptions owing to their dependence on more exposed suppliers. Indeed, Li and Lenzen (2025) estimate that indirect climate losses passed through supply chains can be up to five times larger than the direct damages.

This vulnerability is compounded by the fact that financial protection is inadequate: Zurich Insurance Group (2025) estimates that extreme weather caused $2 trillion in economic losses over the past decade, with only 38 percent of these losses insured in 2023, reflecting a persistent global protection gap[2]. Furthermore, the nature and scale of the risks for global supply chains arising from climate change are far from fully understood. In this paper, we walk through the main ways in which climate-related weather events can disrupt supply chains.

Countries can be affected by climate hazards in two distinct ways: directly, when the impact occurs within their own borders; or indirectly, when the repercussions are transmitted through trade and GSCs[3]. In the case of direct impacts, climate shocks typically disrupt production capacity, by either damaging infrastructure, interrupting operations or reducing labour availability. These disruptions can propagate downstream to other firms that depend on the affected producers and may also depress

[1] In line with the most current climate risk concept of the Intergovernmental Panel on Climate Change (IPCC 2023), we refer to "climate risks" as potential adverse consequences for human or ecological systems from climate change that results from interactions between hazards, exposure and vulnerability. For example, the interaction between a climate-related hazard (e.g. the frequency and intensity of droughts) with exposure (e.g. agriculture land) and vulnerability (e.g. drought resistance of crops, presence or absence of irrigation) of natural and human systems results in the climate risk of damage to agricultural production from drought.
[2] 'Climate risks: Strategies for building resilience in a more volatile world', Zurich Insurance Group, 29 April 2025, https://www.zurich.com/knowledge/topics/climate-change/strategies-for-building-resilience-in-a-more-volatile-world. Monasterolo *et al* (2025) highlighted the persistence of this climate insurance protection gap and outlined a research agenda to better understand its drivers and policy responses.
[3] It is worth noting that some studies, such as Costa and Hooley (2025), measure only spillovers arising from geographical proximity, finding that severe disasters can reduce nearby regions' GDP by over two percent and cause an additional 0.5 percent loss within 100km, even without accounting for the wider transmission of shocks through trade and GSCs.

domestic demand if households are directly harmed (Fahr *et al*, 2024). However, in this analysis we focus on how supply-side disruptions can ripple through GSCs.

While recent events have produced economic impacts that remain somewhat contained, the trajectory is shifting. As climate change progresses, hazards are projected to become both more frequent and more intense, raising the probability of simultaneous disruptions in multiple regions (IPCC, 2023). The warmest year on record was 2024, and there is a 70 percent chance that the average temperature over the next five years will exceed the 1.5 degrees Celsius threshold (WMO, 2025) that the scientific consensus considers to be the maximum sustainable increase without major disruption. The impacts on the economy are hard to calculate but every additional 0.1°C of global warming causes clearly discernible increases in the intensity and frequency of temperature and precipitation extremes, as well as agricultural and ecological droughts (IPCC, 2021). The Network for Greening the Financial System (NGFS, 2022) noted that a global temperature increase of 2°C above pre-industrial levels will lead to heightened exposure to all major hazard types, with the most significant increases expected for droughts and heatwaves.

Consequently, the world is already on a path to more widespread and systemic impacts, and the shift from localised shocks to global consequences is inevitable. Reducing greenhouse gas emissions and maintaining natural carbon sinks are the most cost-efficient way to reduce the cost of climate hazards by limiting their frequency, but climate adaptation will play an increasingly important role.

The European Central Bank (Fahr *et al*, 2024) has identified global trade and supply chains as key transmission channels of systemic risk, as they can significantly amplify the economic losses caused by physical climate hazards[4]. These effects typically occur through two main channels: direct disruptions to production, and impacts on water, energy, logistics and transport. We will consider these two channels before investigating the costs of disruption and the role of policy in responding to climate impacts on supply chains.

