Sustainability Insights | Research

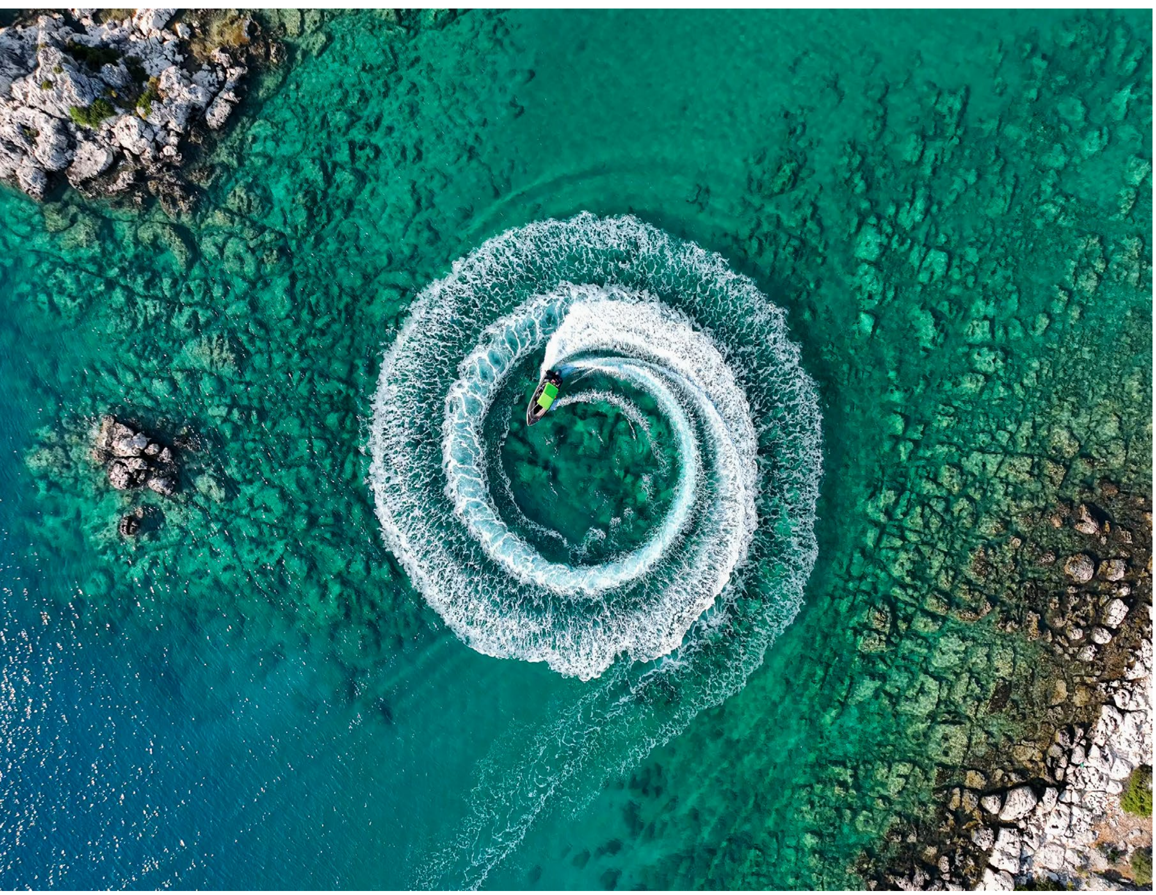
Ripple Effect: How Value Chains Compound Sector Exposures To Physical Climate Risks

March 13, 2025

Exposures to physical climate risks in many companies' value chains can lead to--and possibly compound--vulnerability to operational and financial risks, if unaddressed.

This research report explores an evolving topic relating to sustainability. It reflects research conducted by and contributions from S&P Global Ratings' sustainability research team as well as our credit rating analysts (where listed).

This report does not constitute a rating action



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Exposures of companies to physical climate risks inherited through value chains may be significant. This is more the case for companies operating in sectors with long and/or complex value chains, or those that rely on the natural environment. In this research, we seek to enhance understanding of sectors' exposures to physical climate risks. We do so by looking beyond direct exposures to estimate those transmitted between sectors through value-chain networks.

Using economic input-output data from the U.S. Bureau of Economic Analysis (BEA), we first build value-chain models at the sector level that express the economic inputs and dependencies between sectors. We then layer into these sector value-chain models the direct exposures of different sectors to nine climate hazards. These exposures are drawn from the S&P Global Sustainable1 Physical Climate Risk dataset. This allows us to estimate the exposures to physical climate risks each sector inherits from the sectors in its value chain.

We focus on the potential impacts, or risks, to sectors downstream of the climate hazard event, rather than potential opportunities. This research augments understanding of how climate hazards might transmit through value chains and lead to potentially material credit impacts.

Consistent with our criteria, our credit ratings incorporate the adverse physical effects of climate change--that are sufficiently visible and material--along with all other factors material to our assessment of creditworthiness.

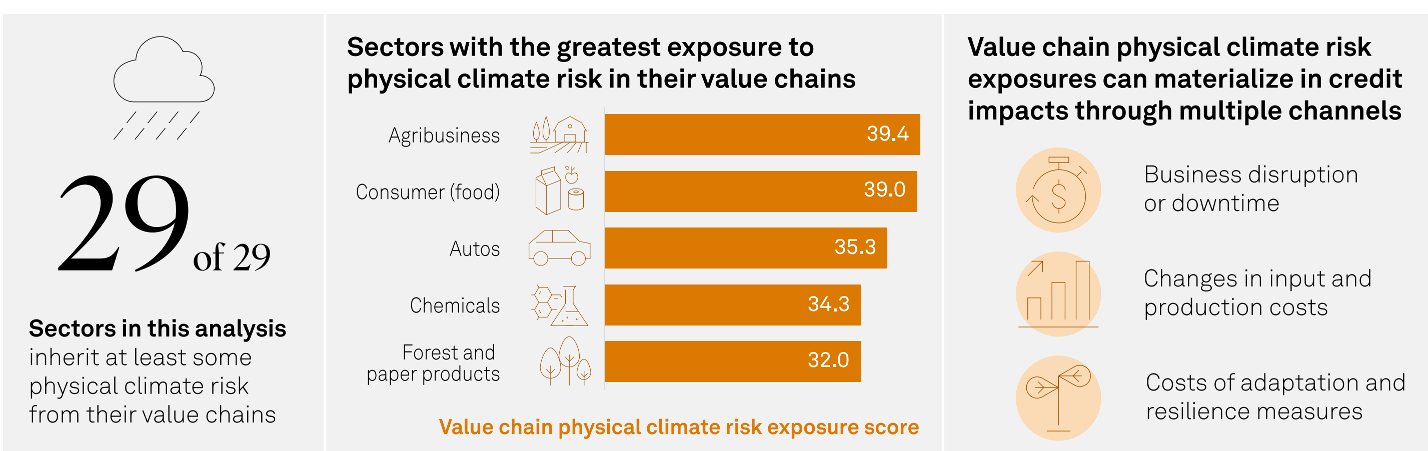
We do this when we believe such impacts could materially influence the creditworthiness of a rated entity or issue and we have sufficient visibility on how they will evolve or manifest.

The findings of this research are currently not part of our base case analysis, given the uncertainties inherent in climate projections.

Key Findings

- **Companies may be underestimating their exposures to physical climate risks if they fail to consider value-chain exposures in their risk analyses.** In turn, they may also be underestimating potential operational and financial impacts.
- **Sectors such as agribusiness, consumer (food), and autos, which rely heavily on more climate sensitive upstream sectors, exhibit the highest value-chain exposures, under a slow climate transition scenario (SSP3-7.0).** However, all sectors inherit at least some physical climate risk exposures from their value chains.
- **Some sectors have relatively lower direct exposures to physical climate risks, but nevertheless have meaningful value-chain exposures.** For these sectors, failure to properly identify and manage these indirect risks could lead to financial or operational impacts.
- **We consider evolving climate risks in our credit analysis.** Intensifying climate hazards, such as rising sea levels and changes in rainfall patterns, may transform industries and business processes. Whether physical climate risks related to value chains have material credit impacts depends on many issuer specificities.

Companies inherit physical climate risk exposures through their value chains



Source: S&P Global Ratings.

Physical Climate Risks Are Rising For Many Companies

Extreme weather events and chronic physical climate risks are worsening in many regions. Globally, economic losses reached $320 billion in 2024, up from an inflation-adjusted $268 billion in 2023. This is greater than the inflation-adjusted averages of the past 10 and 30 years, according to Munich Re, a global reinsurance company.

Economic losses from worsening climate hazards are also growing. Exposure to extreme weather events and chronic changes in climate is rising. Companies and governments may have to divert more of their budgets to addressing the risks posed by climate hazards.

