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Impacts and risks from climate change on trade infrastructure

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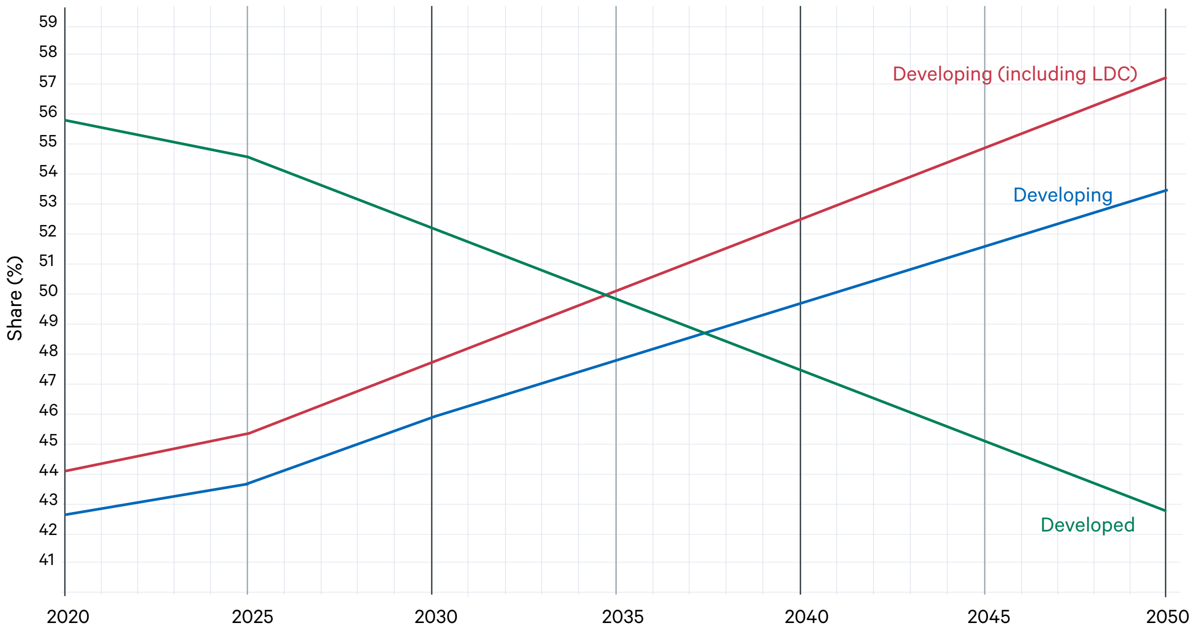
Contents

1. Introduction

Climate change is affecting prospects for trade and economic development around the world as extreme and sudden weather events and natural hazards increase in frequency and intensity. Extreme events, such as hurricanes or floods, can damage roads, railways, bridges and ports, and also disrupt air transport, limiting mobility for goods as well as people. In addition, slow-onset impacts, such as sea level rise, pose serious risks to infrastructure on which global trade depends. For example, the World Meteorological Organization reports that, in 2021, economic damage caused by droughts increased by 63% compared with the 20-year average (WMO, 2022). These and other impacts are causing disruption, delays and increased costs, which could decimate patterns of international trade (Dellink et al. 2017). A recent study found that extreme weather events caused by climate change cost US$143 billion annually, of which a significant majority is due to loss of human life (Newman & Noy, 2023).

Trade is essential for ensuring access to food, goods and services. It has been profoundly shaped by the rise of complex global supply chains and the way the design, manufacture and transport of goods takes place. Since World War II, international trade has grown exponentially, both in scale and importance, which can partly be explained by the decline in global transport costs (Hummels, 2007). Furthermore, despite the recent global pandemic and the increased global insecurity caused by the Russian invasion of Ukraine, global trade reached record numbers in 2022 with a total value of US$32 trillion, according to the United Nations Conference on Trade and Environment (UNCTAD 2022). In terms of future projections of global trade, the WTO estimates that it will continue to outpace growth in real GDP. The WTO also projects a large increase in developing countries' share of global exports (Figure 1). Similarly, the OECD projects that maritime shipping could triple by 2050 (OECD 2019).