2 Types of climate impacts on global supply chains

The gradual shift in the climate will lead to changes in industrial production and force industries to adapt to new climate conditions. If not mitigated, higher average temperatures can decrease labour productivity (ILO, 2019) as workers will suffer greater fatigue, heat and air quality-related illnesses, and psychological harm[5]. Higher temperatures also increase the requirements for industrial cooling processes (Carlin *et al,* 2023). However, the most direct impact of climate change on GSCs occurs when weather events disrupt the production of goods and services. Oxera (2024) estimated that economic losses from such events already amount to around $200 billion annually, both due to physical destruction of buildings and infrastructure but also related deaths, which account for five percent of this economic loss. Swiss Re estimates that, in 2024 alone, total economic losses reached

[4] Fahr *et al* (2024) also noted that trade can mitigate losses when substitution across sectors is possible.
[5] Madeleine North '3 ways the climate crisis is impacting jobs and workers', *World Economic Forum*, 19 October 2023, https://www.weforum.org/stories/2023/10/climate-crisis-impacting-jobs-workforce/.

$328 billion, of which $318 billion were from natural catastrophes and $10 billion from man-made disasters (Swiss Re Institute, 2025). Extreme weather events can physically disrupt production through capital and infrastructure destruction, but events such as droughts and floods also directly affect the availability of water as a production resource. The first is an example of a fast onset climate impact, while the second can also have slow onset climate impacts by progressively increasing water stress over time.

2.1 Disruptions to manufacturing production

The 2011 floods in Thailand, the most severe in over 70 years, illustrate how climate-related disruptions can affect GSCs. Heavy rain combined with tropical storms led to widescale flooding in the north of the country and caused loss and damage amounting to $46.5 billion (World Bank 2012), equivalent to 12.5 percent of Thailand's GDP. Manufacturing was the hardest-hit sector of the Thai economy, as the flooded regions were home to the country's main production centres. According to the World Bank (2012), 70 percent of the total damage occurred in this sector. Automotive and electronic components were the most affected subsectors, with production indices falling by 87.5 percent and 65 percent respectively, and significant declines in exports (Chongvilaivan, 2012).

The disruption was felt not only in the Thai economy, but throughout supply chains. Honda Motors experienced shortages in auto parts that forced production cuts across the globe, from the Philippines to the United Kingdom (Chongvilaivan, 2012). Toyota had to cut production by approximately 240,000 vehicles in 2012 because of the supply disruptions caused by the floods (Toyota, 2012).

Nevertheless, the overall impact on global car manufacturing was limited, despite the severity of the floods and the disruptions experienced by individual firms and production lines. In fact, global car production rose in 2011 by 2.8 percent to 59.8 million units[6], suggesting that the shock was either not large enough to affect global output significantly, or was effectively absorbed by the industry's capacity to adapt. The reasons behind the limited effect on global car manufacturing may include the scale of total global production and the high degree of diversification across supply chains, allowing diversion to sources of supply that were not affected by these floods. In Thailand itself, the flooded regions were able to recover and rebuild production because floods did not recur in subsequent years.

The question then arises of whether this capacity to adapt and recover will remain high enough in GSCs as future climate impacts increase in intensity and frequency. If there are multiple climate hazards in many regions at the same time, at what point will a supply chain be critically affected globally? As climate hazards become more frequent and intense, how fast will the resilience of regions and industries be eroded over time?

Even without large-scale physical destruction, extreme weather events can interrupt production through their effects on water availability. Industries such as steel manufacturing, chemical industries,

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[6] International Organization of Motor Vehicle Manufacturers, production statistics, https://www.oica.net/production-statistics/.

data centres and semiconductor manufacturing rely on large amounts of fresh water either for cooling or directly in production processes. Droughts lead to water shortages that can disrupt production, particularly in geographically concentrated industries that depend on local water supplies.

An example is the semiconductor industry, particularly wafer manufacturing, as it requires large amounts of highly purified water as part of the production process. Over 60 percent of semiconductors globally are produced in Taiwan, including almost 90 percent of cutting-edge chips (Global Taiwan Institute, 2025). Even though Taiwan is considered to be at low to moderate risk of water scarcity (ThinkHazard!, 2020)[7], a water shortage could disrupt this vital supply chain. This risk became evident during the 2020–2021 drought, which followed a year with no typhoon landfalls – a rare occurrence for Taiwan, where typhoons are a major source of rainfall. As a result, the island experienced its worst drought in 56 years, with reservoir levels falling below five percent capacity, a record low[8]. To manage the crisis, local authorities imposed water rationing on businesses and households. In this case, the semiconductor industry, because of its strategic and economic importance, was given priority access to water and thus production was not affected. Nevertheless, the episode highlighted the vulnerability of critical infrastructure to water scarcity, and the broader risks posed to industrial production if adaptation measures are not in place.