Risk isn't isolated to an entity's own assets and operations. An entity or a sector's exposure to physical climate risks includes not only its direct exposure but also indirect exposure via its value chain. Whether due to commodity shortages, geopolitical tensions, logistical bottlenecks, or other causes, disruptions that originate in the value chain can reverberate outward. This can have meaningful operational and/or financial impacts on downstream sectors that depend on the inputs of critical goods and services.

A November 2024 report by S&P Global Market Intelligence, "Big Picture 2025 Supply Chain Outlook: Dealing With Consequences," argues the effects of worsening climate hazards on supply chains, a key component of value chains, can be significant for sectors and individual entities. This should be a growing focus of decision-makers' in siting and sourcing decisions, according to the report.

Impacts from climate hazards on individual companies can be substantial and compounded through value chains. This is despite such hazards often being temporary in nature and sometimes limited to specific sectors and/or geographies. Recent acute and chronic physical climate risks have caused many notable impacts, which have often cascaded through sectors via value chains.

- **Climate hazards affecting the River Rhine in Germany have led to disruptions numerous times in the past few years.** In 2021, the river burst its banks due to heavy rainfall and excess snowmelt, disrupting shipping for several days. The Rhine is one of Europe's most important commercial waterways for commodities such as grains and minerals. The most heavily affected states--North Rhine-Westphalia, and Rhineland-Palatinate--also incurred extensive damage to houses, roads, bridges and other infrastructure (see "Germany And Affected States Can Absorb Response To Devastating Floods," published July 21, 2021).

  A few months later, lower-than-expected rainfall forced cargo ships to reduce their loads by half to avoid grounding. Low water levels again in 2023 saw similar impacts, with vessel operators passing costs to cargo owners to compensate for vessels sailing at reduced capacity, as reported by Reuters. In each case, impacts cascaded through sectors. The energy sector saw significant delays, albeit temporarily, to coal, oil, and gas shipments. Agribusinesses and their downstream customers, meanwhile, suffered disruptions to fertilizer and grain imports. The projected impacts of a month with 30 days of low water levels in the River Rhine on Germany's GDP would be 1%, according to 2023 research led by Martin Ademmer.

- **In early 2023, authorities restricted both the number and size of ships passing through the Panama Canal.** The restrictions, enacted by the Panama Canal Authority, followed one of the driest years on record and historically low water levels in Lake Gatun. The canal is one of the busiest shipping routes in the world, carrying about 3% of world trade by volume each year. The result was disruption to global shipping, prompting shippers across both the bulk and containerized segments to shift their operations and cover higher costs. The Panama Canal

Authority has since announced an $8.5 billion investment to tackle water scarcity and enhance infrastructure. The project includes constructing the Rio Indio Lake and should help provide additional water resources and guarantee sustained reliability for the next 50 years (see "Tear Sheet: Autoridad del Canal de Panama S.A.," Dec. 23, 2024).

- **In Brazil, heavy flooding in the state of Rio Grande do Sul in May 2024 caused significant disruption within specific supply chains.** This affected the value chains of agricultural commodities such as soybeans, wheat, and tobacco, as well as auto parts. It was due to damage to roads, seaports, and airports. The state accounted for more than 93% of Brazil's total tobacco exports in the 12-months through to April 30, 2024 (see "Floods In Brazil's Rio Grande Do Sul State Disrupt Supply Chain," published June 4, 2024). Many of the corporate entities we rate had to halt operations for several days (see "Floods Could Amplify Logistics And Inflationary Strains On Some Brazilian Corporate Sectors," published May, 10. 2024).

The complexity and interdependencies of companies' value chains also contribute to significant disruption and additional costs. Where value chains are more sophisticated with more specialized inputs being traded, there are generally fewer substitution options. This increases the potential for greater transmission of the shock. For example, flooding in Thailand in 2011 caused significant disruption to supply of hard drives and semiconductors. This reached downstream companies in sectors including autos and electronics.

Some companies' value chains--particularly those in specialized sectors such as semiconductors (see "TSMC And Water: A Case Study Of How Climate Is Becoming A Credit-Risk Factor," published Feb. 26, 2024)--may be highly geographically concentrated in more exposed regions. This increases sensitivity of those networks (and those that rely on them) to climate shocks. The impacts of physical climate risks on companies' value chains can therefore cause ripple effects over much wider areas, further compounding economic losses in less developed countries where recovery is often slower (see "Is Climate Change Another Obstacle To Economic Development," published Jan. 16, 2023).

More frequent and severe physical climate risks can pose threats to companies with impacts that are not evenly distributed. By 2030, if mitigation is not stepped up, the number of climate-related disasters could be 40% higher than in 2015, according to a 2022 UN Office for Disaster Risk Reduction report. There could be about 250 events globally per year in such a scenario, the report states. And impacts will vary. Our research suggests that lower- and lower-middle income countries are up to 4.4x more exposed to climate hazards than more developed economies. These economies have the least capacity to adapt (see "Lost GDP: Potential Impacts Of Physical Climate Risks," Nov. 27, 2023).

Two factors may contribute to increased value-chain vulnerability of lower- and lower-middle income countries following climate events. First, these economies have higher concentrations of natural resources such as minerals, agricultural products, and oil and gas. Second, they tend to focus on primary resource extraction and manufacturing.

Companies' progress on adapting to the physical impacts of climate change is not keeping pace with worsening climate hazards. Only about one-fifth of companies have adaptation plans and less than half plan to implement their adaptation plans within the next decade, based on analysis of 6,871 company disclosures in the 2022 S&P Global Sustainable1 Corporate Sustainability Assessment (CSA). This leaves some companies vulnerable (see "Risky Business: Companies' Progress On Adapting To Climate Change," published April 3, 2024).

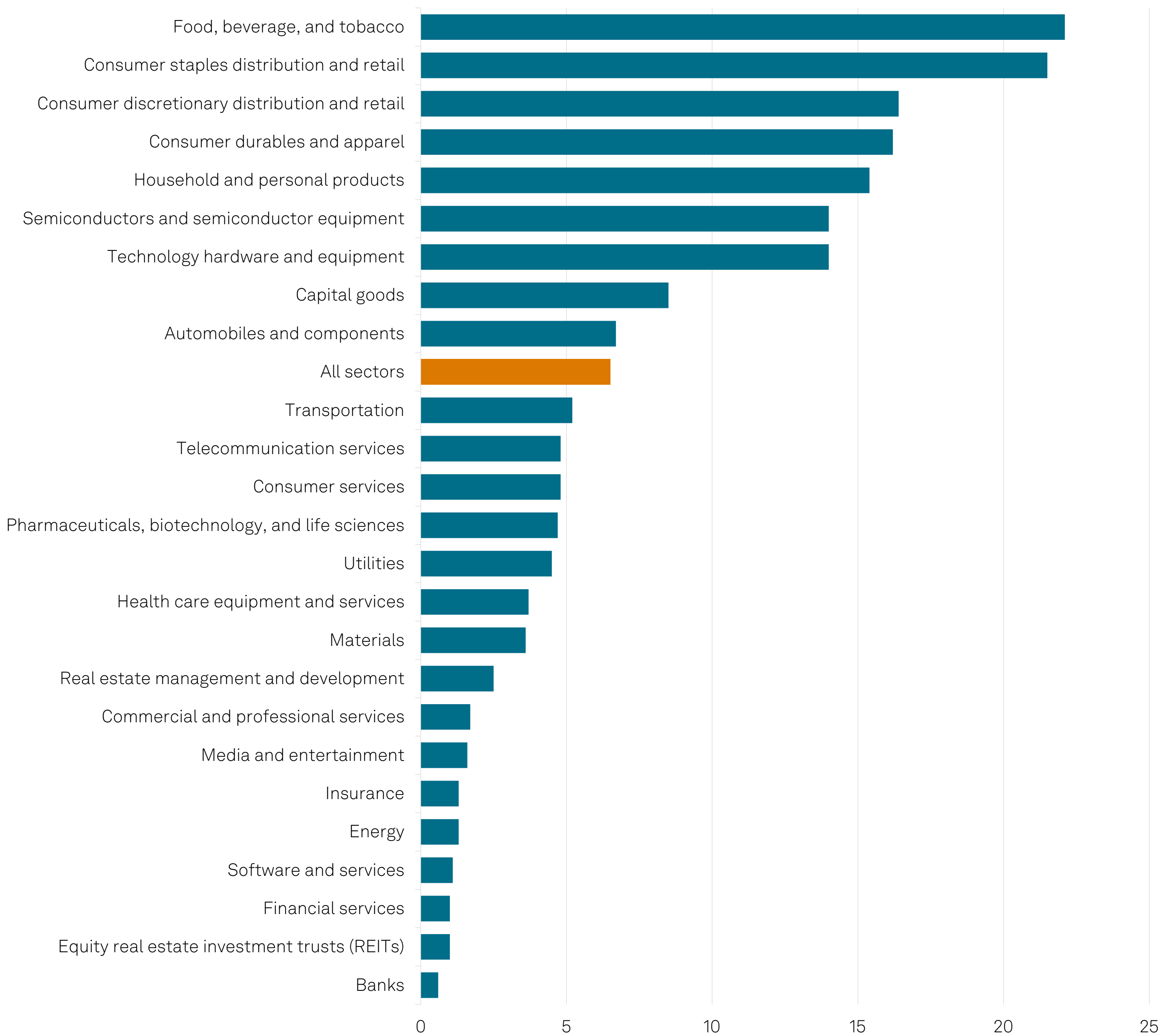
Supply chain management is also not widely considered a top material issue. According to responses from 12,490 companies to the CSA in 2023 (see chart 1), only 6.5% of companies chose supply chain management as a top material issue (see "Assessing The Missing Links In Supply

Chain Management," published April 30, 2024). In combination, worsening climate hazards and the limited progress made by some companies on adapting to those risks may contribute to reduced reliability of their value chains--more so for those companies that are more sensitive to the physical impacts of climate change.