Figure 1. Projected share of exports for developed and developing countries

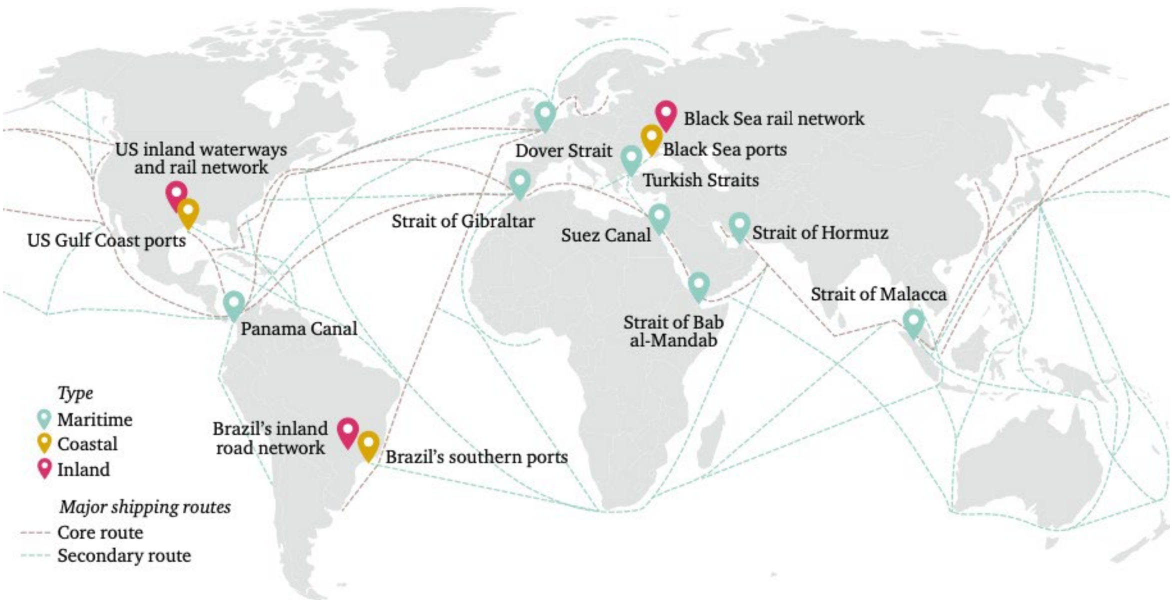


Source: WTO 2023

On the one hand, the global trade system is exposed to serious threats from the rapid increase in the frequency and severity of extreme weather and climate related disasters, which are set to further increase in the coming years (see Table 1). On the other hand, global trade is crucial for achieving a low-carbon transition as well as enhancing the resilience of countries' economies against the impacts of climate change.

The complex and interconnected nature of global value chains that shape today's international trade system also means that disruption in key locations can have an exaggerated effect for the global economy. There is mounting evidence that the global economy is particularly exposed to the impacts of climate change in several critical economic sectors that heavily depend on imports from a small number of geographically concentrated production centres and supply chains in climate vulnerable regions. These so-called chokepoints (Figure 2) are particularly problematic if or when disasters affect production areas that produce highly specialized goods for (e.g. the energy transition) or regions that are important for global food security (Bailey and Wellesley 2017; Hedlund et al. 2022).

Figure 2. Chokepoints for global food trade



Source: Bailey and Wellesley 2017

Global production and trade in agriculture products is a good example of a critical sector as it largely shaped by breadbaskets – regions of advantageous soil and climate conditions for substantial grain production. A study by Stockholm Environment Institute showed that a small number of countries – e.g. Brazil, China, the US and Thailand – are likely to be the source of the bulk of climate risks to global food security, due to substantial reduction in crop yields across different agricultural commodities in these countries (Adams et al., 2021). There are also substantial risks to the international trade in critical raw materials, because around 80–90% of the global processing of rare earth metals is confined within a small region in China that is particularly prone to heavy rainfall (Woetzel, et al., 2020), while other key exporting countries, such as Myanmar and Thailand, are ranked among the countries most vulnerable to extreme weather events according to the 2021 Global Climate Risk Index (Germanwatch, 2021). Thus, severe climate impacts at key geographical chokepoints could cascade and intensify along global supply-chains and become potentially catastrophic for trade infrastructure and ultimately the global economy (Carter et al., 2021).

In this context, this report assesses the current literature on how risks and impacts from climate change will affect physical infrastructure important for global trade. We focus on three areas – marine transport, land-based transport and air transport – and explore how climate impacts such as sea-level rise, flooding, drought, storms, heat, and water scarcity (see Table 1) will affect global trade in the next 25 to 30 years and beyond. In addition, we discuss the importance of each area for global trade and provide examples of recent climate-related disruptions in important chokepoints. To conclude, we discuss what climate impacts imply for trade infrastructure and the broader responsibility to climate-proof the international trade system.