2.2 Reduced agricultural yields

While in the manufacturing sector extreme weather events are most concerning, Araujo *et al* (2025) show that agriculture can be even more vulnerable to the transmission of physical shocks through supply chains. Moreover, for agriculture, even gradual changes in climate have first-order effects. Changing climate conditions require adaptation of the crops grown and of farming methods, while the total productive agricultural land is expected to shrink in the long-term (Hannam *et al*, 2025). Low precipitation can reduce agricultural yields and drought conditions can lead to bad harvests. People living in areas which have aquifers and other water reservoirs to draw on in the short term are increasingly facing a long-term supply issue as their reserves dry up and water tables fall (Walsh *et al*, 2020).

On the other hand, increases in precipitation can also be deeply destructive: precipitation outside of the growing season creates water management problems and soil and nutrient loss, leading to production loss (Walsh *et al*, 2020). Overall, the changing climate leads to degraded soil conditions and drives changes in insect and weed ranges, sometimes increasing the range of and destruction by pests. At the same time, it can lead to a decrease in the population of helpful species such as pollinators (Akca *et al*, 2024). The Augures! project (Climate Strategies, 2025) recognises agriculture as the sector most vulnerable to weather variability, emphasising both the uneven impacts across

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[7] See also Tianyi Luo, Robert Samuel Young and Paul Reig, 'Aqueduct Projected Water Stress Country Rankings', World Resources Institute, 26 August 2015, https://www.wri.org/data/aqueduct-projected-water-stress-country-rankings.
[8] UNU-EHS, 'Taiwan drought', United Nations University – Institute for Environment and Human Security, undated, https://interconnectedrisks.org/2022/disasters/taiwan-drought.

different crops and the heightened vulnerability of small-scale farmers with limited resources for resilience.

These challenges have a direct impact on trade in agricultural commodities, but also on the industries downstream of that sector. Kotz *et al* (2025) compiled recent food price spikes driven by extreme climate events. Examples include the 2023 droughts in Brazil impacting coffee prices in August 2024, the 2024 heatwave in Ghana and Ivory Coast affecting cocoa prices in April 2024, and droughts in Indonesia and the heatwaves in Japan raising local rice prices[9]. So far, however, such episodes have not translated into large-scale or long-lasting global economic disruption. Most climate impacts have been geographically localised or short lived. For instance, such climate-related price spikes are typically not reflected in global commodity price indices. However, impacts are expected to intensify as climate change advances, driven by both fast-onset events such as extreme weather events and by slower onset effects such as chronic water stress from declining supply over a longer period.

2.3 Impacts on infrastructure and trade routes: water, energy, logistics and transport

Beyond impacts on production, climate change also increases weather-related risks for the logistical routes via which commodities and goods are traded. These systems are exposed to similar climate-related hazards as the production system, which can significantly disrupt operations. Disruption to trade logistics typically comes in two forms: damage to critical infrastructure such as ports, roads, railways and storage facilities; and interruptions to transport routes, including inland waterways, maritime corridors and overland pathways essential for the movement of goods.

Waterways represent a critical transportation channel in global trade, with approximately 90 percent of traded goods transported via maritime routes[10]. However, these routes are increasingly vulnerable to climate-induced disruption – particularly droughts, which lower water levels and render key channels impassable for large vessels. In 2023, for instance, traffic through the Panama Canal was severely constrained owing to insufficient rainfall in the area feeding the Gatun Lake, one of the primary water sources sustaining the canal. As a result, authorities were forced to restrict vessel transits and impose cargo limitations[11]. In the last quarter of 2023, cargo volumes transiting the canal were 10 percent lower than in the same period of 2022 (Bureau of Trade Statistics, 2024). To compensate, some traffic was rerouted through alternatives such as the Suez Canal[12], but alternative options involve longer transit times and higher costs.