Chart 1

Consideration of supply-chain management issues varies sharply by industry group

Companies by industry group that chose supply-chain management as a top material issue (%)



Data as of March 26, 2024. Results based on responses from 9,688 listed companies assessed on whether they publicly disclose a supplier code of conduct and 12,490 companies assessed on their top material issues in the 2023 S&P Global Corporate Sustainability Assessment (CSA). The CSA defines a supplier code of conduct as describing the principles, values, standards, or rules of behavior that guide the decisions, procedures, and systems of the supplier in a way that contributes to the welfare of its key stakeholders and respects the rights of all constituents affected by its operations. It usually includes at least three components: human rights and labor, environment, and business ethics. Source: S&P Global Sustainable1.

Physical Climate Risk: Pervasive And Possibly Hidden

According to the S&P Global Sustainable1 Physical Climate Risk dataset, the five sectors most directly exposed to nine physical climate risks (see box below) are agribusiness, forest and paper products, consumer (food), chemicals, and building materials (see chart 2). All sectors face at least moderate exposure, where the projected average sensitivity-weighted composite score this decade is between 30 to 69 out of 100.

What Do The Exposure Scores Mean?

The S&P Global Sustainable1 Physical Climate Risk dataset provides point-in-time exposure to climate hazards relative to global conditions. The exposure scores are normalized on a scale from 1 (lowest exposure) to 100 (highest exposure), representing the exposure of a given location to nine different climate hazards including extreme heat, extreme cold, wildfire, drought, water stress, coastal flooding (sea level rise), fluvial flooding (severe river flooding), pluvial flooding (severe rainfall), and storms (tropical cyclones, hurricanes, and typhoons). The exposure score represents the relative level of exposure for each climate hazard at each location, relative to global conditions and is available for four Shared Socioeconomic Pathways (SSPs) and timescales to the end of the century.

An exposure score between 1-29 out of 100 is considered low, while 30-69 is moderate, and 70-100 highly exposed.

The sensitivity-weighted composite score (hereafter, direct exposure) represents a sector's own direct exposure to changing climate hazards. Asset locations drive direct sector exposures to physical climate risks, which remain highly context and location specific.

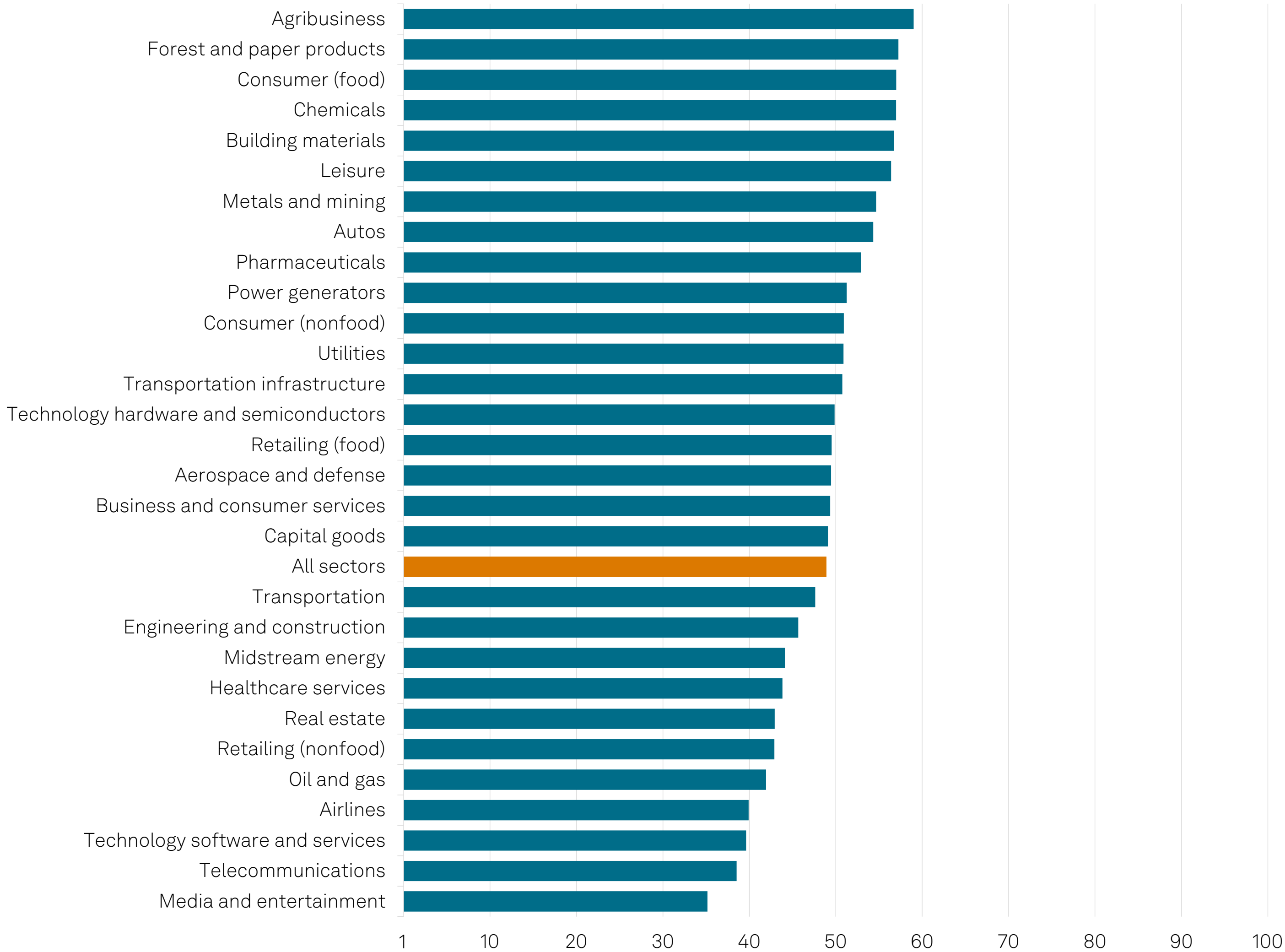
The data used to calculate the direct exposures, therefore, captures the exposure of companies' assets to all nine climate hazards averaged over the 2020-2029 period under a slow transition climate scenario (SSP3-7.0). This scenario equates to a rise in temperature from pre-industrial levels of about 2.1 C by 2050, or 3.6 C by the end of the century. Projected data is available until the end of the century.

Given the lock-in effect of historical greenhouse gas emissions, many physical risks of climate change will materialize regardless of today's policy choices. This is particularly the case for timepoints before the midcentury, as outlined in the Intergovernmental Panel on Climate Change (IPCC's) Sixth Assessment Report: Summary For Policymakers. Countries' current commitments, if met, align with a global temperature increase of 2.4C to 2.6C by 2100, according to the United Nations Environment Program. This is similar to SSP2-4.5. In this research we present findings using SSP3-7.0 through to 2050, which reflects this lock-in effect, and inherent challenges and uncertainties associated with long-term projections.

Chart 2

All sectors will have at least moderate direct exposure to climate hazards by 2030

Total average direct physical risk exposure score by sector under SSP3-7.0 in the 2020s



SSP3-7.0--A slow transition climate scenario. Note: The S&P Global Sustainable1 Physical Climate Risk dataset captures the direct exposure of companies' assets to climate hazards; it therefore excludes any value-chain exposures, such as through banks' and insurance companies' financed assets. Note: The Sensitivity Adjusted Composite Physical Risk Exposure Score ("direct" exposure) is intended to account for both exposure to climate hazards, and the expected sensitivity of companies and assets to each hazard, based on company-level data on water, capital, and labor intensity. Values from 30-69 are considered moderately exposed. Scoring scale 1 to 100 (most exposed/sensitive). Source: S&P Global Sustainable1, S&P Global Ratings.