Table 1. Risks to trade infrastructure from climate change

Climate impacts	Impact on trade infrastructure
Increased temperatures	• Aircraft performance • Damaged equipment or cargo • Increased energy consumption for cooling • Lower water levels restricting inland navigation
Increased precipitation	• Flooding of roads, railways and airports • Higher water levels restricting inland navigation on river waterways
Decreased precipitation	• Lower water levels restricting inland navigation on river waterways
Extreme wind and storms	• Damaged infrastructure (e.g. roads, railway, seaport)
Sea level rise and storm surges	• Damage to port and port-adjacent infrastructure • Change in wave propagation patterns can prevent port operation • Regular or permanent inundation of infrastructure
Reduced ice cover and thawing permafrost	• Infrastructure damage and increasing cost of maintenance • Opening of new shipping routes
Earlier break up of river ice	• Risk of flooding

Source: JRC 2018; Dellink et al. 2017

2. Climate change and global transport infrastructure

Transport infrastructure is critical for economic development and is the backbone of the international trade system, albeit one that will become increasingly frail in the coming years. While transport infrastructure is usually designed and constructed against historical climate records to withstand historical variability in weather, past climate trends are becoming increasingly irrelevant as a predictor of future risks (Rising et al., 2022). The heightened frequency and intensity of extreme weather events, and rising sea levels, in the coming years are certain to cause damage to both existing and newly built transport infrastructure, both acutely and gradually, with implications for the integrity, safety, and performance of the global system of trade.

As matter of fact, the damage and disruption to transport infrastructure and networks already account for most of the cost arising from extreme weather events in Europe, and this cost is set to increase substantially. A 2018 study by the European Commission's Joint Research Centre (JRC) estimated that infrastructure damage from climate impacts alone is likely to triple by the end of 2020's, increase sixfold by mid-century, and increase tenfold by end of the century, with the transportation among the sectors most affected by heatwaves and flooding (Forzieri et al., 2018). More recently, the UN Economic Commission for Europe published a comprehensive study that projects for Canada and Europe a significant escalation in costs from infrastructure damage caused by climate impacts (UNECE, 2020). The study also found North Sea ports and Mediterranean roads to be among the most vulnerable transport infrastructure, whereas key transport networks in coastal British Columbia in Canada, a major trade gateway to Asia, are expected to be particularly affected.

The following sections further examine the risk exposure and vulnerability of different modes of freight transport and what this implies for the international trade system.

2.1 Current exposure of maritime trade infrastructure to climate risk

The overwhelming majority of traded products and goods move around the world using oceans and waterways (WEF, 2022). Meanwhile, trade volume carried by sea from port-to-port accounts for 80% of total trade (UNCTAD, 2022) and is projected to increase, under varying climate scenarios with global temperature increases of 2°C and 4°C (Hanson & Nicholls, 2020; Walsh et al., 2019). Because of its large economic importance, particular exposure to climate risks and natural hazards, and the prediction of a near tripling of maritime trade by 2050, marine and river infrastructure will be increasingly critical for the stability of the global economic system (OECD, 2019; Verschuur et al., 2023).

For instance, the global food market has become increasingly vulnerable over the past two decades due to the growing reliance on international trade routes via maritime chokepoints, according to a recent study by Chatham House (Bailey & Wellesley, 2017). The study examined the vulnerabilities of global maritime trade with respect to critical points in maritime transport routes with significant trading volume, which include maritime corridors (e.g. straits and canals) and coastal and inland transport infrastructure in major crop-exporting regions. The report finds that 55% of internationally traded maize, wheat, rice and soybeans is transported through at least one maritime chokepoint, and that more than half of the global export of these food crops pass through a small number of inland and coastal chokepoints in the US, Brazil and the Black Sea. Operational disruptions to one or more of these trading hubs could result in supply shortages and price spikes, which has been demonstrated in the Russian invasion of Ukraine, because of which Black Sea ports have had limited capacity to operate (Glauben et al., 2022). The Chatham House study also highlighted weather and climate hazards as one of the main and growing risk factors for chokepoint disruptions. Temporary closure of operations can make infrastructure vulnerable to weather-related wear and tear, and can act as a risk-multiplier for non-climatic hazards, including those relating to security and conflict and institutional factors (e.g. restrictions on the passage of food via export controls) (Bailey & Wellesley, 2017).

Inland waterways face similar problems. In Europe, for example, drought has significantly impacted the flow of goods through river waterways. In 2018, transport on the river Rhine, which transports over 300 million metric tons of goods annually, decreased by 27% because of low water levels. Other major rivers such as the Danube were affected by similar issues, which led to an economic downturn in Germany as companies failed to secure raw materials and had to shut down operations. In fact, even a small drop in water levels can lead to significant trade disturbances because river waterways are highly vulnerable to such fluctuations. For example, in the Mississippi River in the United States, a one-inch drop in water levels can reduce tow capacity (i.e. the weight a vessel can carry) by 255 metric tons (US EPA, 2022). Similarly, ships passing through the Panama Canal, which significantly shortens transport between the Atlantic and the Pacific Ocean and handles 6% of global maritime trade, have been forced to reduce cargo weight due to low water levels in the summer of 2023, which are the result of droughts and the canal's dependence on freshwater for its operation.