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[9] In the case of Japan, import restrictions also played a major role in the rice price spike (USDA 2024). This point is discussed further below.

[10] Ewan Thomson, 'Droughts are creating new supply chain problems. This is what you need to know', *World Economic Forum*, 25 October 2023, https://www.weforum.org/stories/2023/10/drought-trade-rivers-supply-chain/.

[11] US Bureau of Transportation Statistics, 'U.S. Trade and the Impact of Low Water Levels in Gatun Lake and the Panama Canal', 2 December 2024, https://www.bts.gov/data-spotlight/us-trade-and-impact-low-water-levels-gatun-lake-and-panama-canal.

[12] Greg Miller, 'Panama Canal crisis forces US farm exports to detour through Suez', *FreightWaves*, 9 November 2023, https://www.freightwaves.com/news/panama-canal-crisis-forces-us-farm-exports-to-detour-through-suez.

The effect of longer or disrupted transit routes is not only longer waiting times for customers, but also reduced cargo capacity, as ships can make fewer trips in the same period. Longer shipping routes thus directly translated into higher transport costs, which together with the decrease in supply that reaches import destinations can lead to higher prices. This is what happened in 2023. The disruption of the Panama Canal occurred at the same time as piracy blocked traffic through the Red Sea, leading to a spike in shipping costs and inflation. J.P.Morgan has estimated that these combined disruptions added about 0.7 percentage points to global core goods inflation, and approximately 0.3 percentage points to overall core inflation[13], representing a significant macroeconomic impact.

Droughts can have similar effects for inland shipping when rivers or channels become non-navigable owing to low water levels. In the EU, inland waterways made up approximately 1.6 percent of total freight transport performance in 2023[14]. While inland shipping via rivers and channels is primarily a domestic transport route, it plays an important role in connecting industries with deep water harbours and thus world markets. This is especially significant for the bulk cargo trade, particularly fossil fuels for power and chemical plants located near rivers. In Germany, the Rhine River is a key artery for transporting coal, oil products and industrial materials such as chemicals to and from major industrial hubs[15]. Similarly, in the United States, the Mississippi River is a key route for transporting agricultural products along with petroleum products, coal and other bulk commodities[16]. Both have experienced major drought-related disruptions in recent years.

Traffic disruption during summer months has become a frequent occurrence on the Rhine River. The Rhine basin supports the largest volume of freight transport among European river systems. In 2022, it carried 292 million tons of cargo, with a total transport performance of 49 billion tons-kilometres, representing 40 percent of all EU inland waterway freight movement (Niu *et al*, 2024). The river flows from Basel to the North Sea, passing through key industrial economies including Switzerland, France, Germany and the Netherlands. In recent years, droughts have led to water levels that are too low for shipping. During the 2022 energy crisis, this created additional strain as coal shipments needed for power generation could not reach plants, worsening supply challenges[17]. However, while disruptive for individual firms and sectors, the aggregate economic impact of these disruptions thus far remains small. Meuchelböck (2025) showed that that droughts on the Rhine reduced the export performance of firms whose inputs were affected. Similarly, Ademmer *et al* (2020) estimated that 30 consecutive days of low water levels in the Rhine can lead to a one percentage point decrease in industrial

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[13] J.P.Morgan, 'What are the impacts of the Red Sea shipping crisis?' 8 February 2024, https://www.jpmorgan.com/insights/global-research/supply-chain/red-sea-shipping.
[14] Eurostat, 'Freight transport statistics – modal split', https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Freight_transport_statistics_-_modal_split.
[15] Will Hares and Patricio Alvarez, 'Critical Rhine level risks commodities, costs', *Bloomberg*, 19 August 2022, https://www.bloomberg.com/professional/insights/trading/critical-rhine-level-risks-key-commodities-costs/.
[16] US Bureau of Transportation Statistics, 'Mississippi River and waterborne freight', 19 May 2021, https://www.bts.gov/modes/maritime-and-inland-waterways/mississippi-river-and-waterborne-freight.
[17] Todd Gillespie and Jack Wittels, 'Low Rhine water levels risk worsening Europe's energy crunch', *Bloomberg*, 8 July 2022, https://www.bloomberg.com/news/articles/2022-07-08/low-rhine-water-levels-risk-worsening-europe-s-energy-crunch.

production in Germany. Therefore, the effect is measurable and occurs on average once a year, even if on a small scale so far.