The adaptation and resilience interventions required will vary. They will depend on where the companies' assets are located and the sensitivity of those assets to climate hazards. For example, companies with operations that are water intensive are likely to be more sensitive to constrained water supply and/or increased water costs than those that are less water intensive.

Likewise, extreme heat events reduce labor productivity more when work is conducted outdoors--such as in agriculture--due to heat stress and its impact on human health, than when activity is indoors, such as in the services sectors. In addition, companies in sectors with a lot of fixed assets--such as those in real estate or transportation infrastructure--face greater exposure to physical climate risks because they cannot be easily moved away from climate hazards (see "Corporate Physical Assets Increasingly In Harm's Way As Climate Change Intensifies," published Oct. 1, 2021).

More than half of sectors are projected to be more exposed to direct physical climate risks than the cross-sector average in the 2020s, absent adaptation. S&P Global Sustainable1's Physical-Risk Sensitivity-Weighted Composite Exposure Scores found 62% of sectors, or 18 of 29, will face higher exposure. The scores are based on the direct exposure of over 20,000 companies' assets, covering more than 98% of global market capitalization (see chart 2). The dataset captures the expected sensitivity of companies' assets to nine climate hazards. It excludes any value-chain exposures, such as through banks' and insurance companies' financed assets or food and beverage companies' exposure to a raw material input.

Direct sector exposure may not represent total exposure

Some sectors with complex and/or long value chains fall below the sector average direct exposure score. This is the case, for example, for companies in the engineering and construction and retailing (nonfood) sectors. Nevertheless, the impacts from physical climate risks could be significant where companies in those sectors face high indirect exposure to climate hazards in their value chains, absent adaptation to those risks.

For example, the retailing (nonfood) sector may rely on apparel companies in the consumer (nonfood) sector whose own suppliers rely on materials such as textiles, metals, plastics, and wood. The sector could be more indirectly exposed as worsening climate hazards affect agricultural outputs such as cotton. Those risks may spread to more sectors linked to the agricultural value chain (see "Agricultural Industry Is Still Sweating This Year's Droughts," Oct. 13, 2022). Understanding the full extent of sectoral exposure to physical climate risks, therefore, requires a view on these value-chain exposures.

How we assess physical climate risk in value chains

In this analysis, we estimate sector indirect exposures to physical climate risks through value chains. We focus on value chains rather than just supply chains. As explained in greater detail in the Appendix, value chains include all value-add activities, as captured in the U.S. BEA data. This value may come from activities outside of what is commonly considered part of a product supply chain, which typically includes just the steps required to transform raw materials into finished goods and deliver them to market.

To estimate the physical climate risk exposures inherited by sectors from their value chains, we take a three-step approach (see chart 3).

- **Step 1:** We examine economic relationships between sectors by building value-chain models for each sector, using input-output supply data from the U.S. BEA to determine the proportion of a sector's total output that comes from a contributing sector's input. We use these percentages as the basis for estimating how physical risk realized in one sector might be passed onto other sectors.
- **Step 2:** To calculate the physical climate risk exposure one sector inherits from another via its value chain, we use the quantitative economic relationships (represented as percentages) established in the value-chain models as weightings and multiply them by each contributing sector's direct physical risk exposure.
- **Step 3:** To calculate each sector's overall value chain physical risk exposure, we sum the internal value chain and each upstream sector's weighted value-chain exposures.

Chart 3

Three-step process to calculating each sector's value-chain physical climate risk exposure

		Step 1		Step 2			Step 3
		Value contribution to Sector X's output		Upstream sector's direct exposure		Weighted value chain exposure	Sector X's aggregate value chain exposure
Internal value chain	Sector X	12.5%	x	50	=	6.3	10.5
Upstream sectors	Sector 1	4.2%	x	32	=	1.3	
	Sector 2	3.5%	x	65	=	2.3	
	Sector 3	1.6%	x	21	=	0.3	
	Sector 4	0.7%	x	37	=	0.3	

Notes: In the example, Sector X's value chain physical climate risk exposure includes the weighted exposure inherited from five upstream sectors. "Exposure" refers to physical climate risk exposure. Source: S&P Global Ratings.

Inherited Value-Chain Exposure Can Be Sizeable

All sectors inherit at least some physical climate risk exposure from their value chains (see chart 4). However, the magnitude of value-chain exposures to physical climate risks are heterogeneous.

The agribusiness sector has the greatest exposure to physical climate hazards through its value chain. That is under a slow transition scenario, SSP3-7.0 (see chart 4). We expect those sectors that rely more heavily on their value chains for contributions to their own output--such as agribusiness, chemicals, or autos--will see the most pronounced value chain exposure. This effect can be particularly acute for sectors heavily reliant on more highly exposed upstream sectors.

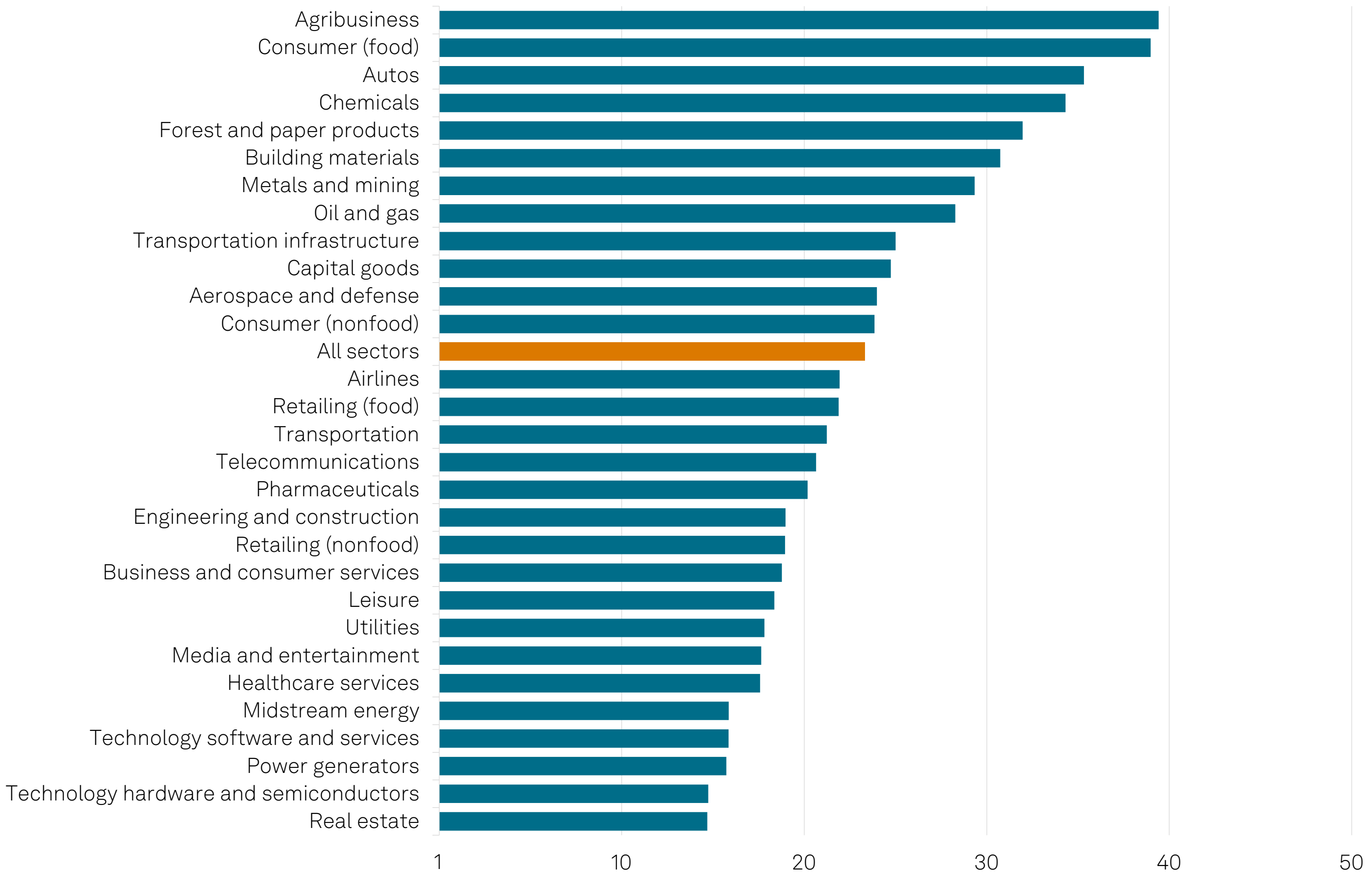
The consumer (food) sector is a particularly strong example of a sector with upstream exposures that compound already high direct exposures. The consumer (food) sector depends on its value chain for nearly 71% of its output (the highest percentage of all 29 sectors; see Table A1 in the Appendix). And agribusiness--the sector with the greatest direct exposure--alone contributes 32.2% of value to consumer (food) companies. Consequently, companies in this sector aiming to most effectively manage their inherited exposures to climate hazards may consider looking beyond their own assets and operations to their key upstream agribusiness suppliers.