2.2 Future exposure of maritime trade infrastructure to climate risk

Maritime transport is particularly exposed to climate-related risks, in particular sea-level rise, storm surges and flooding. Sea level rise is a direct threat to the full operation of sea ports and changes in precipitation affect critical nodes and passageways along main marine transport channels (LSE, 2023; UNCTAD, 2021). Most recent data suggest a global mean sea level rise of about 4 cm per decade (WMO, 2021). However, the IPCC is continually revising its projections upwards (Fox-Kemper et al., 2023).

Around half of global trade in value terms is maritime trade, so ports and coastal transport infrastructure play a vital role in global trade and logistics. In fact, just five of the world's largest ports account for nearly 1.4% of global economic output (Verschuur et al., 2022). At the same time, ports are particularly vulnerable to extreme weather events and rising sea levels driven by climate change, which can cause damage to ports and other critical infrastructure, and logistics losses (Izaguirre et al., 2021; Verschuur et al., 2023). Because ports are located in low- lying estuaries and deltas or along open coasts, they are susceptible to a many natural hazards, such as storm surges, waves and winds, and riverine and pluvial flooding because of excess rainfall (Christodoulou et al., 2019; Zhang et al., 2020).

Recently, researchers from the University of Oxford carried out asset-level risk assessment of global port infrastructure (1340 ports) to quantify the impacts of climate and other natural disasters on physical infrastructure and associated logistics and trade. The assessment showed that 86% of ports are exposed to more than three climate and other natural hazards, and 40% of ports are exposed to extreme maritime conditions that disrupt their operational capabilities. Ports in Japan, the West Coast of the US, Central America, New Zealand, Taiwan, and parts of mainland China, were identified as being particularly exposed to multiple climate and other natural hazards, whereas ports in mainland China and Taiwan, the Gulf of Mexico and in Western Europe were found to be most exposed to expected port-specific risks from such hazards (Verschuur et al., 2023). Meanwhile, small island developing states (SIDS), face a disproportionately high risk due to their high dependency on maritime transport (Verschuur et al., 2022).

Another study that draws on current and historical risk to port infrastructure explores impacts under high-end future scenarios (the IPCC's RCP 8.5). The study estimates that because of sea-level rise by the year 2100, ports exposed to very high risk will increase from 3.8% to 14.4%. Ports in the Mediterranean will face the most striking increase, going from low or medium risk to very high risk due to an increase of overtopping and high temperatures (Izaguirre et al., 2021). Another study that compared the effects of climate change on European ports under two climate scenarios (RCP 4.5 and RCP 8.5), estimated that 25% more shipping cargo will be affected by extreme water levels by the end of the century. Countries with ports on the North Sea are expected to be most affected, including in the UK, Germany, Belgium, France and the Netherlands (Christodoulou et al., 2019; Ciscar et al., 2018).

Apart from impacts to port assets (e.g. cranes and terminals), ports are themselves embedded in local infrastructure networks that are critical for their operations, including rail, road, water and electricity. Even if ports avoid damage from natural hazards, damage to port-adjacent infrastructure can halt port operations.

Verschuur et al. (2023) identified impacts on this infrastructure as a key chokepoint for ports across the world, both in developing and developed countries. Indeed, the authors note that port-adjacent infrastructure is often more exposed to fluvial (i.e. flooding from the breaking of riverbanks) and coastal flooding than port terminals, which are often built at higher elevations and are comparatively less vulnerable.

Furthermore, port closures can result in wide-ranging economic losses that cascade through maritime transport and global supply-chain networks that depend on functioning ports (Becker et al., 2013; Carter et al., 2021). In Europe, for example, a study found that more than 60% of port traffic depends on connections with other ports with higher exposure to sea level rise. These ports, including several Mediterranean ports, are exposed to considerable indirect risk to their operations because of possible disruptions in other ports, including those in Northern Europe (Christodoulou et al. 2019).

Other risks to maritime transport infrastructure include important ocean, river and canal waterways. Inland waterways accounted for almost US$18 billion of global trade in 2023. In many parts of the world, they are crucial for freight transport. In Europe, for example, freight transport is considered as reliable as rail (Christodoulou et al., 2020). However, extreme weather events can severely limit navigation if they result in water levels that are too high or too low (Jonkeren et al., 2014). Droughts are particularly important because they can disrupt operations for long periods of time, as shown in Section 2.1.

To assess the future impacts on inland waterways in Europe, Christodoulou et al. (2020) used regional climate models based on the RCP8.5 global climate scenario. Their findings show, however, that even under the worst-case emissions scenario (i.e. RCP 8.5), future climate change can have negligible or even positive impacts on trade. The authors' simulations projected increased discharge for the Rhine and the Danube rivers, due to an early start of the ice melt season, which would reduce the number of days with a water level below the minimum required for navigation, both in the medium term (2040–70) and long term (up to 2100).