A similar picture emerges in the United States, where low water levels on the Mississippi River in 2022 forced barges to lighten their loads and were estimated to have caused around $20 billion in lost trade[18]. With the expected increase in frequency of droughts, the economic effects in these economies are likely to intensify.

Droughts can also have disruptive effects on supply chains by disrupting power generation. Electricity generation in nuclear and fossil-fuel power plants relies on water as a medium to transfer thermal power into electricity via turbines and for cooling. Hydropower stations can only operate when their water reservoirs are sufficiently full. Drought conditions are already leading to water supplies that are too low to generate electricity through hydropower. For instance, in 2022, hydropower output in Europe dropped by nearly 20 percent compared with 2021, driven by severe droughts (VGBE, 2024). Similarly, in the UK, early 2025 brought the driest start to the year in decades. As a result, one major renewable operator reported a four percent decline in hydropower output due to the dry spring months[19].

3 How the private and public sectors can prepare for future climate impacts on supply chains

The supply chain disruptions experienced during the COVID-19 pandemic showed how factory closures and logistical disruption can have substantial sectoral and macroeconomic effects. Lockdowns in major manufacturing hubs, particularly in China, disrupted globe-spanning production networks and led to cascading shortages. According to the IMF, global GDP contracted by 2.7 percent in 2020, a direct reflection of lower industrial activity and trade[20].

However, the mental model created by this experience should not set expectations on how climate change will impact supply chains in future. The shock effect of the pandemic was the result of simultaneous restrictions in all types of sectors, something that is unlikely to happen because of climate hazards. Climate change tends to have effects that are more localised to specific places and occur multiple times over many years, whereas the pandemic affected nearly every region on the planet almost simultaneously. Nevertheless, the COVID-19 pandemic demonstrated how even local impacts can disrupt supply chains in other regions (Moffatt and Poitiers, 2024). In the following sections, we look at what policy responses should and should not try to do to mitigate climate impacts.

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[18] Stephen Starr, 'Millions depend on the Mississippi—but the mighty river is running dry', *National Geographic*, 26 September 2024, https://www.nationalgeographic.com/environment/article/mississippi-river-drought-climate-change-shipping.
[19] Rachel Millard, 'UK drought hits SSE's hydropower generation', *Financial Times*, 17 July 2025, https://www.ft.com/content/50e20dd4-0742-44cf-844c-05c66c00e9b4.
[20] IMF, 'World Economic Outlook Database: April 2025 Edition', https://www.imf.org/en/Publications/WEO/weo-database/2025/april.

3.1 Options for firms to reduce shock transmission through GSCs

So far there are few examples of severe supply chain disruptions caused by climate change. Nevertheless, the well-studied case of the 2011 earthquake in Japan provides an analogy of how such shocks could propagate through GSCs. While the earthquake was not a climate-related event, it can help us understand the mechanisms of how natural disasters affect GSCs. Zimmer (2024) studied how this event affected French companies that were downstream of Japanese suppliers affected by the earthquake. French firms with pre-existing supplier relationships in Japan experienced an eight percent relative drop in imports from Japan, driven by supply disruptions. These firms partially mitigated the shock by increasing imports from other countries, particularly China, which saw a 12.8 percent relative increase in exports to affected French firms. Similarly, Forslid and Sanctuary (2022) showed that during the 2011 floods in Thailand, Swedish firms with Thai suppliers experienced significant declines in performance: firms with high dependence on Thai imports saw an eight percent drop in output in 2012. Notably, the disruption persisted beyond the recovery of Thai production, suggesting high fixed costs in rebuilding supply chain links.