We describe the components that we may use to assess the efficacy of companies' adaptation plans in "Risky Business: Companies' Progress On Adapting To Climate Change," published April 3, 2024. We view adaptation plans that can demonstrate a greater number of these components as advanced and believe companies with such plans are likely to be well placed to adapt to and cope with physical climate risks.

Chart 4

Sectors with greater economic dependency on highly exposed upstream sectors inherit more physical climate risk exposure from their value chains

Value-chain physical risk exposure scores by sector



Notes: Under a slow transition climate scenario (SSP3-7.0) in the 2020s. The S&P Global Sustainable1 Physical Climate Risk dataset captures the direct exposure of companies' assets to climate hazards; it therefore excludes any value chain exposures, such as through banks' and insurance companies' financed assets, which are omitted from this chart. Scores based on decadal average. Excludes extreme cold due to reduced impact of this hazard with greater warming. The sensitivity of companies to climate hazards is based on company-level data on water, capital, and labor intensity. Source: U.S. BEA, S&P Global Sustainable1, S&P Global Ratings.

Other sectors, such as building materials, could also see significant inherited physical climate risk exposures from their value chains. This is because companies in the chemicals and metals and mining sectors--which include fixed assets like factories, mines, and specialist processing facilities--contribute nearly a quarter of the value of the building materials sector's total output.

Not all value chain exposures are inherited from upstream sectors--internal sector value chains can also exacerbate a sector's exposure to physical climate risks. The chemicals sector provides a good example. Chemicals companies depend on other companies in the same sector, such as those that process raw materials or produce specialty chemicals inputs, for 34.2% of the value of their output (see table A1 in the Appendix). This trade within the sector, therefore, compounds the high direct exposures it already faces. Chemical companies face direct physical climate risks threatening their own facilities and those risks facing peers within their sector on which they rely.

Power generators (30%) and real estate (34%) are examples of sectors that draw relatively less value from their value chains. They therefore see relatively modest value chain exposures (see chart 4).

Value-chain exposures can be considered with direct exposures

Some sectors see relatively high exposure to climate hazards from both direct and value chain sources. The consumer (food), agribusiness, autos, and chemicals sectors are among the most exposed sectors in terms of both direct and value-chain exposures (see top right quadrant of chart 5). It is these sectors that face outsize exposures, absent efforts to adapt and build resilience to worsening climate hazards. There may also be cases where a sector may have less direct exposure to climate hazards but comparatively greater exposure through their value chains.

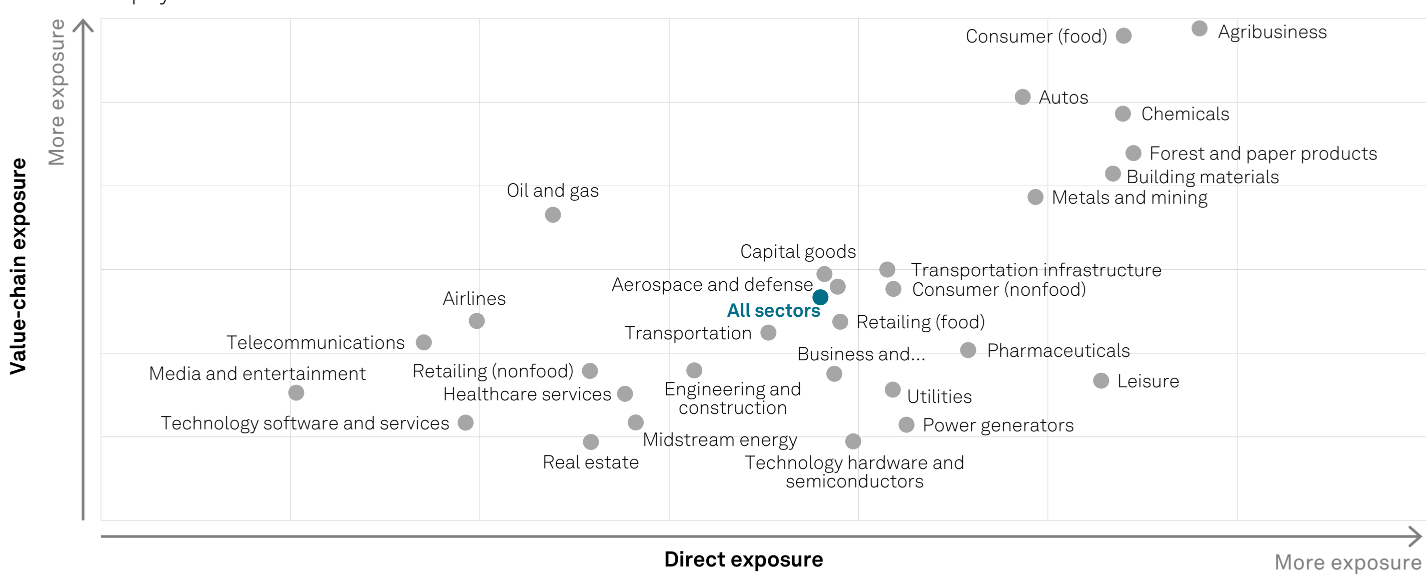
Sectors with relatively lower direct exposures may nevertheless have comparatively higher value-chain exposures. Airline companies, for instance, are themselves not highly exposed to climate hazards. However, they rely heavily on airport operators and other entities in the transportation infrastructure sector, and thus, may be more greatly exposed to both acute and chronic climate hazards (see "Scenario Analysis Shines A Light On Climate Exposure: Focus On Major Airports," published Nov. 5, 2020, and "ESG Materiality Map: Airlines," published July 20, 2022) through these entities. Consequently, while airlines ranks as the 26th most directly exposed sector (out of 29) in our analysis, it is 13th from a value-chain perspective.

The value-chain exposure of the oil and gas sector moves it from the 25th most exposed sector when looking just at direct exposures, to the 8th most exposed from its value-chain exposures. The oil and gas sector derives about 64% of its total output value from its value chain. Other companies within the sector (internal value chain) account for 44% of total value. However, a further 20% of value comes from upstream sectors that are generally more highly exposed to climate shocks, such as chemicals and metals and mining (see table A1 in the Appendix for a full breakdown of sector value contributions).

Chart 5

Physical risk exposure can be viewed through direct exposure and value-chain exposure

Sectors located farther up and to the right may be relatively more exposed to both direct and value-chain physical climate hazards