Climate change will also lead to the opening of new waterways. For example, the latest IPCC report states that the Arctic Sea is expected to be ice free before 2050 (Fox-Kemper et al., 2023). More recently, Kim et al. (2023) note that even under the best-case scenarios we need to prepare for a seasonally ice-free Arctic. As the Arctic Sea ice melts, northern sea routes will be navigable for longer periods of time. Moreover, sea routes across the Arctic Sea between Asia and Europe can cut the length of voyages by up to 40% compared with the Suez Canal (Dellink et al. 2017). However, even in the summer, the Arctic ocean can be stormy and unpredictable and may become more so as the planet warms, which creates large uncertainties for using this route for global trade (Ng et al., 2018).

2.3 Current exposure of land-based trade infrastructure to climate risk

Land-based transport infrastructure plays a critical role in international trade by facilitating intra-regional transport of goods between seaports and airports and their destinations. Rail freight, which accounts for 7% of freight transport, is also an integral part of international supply chains and especially important as a high-capacity mode of transport for heavier loads and large volumes of landlocked resources, such as coal, timber and minerals (International Energy Agency, 2019). Freight rail transports more cargo per ton mile than any other mode of transport. It also offers a cost-effective and low-emission transport option and benefits from extensive railway networks across China, India, Europe, the US and Russia. On the other hand, road transport is critical to trade, with road freight accounting for as much as 40% of total goods transported (ITF, 2022). Compared to rail, roads provide far more comprehensive transport infrastructure with greater reach to inland destinations. Roads also frequently complement all other modes of transport in supply chains. Another advantage of road transport is that it is less dependent on logistical hubs such as ports, airports or train stations, and it can be a favourable option when there is a need to minimize risk of damage and excessive handling in cases of high value or sensitive freight (Stepper, 2022). Both railways and roads therefore serve an essential role in various parts of global supply chains.

Yet land-based transport is particularly vulnerable to climatic hazards because of its extensive and fixed spatial coverage relative to air and shipping, which benefit from greater flexibility in their routes. Rail networks are particularly vulnerable because of their expensive infrastructure, high safety standards and system-related restrictions in reacting to disruptions in a flexible way. Roads, on the other hand, are vulnerable because of their dominance across all transport markets (Doll et al., 2014). Flooding caused by rising sea levels and storm surges can severely affect roads, bridges and railways in coastal areas, while heavy rainfall inland can result in acute flooding and mudslides that cause damages to highways, railways, tunnels, and bridges. Droughts can also increase the risk of wildfires, which can destroy transport infrastructure and cause disruption through pollution and impaired visibility for transport operators (UNECE, 2020).

Beyond the acute damages and disruptions to land-based infrastructure, climatic hazards (such as thawing of permafrost) can have longer term consequences for the transport network by harming performance, reliability, and safety through wear and tear (US EPA, 2022). So it is important that adaptation action and investments take place today to future-proof railway and road networks against climatic hazards in coming years, given their long lifespan. While rail tracks, road layers and bridges are usually exchanged after a couple of decades, their alignment, tunnels cuttings and embankments, remain in use for a far longer period (Doll et al., 2014).

2.4 Future exposure of land-based trade infrastructure to climate risk

Over the last few years, a growing body of work has sought to assess and quantify the extent to which land-based transport infrastructure is exposed to both the current and potential risk of climatic hazards. However, literature in this area is still emerging and we found only one study that explicitly explored climate risk exposure under multiple climate scenarios.

The World Bank, Oxford University and the European Commission Joint Research Centre (JRC) recently carried out a multi-hazard risk assessment of road and railway infrastructure around the world by layering the latest road and railway asset data onto a high-resolution global map of natural hazards (Koks et al., 2019). The analysis deployed conventional risk models to examine the exposure of transport infrastructure on an asset level to the most frequent and costly natural hazards, such as tropical cyclones, earthquakes, and surface, river, and coastal flooding. The findings showed that around 27% of all global road and railway assets are exposed to at least one climatic or other natural hazard, and that around 7.5% of assets are exposed to 1 in 100 years flood events. Japan and China were also found to face the greatest exposure to multiple hazards.

The results also showed land-based transport networks in high and upper-middle income countries to be particularly exposed to cyclones, including in the Caribbean, US Gulf and East Coasts, Eastern China, South Asia, and Japan, whereas Africa's exposure to river flooding accounted for the largest share of hazard risk to low and lower-middle income countries. The assessment also projected the expected annual cost from infrastructure damage ranging from US$3.1 to 22 billion, depending on assumptions about road vulnerability and construction and repair costs, with as much as roughly three quarters of the cost caused by surface and river flooding. In some countries, this cost was found to amount up to 0.5 to 1% of GDP annually (Koks et al., 2019).