Most supply chains are rather diversified, such that the bar is relatively high for localised disruption to cause macroeconomic effects in other economies. The same is true for agricultural production. Extreme weather events are somewhat correlated through macro weather phenomena such as El Niño and La Niña. However, even foodstuffs for which production is more geographically concentrated, such as rice and cocoa, are produced over vast areas in many different countries. This makes it less likely for a flood event to cause global food shortages. Nevertheless, the absence of shortages of the type experienced during the pandemic does not mean that there are no direct macroeconomic costs associated with such events. They increase the scarcity in commodity markets and thus affect prices (Lau *et al,* 2023). As extreme weather events become more frequent, it becomes both more likely that events occur concurrently and amplify each other (Zhou *et al,* 2023). The increasing frequency of supply shocks to weather-sensitive commodities such as agricultural goods has the potential to increase the volatility of prices as periods of relative scarcity become more frequent. Similarly, there will be more disruptions to production of manufactured goods and logistics networks. Although so far extreme events such as the Thai floods have had short-lived effects, with most companies being able to recover within half a year (Chongvilaivan, 2012), climate impacts that occur more often will reduce the resilience of firms and the ability of communities to recover from them. If a flood happens once every 10 years, the people in the flooded area have time to recover and rebuild; if floods start happening every year, then the region's capacity to recover will diminish, and rebuilding may become impossible.

Moreover, more frequent shocks that in themselves do not cause significant shortages can nevertheless increase overall costs by necessitating costly mitigation measures. For example, to smooth the volatility of closures of certain shipping routes, maritime companies might decide to increase the sizes of their fleets beyond what would be optimal for a less-volatile market. More stockpiling of commodities and components would be the efficient response by private companies, but would also incur a direct cost to commodity traders and manufacturers. Running geographically diversified supply chains reduces the exposure to a catastrophic event in one location that might disrupt downstream production. However, that response requires investing in excess capacity and multiple supplier relationships, which reduces the efficiency of the overall system. The cost of building multiple supplier relationships is especially important in the context of developing countries, where contractual relationships have more limitations and less flexibility due to weaknesses in the institutional environment and the rule of law (Boudreau *et al*, 2023). One common mechanism for organising such relationships is 'contract farming', where buyers provide inputs or credit in exchange for a guaranteed delivery of agricultural outputs. However, climate-related shocks can significantly undermine these arrangements. Weather-sensitive cash crops such as coffee and cocoa are particularly vulnerable. Climate variability can reduce yields, affect quality and cause delivery delays, making it difficult for farmers to meet contractual obligations and for buyers to rely on stable supply (Li *et al,* 2024).

3.2 The role of policy in increasing resilience to climate hazards

In principle, companies have incentives to build resilient supply chains by diversifying supply and logistics options to reduce their exposure to climate hazards and ensure long-term supply of water and energy. However, there are collective and systemic problems that individual economic actors – and even whole industries – have inadequate incentives to address.

The first is information costs. The benefits of a better understanding of supply chain risks often extend beyond a particular industry, let alone a single company. Supporting such research and analysis through government policy is, therefore, justified. Furthermore, for certain strategic goods, the public benefits of their provision exceed the private benefits gained by their producers. This is especially the case for goods such as medicines, where shortages threaten public welfare beyond direct economic costs. Companies may not fully take into account the benefits of the resilience of their whole supply chain, consequently under-investing, especially if measures also benefit their competitors[21].

Although the state should incentivise and encourage mitigation measures that ensure supply chains for public goods, it should avoid policies that exacerbate the risks. Policymakers must be cognisant of the moral hazard involved in the state taking on too much of the burden of securing global supply chains, which can undermine incentives for the private sector to investment in climate mitigation (Gözlügöl, 2025). For example, governments generally have a political preference for maintaining industries at existing locations (thus ensuring employment continuity), and companies are rarely forced to internalise environmental costs (eg by making them transparent on their balance sheets). That preference often causes governments to offer bailouts after flood events to maintain economic activity in an area that is at risk of future floods, while insurers are not always allowed to price flood risks appropriately (Robinson *et al,* 2021). This results in prices not reflecting risks and companies not

[21] For a discussion of the role of supply chains in economic security, see McCaffrey and Poitiers (2024).

having sufficient incentives to reduce environmental risks by moving or investing in nature-based solutions to ensure future supply of essential but generic inputs, such as water or pollination.