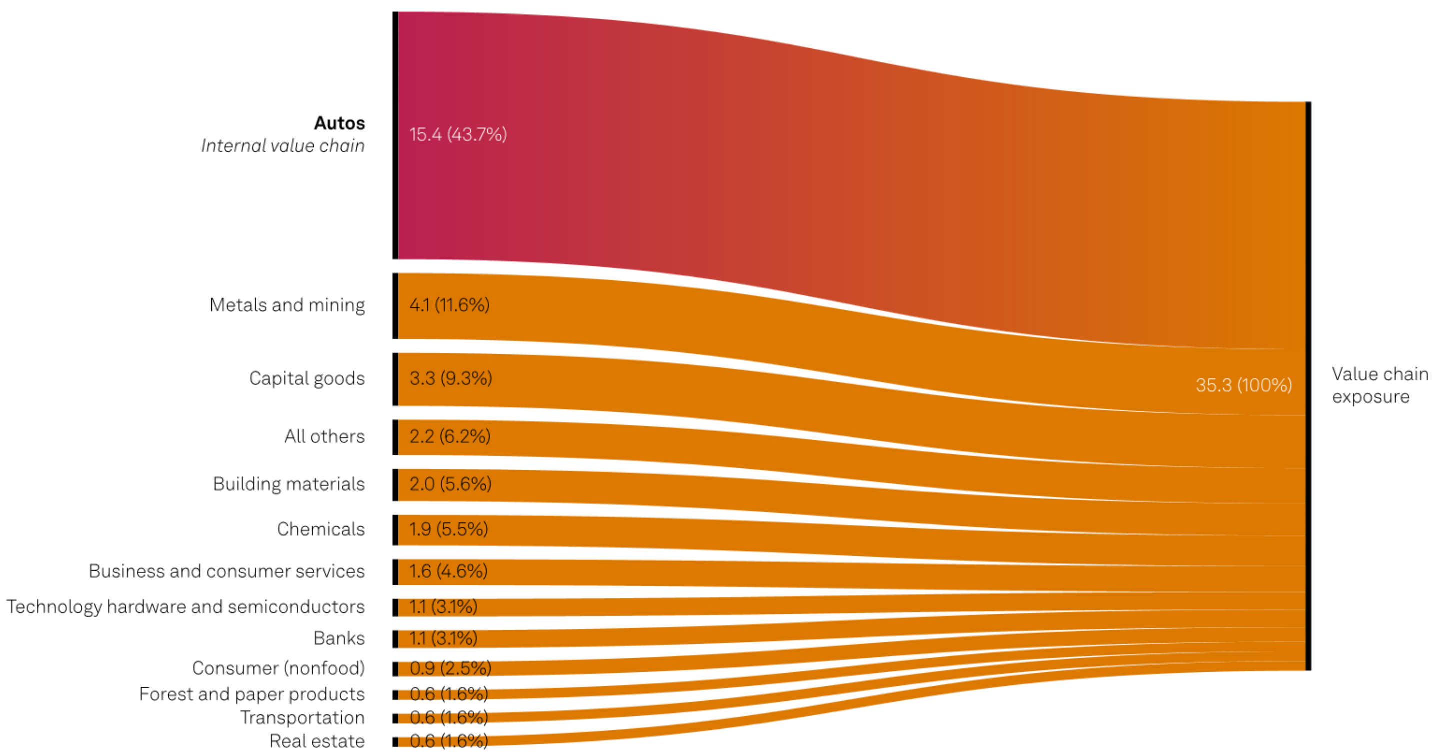
Notes: Under a slow transition climate scenario (SSP3-7.0) in the 2020s. The S&P Global Sustainable1 Physical Climate Risk dataset captures the direct exposure of companies' assets to climate hazards; it therefore excludes any value chain exposures, such as through banks' and insurance companies' financed assets, which are omitted from this chart. Scores based on decadal average. Data sorted in descending order by total physical climate risk exposure score. Excludes extreme cold due to reduced impact of this hazard with greater warming. The sensitivity of companies to climate hazards is based on company-level data on water, capital, and labor intensity.
Sources: S&P Global Sustainable1, S&P Global Ratings.

The data can be helpful for examining the precise source of value-chain exposures. For example, the autos sector depends on contributions from many sectors for the value of its output (see table A1 in the Appendix). This contrasts with the consumer (food) sector, which inherits substantial exposure from just one upstream sector (agribusiness). Certain upstream sectors for autos, such as metals and mining and capital goods, may be particularly exposed to worsening climate hazards, such as flooding and extreme temperatures. These hazards can damage assets and/or cause disruption. The autos sector also depends heavily on its own internal value chain (that is, auto parts manufacturers supplying auto companies), which alone contributes 43.7% of the sector's value-chain exposure to physical climate risks (see chart 6).

Chart 6

43.7% of autos sector value chain physical climate exposure comes from suppliers within the sector

Sectoral contribution to the autos sector value chain physical risk exposure



Note: Under SSP3-7.0 in the 2020s. Source: US BEA, S&P Global Sustainable1, S&P Global Ratings.

By the 2050s, value-chain exposures to climate hazards rise for all sectors in a slow transition scenario (SSP3-7.0), absent adaptation

With more time and under more severe warming scenarios, economies could see rising losses across all scenarios and timepoints. By 2050, if global warming does not stay well below 2 C, up to 4.4% of the world's GDP could be lost annually, absent adaptation (see "Lost GDP: Potential Impacts Of Physical Climate Risks," Nov. 27, 2023). Faced with worsening climate hazards, and without adaptation and resilience investments, companies in the most climate-sensitive sectors could see outsize impacts on both their own assets and operations and those in value chain partners on which they rely.

Across all sectors, we find direct and value-chain risk exposure to potential climate impacts is set to rise by more than 8% by 2050, under a slow transition scenario (SSP3-7.0) and absent adaptation. While this is based on a static view of sectoral distributions and geographical locations in the economy, it informs us of the rising importance of climate risks, all other things equal. It suggests companies will increasingly be forced to actively manage this risk directly and within their supply-chains. Any active management would be a mitigating factor not accounted for by our metrics. It can affect the risk distribution by 2050.

Importantly, direct sector physical climate risk exposure is projected to increase for 93% of sectors--27 of 29--by the 2050s. Sectors with the greatest increase in direct exposure by midcentury are those with comparatively more fixed assets (see table 1). These include oil and gas (19.9% increase, or a rise in direct physical climate risk exposure score of 8.3 points); real estate (16.7%, 7.2 points); utilities (16.4%, 8.4 points); and midstream energy (14.5%, 6.4 points).

Sectors that have links to the natural environment such as forest and paper products (10.9%, 6.4 points) and agribusiness (9.8%, 6.4 points) also see significant increases in direct exposure by midcentury under SSP3-7.0. The implication is that companies in highly exposed sectors will continue to face outsized exposure to worsening climate hazards, absent adaptation. We have previously described the relatively limited progress made by many companies in addressing adaptation (see "Risky Business: Companies' Progress On Adapting To Climate Change," published April 3, 2024). Among consumer staples companies, which includes consumer (food), agribusinesses, and forest and paper products companies, only 23% (119 of 519) disclosed that they have an adaptation and resilience plan.

Value-chain physical climate risk exposure is projected to increase for all sectors by the 2050s. This is under SSP3-7.0, absent adaptation and assuming that sector value contributions remain constant. As a consequence, managing the impacts posed by worsening climate hazards to companies' value chains are likely to be increasingly important for those sectors with the greatest change in value-chain exposure, where those risks are not otherwise being managed. The sectors with the greatest increases in value chain exposure by the 2050s are: oil and gas (15.7% increase, or a rise in value-chain exposure to climate hazards of 4.4 points), agribusiness (10.8%, 4.2 points), chemicals (10%, 3.7 points) and forest and paper products (10%, 3.4 points). Across all sectors, value-chain exposures increase on average by 8.2%.

Table 1

Direct and value chain exposure to potential climate impacts is set to rise by more than 8%, under a slow transition scenario (SSP3-7.0) and absent adaptation by the 2050s

	Direct exposures				Value chain exposures			
Sector	**2020s**	**2050s**	**Change**	**%**	**2020s**	**2050s**	**Change**	**%**
Aerospace and defense	49.5	51.7	2.2	4.5%	24.0	25.4	1.4	5.9%
Agribusiness	59.0	65.5	6.4	10.9%	39.4	43.7	4.2	10.8%
Airlines	39.9	39.1	-0.9	-2.2%	21.9	23.8	1.9	8.6%
Autos	54.3	57.1	2.8	5.1%	35.3	37.7	2.4	6.7%
Building materials	56.7	61.0	4.2	7.5%	30.7	33.5	2.8	9.1%
Business and consumer services	49.4	51.0	1.6	3.3%	18.8	19.9	1.1	6.1%
Capital goods	49.1	52.5	3.4	7.0%	24.7	26.4	1.6	6.6%
Chemicals	57.0	63.7	6.7	11.8%	34.3	38.0	3.7	10.7%
Consumer (food)	57.0	62.6	5.6	9.8%	39.0	42.7	3.7	9.6%
Consumer (nonfood)	50.9	54.5	3.6	7.1%	23.8	25.4	1.6	6.6%
Engineering and construction	45.7	50.0	4.4	9.6%	19.0	20.3	1.3	7.0%

	Direct exposures				Value chain exposures			
Sector	**2020s**	**2050s**	**Change**	**%**	**2020s**	**2050s**	**Change**	**%**
Forest and paper products	57.3	64.3	7.0	12.3%	32.0	35.4	3.4	10.7%
Healthcare services	43.8	46.4	2.5	5.8%	17.6	18.8	1.2	7.0%
Leisure	56.4	58.8	2.3	4.2%	18.4	19.6	1.3	6.9%
Media and entertainment	35.2	35.4	0.2	0.6%	17.6	18.3	0.6	3.5%
Metals and mining	54.7	61.1	6.4	11.7%	29.3	32.1	2.8	9.4%
Midstream energy	44.1	50.5	6.4	14.5%	15.9	17.0	1.1	7.1%
Oil and gas	41.9	50.3	8.3	19.9%	28.3	32.7	4.4	15.7%
Pharmaceuticals	52.9	58.3	5.4	10.2%	20.2	21.9	1.8	8.7%
Power generators	51.3	58.2	7.0	13.6%	15.7	17.0	1.2	7.8%
Real estate	42.9	50.1	7.2	16.7%	14.7	15.6	0.9	6.4%
Retailing (food)	49.5	53.3	3.8	7.6%	21.9	23.6	1.7	7.8%
Retailing (nonfood)	42.9	46.1	3.2	7.5%	18.9	20.0	1.1	5.8%
Technology hardware and semiconductors	49.9	54.1	4.2	8.5%	14.7	15.9	1.1	7.8%
Technology software and services	39.6	37.6	-2.0	-5.1%	15.9	16.4	0.5	3.2%
Telecommunications	38.5	41.3	2.7	7.1%	20.6	21.9	1.2	5.9%
Transportation	47.6	51.3	3.7	7.8%	21.2	22.8	1.6	7.4%
Transportation infrastructure	50.8	53.8	3.0	6.0%	25.0	27.1	2.1	8.4%
Utilities	50.9	59.3	8.4	16.4%	17.8	19.4	1.5	8.7%
All sectors	**48.9**	**53.1**	**4.1**	**8.5%**	**23.3**	**25.2**	**1.9**	**8.2%**

Note: values are rounded. Based on a static view of the economy, not accounting for adaptation to climate hazards, changes in economy's geography and structure, or any other growth dynamics. Source: S&P Global Sustainabl1, S&P Global Ratings.