A recent analysis by the JRC and the University of Potsdam combined infrastructure-specific damage models together with climate and hydrological models to examine future flood risk to railway infrastructure on a European level under different warming scenarios (Bubeck et al., 2019). The findings revealed that the estimated economic toll from flood damage to railway infrastructure was €581 million per year on average over the period 1976 to 2005, where Germany and France face the greatest flooding risk at an estimated annual cost of €165 million and €106 million, respectively. More importantly, the cost of flood damage is projected to increase threefold to €1.8 billion under a 3°C warming scenario, with Slovakia, Austria, Slovenia, and Belgium bearing the brunt of the cost. However, the estimate of annual costs from flood damage to railway infrastructure could be reduced annually by €317 million if 1.5°C targets were to be met.

While no similar risk assessment has been recently carried out for road infrastructure, an earlier economic analysis by the JRC assessed risks from climate-driven weather extremes to road and rail infrastructure for all EU member states under different time periods and climate scenarios (Nemry & Demirel, 2012). One key finding was that the EU overall could face between €50–192 million in extra road infrastructure costs annually under a "business-as-usual" scenario over the period 2040 to 2100, owing to more frequent and extreme rainfall and floods, alongside increased costs from additional maintenance needed because of increasing temperatures.

The assessment also projected that around 4% of Europe's coastal road network would be at risk of permanent or temporary inundation in the event of a one metre rise in sea levels by the turn of the century. Moreover, the share of coastal roads affected was also found to be significantly higher for low-lying areas, such as in the Netherlands, Belgium, and northern Germany. However, it is likely that these findings underestimate the severity of the risks that climatic hazards pose for land-based transport, as the these were generated by earlier climate models that are known to be too conservative because they do not sufficiently account for more acute and volatile climate impacts, as well as the compounding effects of synchronous events (Nemry & Demirel, 2012).

2.5 Current exposure of air freight infrastructure to climate risk

While being the smallest of the three modes of transport, air freight plays a significant role in international trade and is an increasingly important component of global supply chains. Although air freight accounts for less than 1% of global trade by volume, it is responsible for the transportation of US$6.8 trillion worth of freight annually, or an estimated 35% of the value of all international freight transport (IATA, n.d.). Air freight is also essential for connecting distant markets in a fast and reliable manner and especially important for the transport of commodities that are of high-value (e.g. electronic components), dangerous (e.g. lithium), and time sensitive and perishable (e.g. pharmaceuticals, fruits and vegetables) (Bartulović et al., 2022).

While air transportation of freight can be expensive for many types of commodities, the advantages of faster transportation and more efficient customs clearing reduces the need for local warehousing, which saves both time and other expenses. Air freight connectivity has been associated with increased trade in value terms: a 1% increase in a country's air freight connectivity has been found to be associated with a 6.3% increase in total export and imports (IATA, n.d.). At the same time, the demand for air freight has been growing significantly in recent years and is projected to double by 2035 (Maersk, 2022).

As with other modes of transport, air freight is certain to be significantly affected by climate change and there are already clear links between high impact weather events and disruptions to aviation. Heavier precipitation events can affect airport throughput by requiring a greater distance between aircrafts landing and taking off and can also increase the risk of runway and taxiway flooding. More intense snowfall or snowfall can cause increasing flight delays and disruptions (Burbidge, 2016). At the same time, high temperatures can cause damage to physical airport infrastructure, including heat damage to tarmac and surface melting of tarmac runways. In addition, a rise in air temperature and decline in air density can cause aircraft wings to generate less lift on take-off, and thus force airlines to impose weight restriction on aircrafts. One study, that assessed the impacts of climate change on aircraft take-off for several common commercial aircraft across 19 major airports around the world, showed that on average 10 to 30% of annual flights departing at times of peak temperature may require weight restrictions (Coffel & Horton, 2015). Another more recent study found that climate change might be affecting the North Atlantic jet stream more severely than previously thought, causing more turbulent and hazardous flying conditions for aircraft using the transatlantic flight corridor (Lee et al., 2019).

2.6 Future exposure of air freight infrastructure to climate risk

Unfortunately, no global assessments of climate risk to air transport infrastructure have yet been conducted. However, in a recent survey by the International Civil Aviation Organization of its member countries, nearly three-quarters of respondents reported that their aviation sectors were already being affected the impacts of climate change, with a further 17% expecting their sectors to be affected by 2030 (ICAO, 2019). Despite this, less than a third of the respondents reported that adaptation measures had begun to be implemented.

Moreover, a recent climate risk assessment was carried out by Eurocontrol to examine the impacts of climate change on the European aviation industry (EUROCONTROL, 2021), which showed that by 2050, the increased frequency and severity of storms bought about by climate change are likely to reduce flight efficiency and increase delays. According to the assessment, around two thirds of coastal and low-lying airports in Europe are forecast to be at risk of some level of runway flooding by 2090 under both 1.5°C and business-as-usual scenarios, posing a serious threat to the entire European Air Traffic Management system. More specifically, the vast majority (91%) of airports at risk were found to be small airports, while countries in the North Sea are expected to be particularly affected.