The strategic importance given to a sector by a national government can also lead to preferential treatment over other users, such as households. For example, the semiconductor industry could rely on receiving sufficient water even in drought conditions because the Taiwanese government gave the industry priority in water supplies. This kind of policy preference can lead to factories being built in water-scarce regions and becoming politically unsustainable if citizens lose out as a result. A similar situation can be observed with data centres, which are highly energy and water-intensive facilities that often receive preferential access to water resources due to their perceived economic value. For example, in Chile, during a severe and prolonged drought, a data centre in Santiago was granted permits to extract more than 7 billion litres of water annually[22].

It is, therefore, important to maintain accurate price signals associated with climate risks. It is counterproductive for governments to subsidise private insurance or offer state insurance in areas with high levels of climate risk if they set no corresponding incentives for firms and households in that area to move elsewhere or otherwise reduce their exposure to the hazards.

In the case of the semiconductor manufacturing supply chain, mitigation of climate risks is possible through diversification and improving resource efficiency. Geographical diversification, while unlikely in the medium-term for geopolitical reasons, could limit the risks of a single drought severely disrupting global supply. Furthermore, use of reclaimed water in production could drastically reduce the dependence on supplies of fresh water, making the industry more water resilient. Taiwan is investing in water reclamation infrastructure and aims to meet a significant share of its water needs through reclaimed water in the coming years (TSMC, 2023). It is also expanding desalination capacity with a large plant under construction in Hsinchu[23] – though such projects raise their own environmental and energy concerns.

3.3 The importance of international cooperation

While climate-related disruption can have significant economic consequences, policy responses to disruption can exacerbate costs and contribute to volatility in global markets. As climate change intensifies and disruptive events become more frequent, there is a growing need to understand not only the physical risks, but also the behavioural and policy dynamics that arise. There are instances of the reaction to a shock, rather than the shock itself, having a greater impact on trade flows or prices. A fear of scarcity and political pressure to secure domestic supplies can lead to protectionist policies

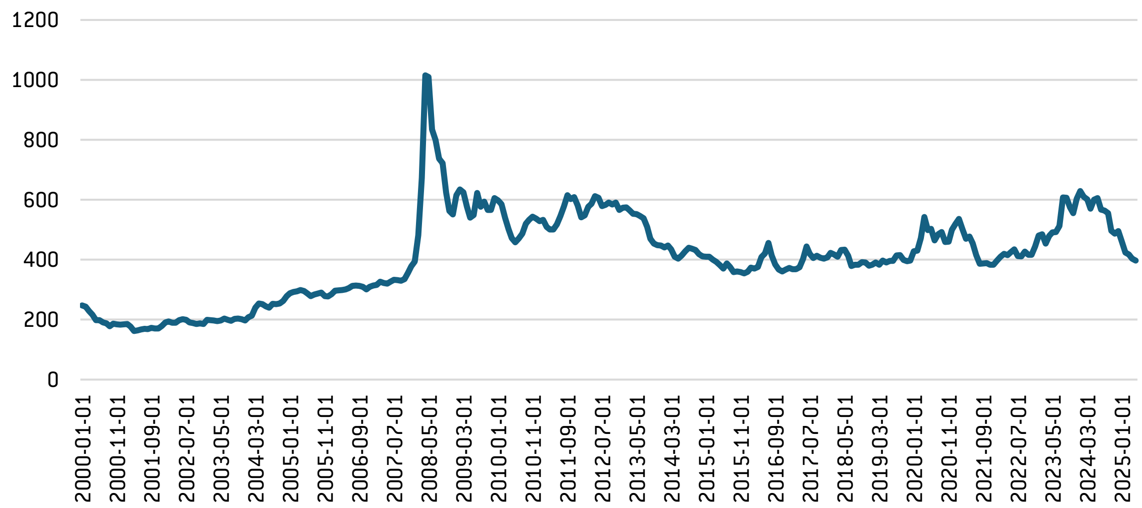
[22] Claudia Urquieta and Daniela Dib, 'U.S tech giants are building dozens of data centers in Chile. Locals are fighting back', Rest of World, 31 May 2024, https://restofworld.org/2024/data-centers-environmental-issues/; see also Government of Chile, 'Ficha del Proyecto: Cerrillos Data Center', https://seia.sea.gob.cl/expediente/ficha/fichaPrincipal.php?modo=normal&id_expediente=2143763121.