Results may misstate total sector physical climate risk exposures

We identify three primary reasons why the value chain physical risk exposure estimates may be under- or overstated, with additional analytical limitations identified in the appendix:

- Our value-chain models are based on the value-added contribution to total output. However, the degree to which one sector relies on another may not be fully reflected in that value contribution. For instance, an automaker may require a relatively low value component to complete and ship a car. That part may contribute little value, but its absence could severely disrupt the automaker's ability to get its products to market.

- Our analysis does not account for potential secondary (and compounding) effects as value-chain exposures feed back into and contribute to higher direct physical climate risk exposures used to calculate upstream exposures.

- Our approach assumes that climate hazard exposures are independent. That is, the likelihood of occurrence and any associated impacts-- should they materialize-- of a specific climate hazard is unrelated to the annual frequency and impact of all other climate hazards.

Value Chains And Credit Risk: Constantly Evolving

As identified in our Oct. 17, 2023, report "Supply-Chain Risks: A Credit Perspective," S&P Global Ratings takes into consideration disruptions where their materiality and severity could dampen the capacity and willingness of an entity to meet its financial commitments. The report identifies negative ratings actions related to supply chain events on more than 200 corporate issuers between 2020 and the end of 2022.

Physical climate hazards are among those risks that could cause material value-chain disruptions. However, the actual financial impact of a physical climate hazard in the value chain will depend on the nature of the impact and unique characteristics of a company. Among other things, exposure to physical climate risks is heterogenous, and the geography of one company's value chain may differ substantially from that of its broader sector. These factors can increase or decrease sensitivity to climate hazards.

The total value-chain-adjusted sector physical climate risk exposures provide directional insight into the degree of upstream exposure to climate hazards. For entity level analysis, it is therefore important to consider the specific channels through which physical climate risks may be transmitted through value chains leading to financial impact. Considering company-specific factors that may increase or decrease the likelihood of these impacts materializing is also important.

Factors can offset or exacerbate potential impacts of value-chain risk

Here we explore the key transmission channels through which these risks can lead to financial impacts and the individual company or value-chain characteristics that can either exacerbate or mitigate that exposure.

Value-chain risks may manifest as financial risks through three key transmission channels. These are operational disruption, increased input costs, and/or adaptation and resilience investments (see chart 7).

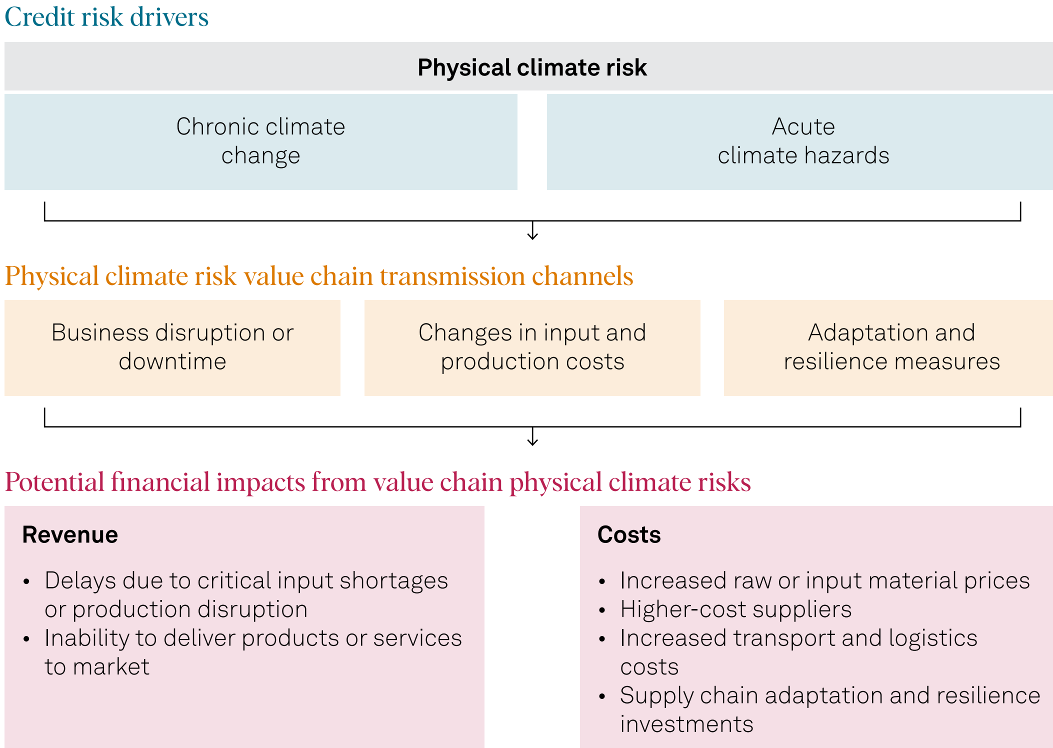
- **Business disruption or downtime**: Physical climate events, particularly those impacting upstream materials or production sites and transportation infrastructure hubs, can lead to delays in accessing critical inputs, disruptions in production, or the ability to deliver products or services to market, with direct effects on revenue generation.

- **Changes in input and production costs**: The effects of physical climate risks can limit input supply and increase input material prices, force companies to source from more expensive suppliers, or increase transportation and logistics costs resulting in margin pressures.

- **Costs of adaptation and resilience measures:** Exposure to physical climate risks may prompt investments associated with adapting business or supply-chain models to build resilience and more proactively mitigate exposures, adding near-term costs even if they prove to be beneficial in the longer term.

Chart 7

How physical climate risks in value chains can lead to material financial impacts



Source: S&P Global Ratings

The sensitivity of any one company to these transmission channels will hinge on certain attributes of its value-chain structure. These include:

- **Geographic concentration:** Because climate events are location specific (though the scope of geographic impact can vary widely), geographic concentration of a company's suppliers, nodes of transport (such as seaports), critical input materials, or costumer markets could heighten the risk that a weather event creates a material disruption. The semiconductor industry, on which many downstream companies rely, for instance, is heavily concentrated in East Asia, and Taiwan and South Korea in particular.
- **Supply-chain model:** The supply-chain or sourcing model that a company employs can influence whether a disruption can be more easily managed. A just-in-time model, for instance, may be more vulnerable to impacts from a disruption. This is because a company may not have the inventory on hand to bridge the supply gap a disruption causes. Like geographic concentration, a heavy reliance on a few strategic suppliers may introduce further vulnerabilities to weather-based disruptions. On the other hand, strategic relationships with a few key suppliers may enhance a company's ability to work with those suppliers on more actively managing risk and building resilience to climate hazards.
- **Substitutability of inputs:** A company that relies on more specialized inputs is likely to be more vulnerable to material financial impacts arising from value-chain disruptions. Greater substitutability of inputs (and the suppliers of those inputs), on the other hand, increases the likelihood that a company could quickly find viable alternatives, at reasonable prices, elsewhere.

- **Redundancy and planning:** Companies that proactively monitor physical risks plan for potential disruption can be expected to respond more quickly and effectively to manage the potentially deleterious impacts of a physical climate event in their value chains.
- **Where in the value chain a physical climate risk resides can also influence a company's ability to manage it.** If the physical climate risk exposure exists in a company's tier 1 supplier base, they are likely to have greater visibility into and control over managing and mitigating those risks, for instance, through working with strategic suppliers on resilience measures or by diversifying the geographic concentration of its suppliers. If the risks, however, reside further up a value chain--such as with raw materials--companies are likely to have less visibility into and ability to manage those risks effectively. And the measures available to adapt with tier 1 suppliers (such as geographic diversity) may be offset by, for instance, heavy geographic concentration of tier 2 or above suppliers.

We consider climate risks in our credit rating analysis

Climate change is a megatrend that has a magnitude we would typically consider high. This is because of both climate transition risks and physical climate risks. The impact of climate change ranges from the potential disruption on a company's business model due to economies moving away from reliance on fossil fuels to the increasing frequency and severity of physical climate risks due to a rise in temperature, even under the global scientific consensus' most optimistic transition scenario.