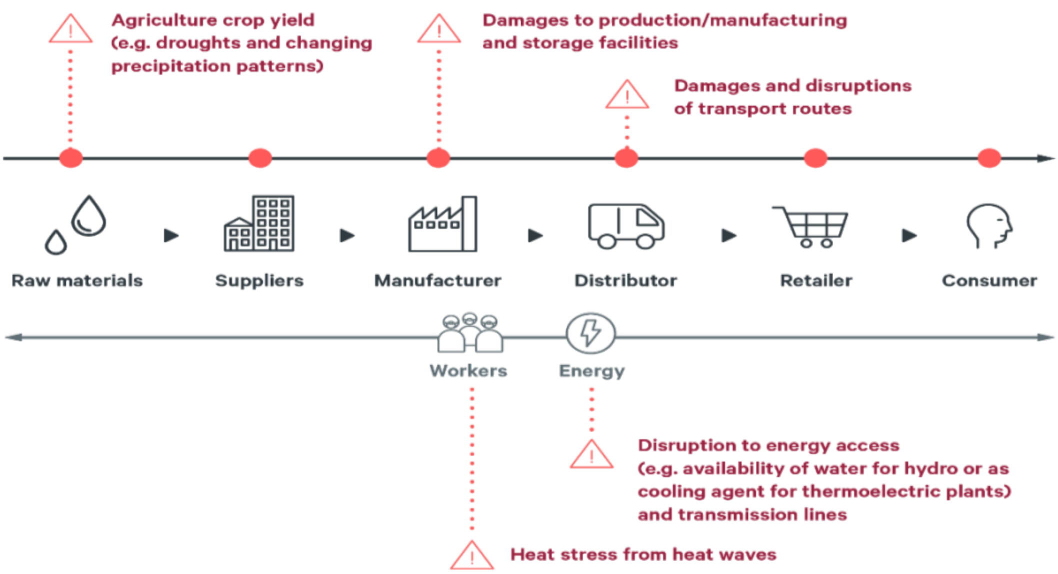
Similar findings were reported in an earlier analysis by the JRC in 2012, which identified as many as 42 airports across Europe to be at risk from coastal flooding (1-3 metres) by the end of the century, as result of sea level rise and extreme weather events, under a business-as-usual scenario. The assessment also found that airports in countries by the North Sea were found to be at greatest risk, including in the UK, Germany, and Norway (Nemry & Demirel, 2012).

3. Climate-proofing the international trade system

As the global transport infrastructure that underpins the international trade system becomes increasingly exposed to climate hazards in the coming years and decades, governments and businesses need to step-up actions and bolster investments in adaptation to strengthen the integrity of global supply chains and enhance their resilience to the impacts of increasingly volatile climate conditions. The risk of catastrophic disasters in key chokepoints across the international trade system continues to persist and is certain to grow in the coming years, alongside the continued rise of global temperatures.

It is also important to recognise that transport infrastructure is only one of the many sectors through which climate change impacts can disrupt international trade (see Figure 3). For instance, more frequent and severe storms and floods can for instance wreak havoc on manufacturing hubs and have devastating consequences for the health, lives, and livelihood of workers. As a well-known case in point, Thailand suffered the worst flooding in half a century in 2011 that lasted for several weeks and inundated entire provinces in industrial areas near Bangkok, placing many regions three metres under water at the peak of the flooding. The flooding caused significant damage to both manufacturing and transport facilities and led to widespread disruption to global automotive, electronics and food supply chains, resulting in a total economic cost of $45.7 billion, according to World Bank estimates (World Bank, 2012).

Figure 3. Different transmission pathways through which climatic hazards can propagate their effects and cause disruptions to supply chains.



Source: Mikaelson et al. 2023

Recently, the Cross Dependency Initiative (XDI), a private-sector initiative on physical risk analysis, quantified the risk to capital value in the built environment from extreme weather and climate change in over 2600 territories around the world. The assessment showed that 80% of the top 50 at-risk states and provinces are in the key manufacturing countries of China, India and the US, including the Chinese manufacturing provinces of Jiangsu and Shandong, which are critical to achieving a global energy transition (XDI, 2023). Yet despite the growing threat that the physical impacts of climate change pose for international trade and business, the world is not prepared. For example, both public and private finance for climate adaptation is scarce (Zamarioli et al., 2021), while findings from recent business surveys show that just over a quarter of companies have conducted assessments of climate risk to their supply chains and as few as one in five companies have plans to implement adaptation measures (Laidlaw et al., 2023).

The lack of effort by national governments and businesses to plan and implement adaptation measures to manage the growing risk from climate impacts is particularly concerning for the resilience of the international trade system, because a lack of planning and implementation translates into highly vulnerable supply chains that are unlikely to withstand and/or recover from the anticipated climatic impacts. For instance, a recent study published in the Harvard Business Review showed that only 11% of suppliers in the US, China and Taiwan are fully prepared for weather-related disruptions, even though 49% of US suppliers and 89% of the Asian suppliers reported having experienced increasing climate volatility (Boyson et al., 2022).