[23] See Suez press release of 18 June 2024, 'SUEZ Wins Contract for Taiwan's Large-Scale Municipal Seawater Desalination Plant to Enhance Water Supply Stability in Hsinchu City', https://www.suez.com/en/news/press-releases/suez-wins-contract-taiwan-large-scale-municipal-seawater-desalination-plant-enhance-water-supply-stability-hsinchu-city.

that worsen the very risks that they aim to contain. One example is the imposition of export restrictions during climate-induced crop failures. While often intended to stabilise domestic markets, such measures reduce global supply and trigger price spikes, magnifying the original disruption.

An example is the 2024 rice harvest. While 2024 was not a bad harvest for rice globally (Childs and LeBeau, 2024), high import protections in Japan meant that a local poor harvest, coupled with rising demand, directly translated into shortages in supermarkets (Fujibayashi, 2024). Local rice prices spiked by 28 percent compared to the previous year (Fujibayashi, 2024), while global rice prices remained stable. A more important example was the rice crisis of 2007-2008, when global rice prices tripled in just six months (FAO, 2011). While broader inflationary pressures, such as rising oil prices and increases in the prices of substitute crops like corn and wheat, contributed to market tensions (Childs and Kiawu, 2009), it was the policy interventions that transformed a regional imbalance into a global price shock (FAO, 2011). Notably, global rice stocks were not unusually low at the time (Bobenrieth and Wright, 2009), and the price spike was not the result of poor harvests but of government trade restrictions imposed by major exporting countries to stabilise their domestic prices. Vietnam banned commercial rice exports, while India introduced a minimum export price and banned exports of non-basmati rice. Similar measures were adopted by Cambodia, Pakistan and others (Childs and Kiawu, 2009). These actions severely restricted global supply and triggered panic buying, driving prices far beyond what underlying fundamentals would have justified.

Figure 1: Rice prices, 2020-2025 ($ per metric tonne)



Source: FRED, Federal Reserve Bank of St. Louis. Note: Values represent benchmark prices that serve as indicators of the global market. They are determined by the main exporter of the commodity. Prices are period averages in nominal US dollars.

Export restrictions in response to climate hazards are a prisoner's dilemma type of policy coordination problem. Each government of a net-exporting country has an incentive to put its own citizens first, even if the collective impact on global markets is negative. It seems unlikely that governments can credibly constrain themselves from applying export restrictions through international agreements. In cases of impending local shortages, it is likely that governments will prioritise their domestic markets. This is what happened during the pandemic, when there was considerable debate about whether vaccine nationalism would reduce the overall production capacity for providing vaccines globally. When it comes to agricultural commodities, policy has the potential to significantly amplify the effects of an otherwise localised damaging weather event. Moreover, recent geopolitical trends are pushing supply chains toward concentration in fewer, politically aligned countries, which could increase their vulnerability to localised disruptions. International coordination and governance – which are in increasingly short supply – are essential because of the global nature of climate hazards and of the supply chains that they affect.

4 Conclusion

The consensus from international research on climate science is that the frequency and severity of extreme weather events will increase considerably in future. In this paper, we have looked at the disruptive effect that climate-change-linked extreme weather events can have on GSCs.

For policy to make global supply chains more resilient to climate-related disruptions, there are some positive lessons from recent, analogous experiences and some lessons about what to avoid. Climate adaptation requires investments in physical infrastructure, for example, to make key logistical bottlenecks such as ports and canals more resilient to climate events. However, it also requires policy to adjust to the new realities revealed by climate science, and to set consistent incentives for economic actors to mitigate climate risks to supply chains. Therefore, governments need to take due account of climate science and investigate the weak links in global supply chains that are vital for provision of essential goods and services. They should use public policy to encourage investments in infrastructure to reduce climate-related disruption and incentivise more flexible logistics and procurement chains, but they should avoid dimming price signals such as insurance costs, and thus disincentivising economic actors from reducing their own exposures to climate hazards. They should also encourage diversification of inputs at all levels of the supply chains for essential products and services.

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