In light of the growing risk exposure and existing vulnerability of the international trade system to the effects of climate change, governments and businesses need to work in concert to strengthen the resilience of the international trade system through increased investment and by implementing climate adaptation solutions in the transport sector. The failure to anticipate and proactively manage the physical climate risks are likely to come at an enormous cost for countries around the world and the global economy at large, although the cost is certain to spread unevenly across sectors and regions. For instance, the agriculture and manufacturing sectors (e.g. semiconductor) are likely to be disproportionately affected compared to others, while smaller economies or landlocked countries that rely on fewer trade channels are likely to be especially vulnerable (Janssens et al., 2021; WTO, 2022). Conversely, investments in adaptation have been found to significantly reduce the cost of climate impacts on transportation infrastructure (Neumann et al., 2021).

4. Conclusion

Based on the evidence set out in this report, it is clear that the international trade system is seriously exposed to the physical impacts of climate change, both in the short- and long-term, which stresses the need for greater efforts by governments and businesses to climate-proof trade linkages. We conclude this report by discussing potential actions that can be taken to make the trade system more resilient.

Mandatory integration of climate risk assessments and scenario analysis into the spatial plans and building codes needs to become a commonplace practice for new transport and other types of critical infrastructure, while public investment in adaptation is needed to make existing infrastructure more climate resilient.

However, public investment in adapting trade infrastructure will not be sufficient on its own to safeguard international trade channels, because the interconnectedness of the global economy and the systemic nature of climate change warrants a more global approach that galvanizes both public and private sector action on climate adaptation (Dzebo et al., 2022).

To this end, strong legislative measures and economic incentives by governments are essential to propel businesses to act on climate adaptation in order to enhance the resilience of global supply chains against increasingly volatile weather patterns, as well as the gradual effects of climate change. Unfortunately, governments and international organizations have thus far failed to create the enabling environment that is urgently needed to accelerate business-led adaptation. This is largely because the international trade system has been profoundly shaped by the free- trade agenda and market liberalization of the last few decades, which has brought about a strong “market-first” approach by many governments, whereby financial institutions and businesses have been presumed to be best positioned to design and implement risk management strategies. Yet this approach has left global supply chains dangerously vulnerable to both climatic and non-climatic risks, as became evident in the wake of the Covid-19 pandemic, the Suez Canal obstruction in 2021, and Russia’s war in Ukraine (see also the evidence presented above). In fact, businesses have been increasingly calling on governments to introduce legislation and market incentives to help accelerate much-needed business-led adaptation to strengthen the climate resilience of international trade (Mikaelsson et al., 2023).

National governments, businesses and international organisations should pool resources to jointly ensure the resilience of trade infrastructure, not least because they all depend on it. A country or a business in the Global North that considers itself resilient to climate impacts can nevertheless be vulnerable if its prosperity depends on production and transport of products from highly vulnerable areas.

This means that climate risks and impacts are transboundary risks, and that there is a false assumption that vulnerability of countries and businesses in the Global North and the Global South can be understood independently of their connections and interdependencies (Benzie & Persson, 2019). The Paris Agreement acknowledges this in proclaiming adaptation as a global challenge (UNFCCC, 2015 Art. 7), but more needs to be done internationally to create the necessary enabling environment and regulatory framework that can drive business-led adaptation on the scale needed and deliver systemic change throughout the international trade system.

It is also important to recognise that although the impacts of climate change can propagate and amplify through global trade links and supply chains, international trade can also play an important role in bolstering the climate resilience of countries, especially when underpinned by strong multilateral cooperation and coordination. International trade can facilitate risk sharing between countries through the diversification of supplies and enable them to hedge against climate disruptions of individual production regions or transportation channels. In contrast, a fragmented trade system and disintegration of the multilateral rule-based order risks exacerbating the probability and severity of the impacts from climate-induced trade disruptions, as indicated in scenarios set out in the newly published Future of Trade in a Net Zero World report, coordinated by the European Climate Foundation.

Lastly, international trade plays an instrumental role in countries' net-zero transitions because low carbon innovations, such as renewable energy technologies, electric vehicles, and battery storage systems, rely on a range of critical raw materials that can only be sourced in specific geological locations. Yet, as discussed above, these regions are becoming increasingly vulnerable to climate change. This reciprocal interplay between climate mitigation and adaptation in the context of international trade highlights just how important it is that governments and businesses take bold and systemic action on climate mitigation and adaptation together. The failure to adapt the international trade system to the escalating impacts of climate change risks thwarting countries' decarbonisation efforts and our ability to meet climate targets. At the same time, our failure to meet climate targets will likely set us on a trajectory towards climate impacts of such scale and severity that it will be beyond our ability to adapt.

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