We find that clarity of how physical climate and climate transition risks are transmitted to creditworthiness and, ultimately to credit ratings is generally low. For physical climate risks, this is due to the inherent unpredictability of the timing and extent of climate hazards. Similarly for climate transition risks, many aspects of the transition are still evolving, including technology, public policy, and market changes or requirements related to mitigating climate change (see "Assessing How Megatrends May Influence Credit Ratings," published April 18, 2024).

We consider uncertainty about the effects of climate change in our credit analysis. Our long-term issuer credit ratings do not have predetermined time horizons. The uncertainty about when and how a credit factor can change can be very high. With risks related to climate change--which can have a high magnitude should an event occur, and low clarity of how these risks are transmitted to credit risk--we would typically continue monitoring it without necessarily making specific assumptions about it in our analysis. However, as the timing and likelihood of events become clearer, we may incorporate the impact of those risks into our view of creditworthiness. We therefore analyze long-dated risks such as climate risk exposure: These megatrends may be slow moving, but they can transform industries and business processes in fundamental ways.

In "Evolving Risks In North American Corporate Ratings," published Oct. 29, 2024, and "Evolving Risks In North American Corporate Ratings: Supply Chain Disruption," published Oct. 29, 2024, we outlined some megatrends. These included climate change (climate transition risks and physical climate risks) and supply-chain disruptions. We considered their impact on North American corporate sectors, and how they may influence credit quality.

Looking Ahead

More frequent and severe climate hazards are increasingly exposing companies to impacts, touching all sectors in some way--and to varying extents-- without efforts to adapt. Investments in adaptation and resilience may protect companies and countries from climate shocks.

There may be a positive externality--or ripple effect--of the benefit of adaptation and resilience investments. For example, companies with operations in countries that are better adapted to worsening climate hazards are more likely to indirectly benefit from more robust infrastructure. Policies that provide effective support in the face of, or following, climate shocks also can be of benefit. Adaptation in one sector may also contribute to the resilience of one or multiple downstream sectors via value-chain effects.

Understanding companies' value chain exposures to physical climate risks can also help prioritize areas where investments in adaptation and resilience may have the greatest impact on supply chain resilience. By analyzing specific vulnerabilities, investments may be directed toward adaptive solutions, such as infrastructure hardening and supply chain diversification. At the same time, those investments may foster innovation in terms of the technologies, products, or services that are needed to address the threats posed by worsening climate hazards.

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Steven Ader and Andrew Palmer of S&P Global Ratings contributed to the penultimate subsection on value chains and credit risks. The authors also thank members of the S&P Global Ratings Sustainability Insights Scientific Council for their contributions to this research.

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Appendix

Our approach to building sector value chain models and applying them to physical climate risk data to calculate sector value chain physical climate risk exposures is described below, followed by detailed sector-by-sector results in tables A1 and A2. Limitations of the approach and analysis are described thereafter.

Estimating physical climate risk exposures from sector value chains

To estimate the physical climate risk exposures inherited by sectors from their value chains, we take a three-step approach. Note that we describe our approach to building sector value chain models (step 1), including its limitations, in greater detail below.

- **Step 1: Build economic sector value chain models:** We first examine the relationships between sectors through their value chains, based on the value contribution of one sector into the outputs of another sector. To do so, we use input-output supply data from the U.S. BEA. Input-output data provides insight into the interdependencies between different sectors, illustrating how the value of one sector's total output might depend on inputs from other sectors. The total value of a sector's output is the sum of value contributed by upstream sectors, the sector's own internal value chain, and its direct value add (see definitions in the box below).

Definitions: Origin of value in a sector's total output

The total value of a sector's output can come from three sources:

Upstream: Value contributed by other sectors through input into the value of a given sector's output. For example, a metals and mining company's supply of steel to an autos company for the body of a car, or a business services company's provision of strategic consulting services to an autos company. This also includes the value from indirect inputs, such as the raw materials that go into intermediate inputs supplied to a sector.

Internal value chain: The value a sector derives through inputs from entities from *within* its same sector. For example, an auto parts company supplying an auto manufacturer within the broader autos sector.

Direct value add: A sector's own value contribution through an entity's value-add activities. For example, the value an auto manufacturer creates on its own by designing and assembling a car**.**

- We use this data to identify sector-to-sector economic relationships based on the percentage of one sector's output that is dependent upon another sector's input. For example, according to the BEA data, for every $100 of output from the autos sector, $7.50 (or 7.5%) of that value comes from value contributed through inputs from the metals and mining sector (e.g. the steel that goes into the bodies of automobiles). These percentages can then be used as weightings in the next step to layer in the exposure of sectors to physical climate risks.

- **Step 2: Calculate each sector's value-chain physical climate risk exposure:** To then estimate the physical climate risk exposure each sector inherits from its value chain, we start with the sector direct physical climate risk exposures scores calculated using the Physical Climate Risk dataset from S&P Global Sustainable1. We then use the quantitative economic relationships established in the value-chain models, represented as percentages, as weightings and multiply them by each contributing sector's (including upstream sectors and the sector's own internal value chain) direct physical climate risk exposure score.

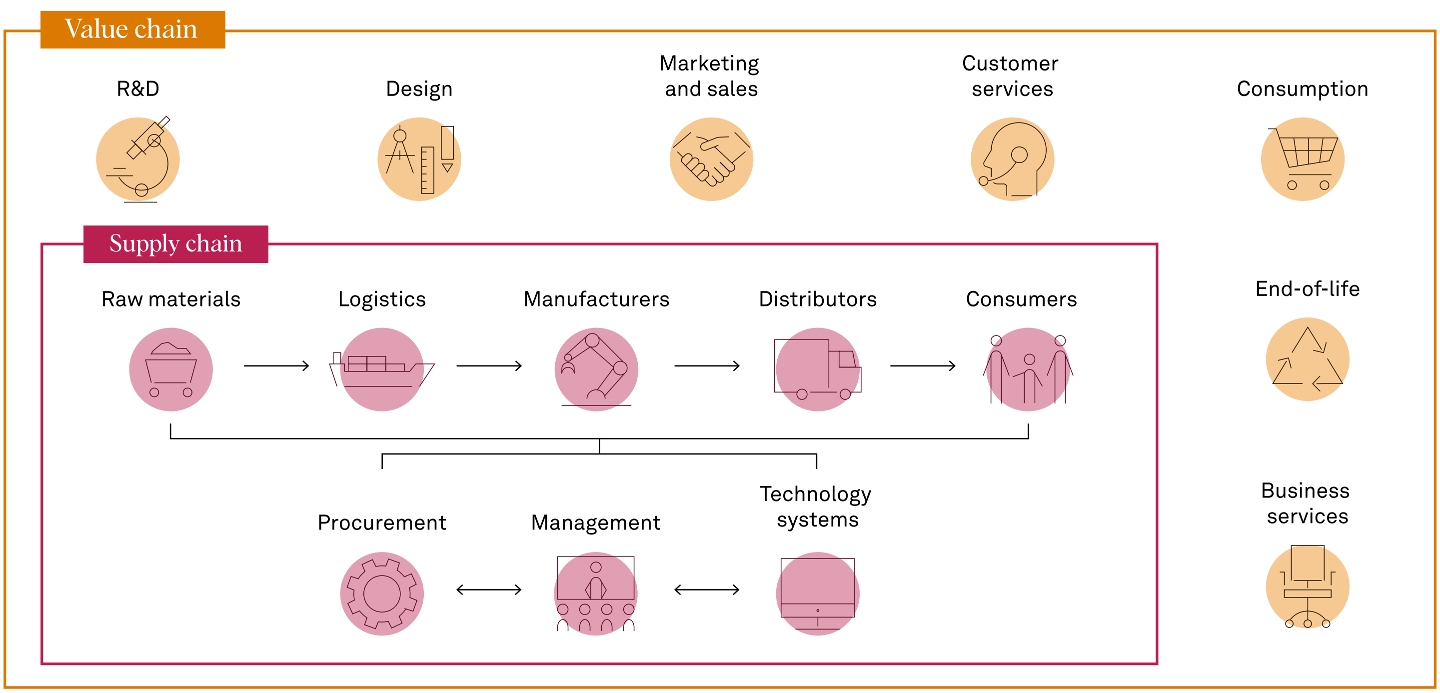
- The metals and mining sector, for instance, has a direct physical climate risk exposure score of 55 out of 100 (scores between 30 and 69 out of 100 are considered moderately exposed) and contributes 7.5% of value to the autos sector. Autos therefore inherits 4.1 points (55 multiplied by 0.075) of additional value-chain exposure from the metals and mining sector. See table A2 below for detail on each sector's value chain exposures and the sectors that contribute those exposures.
- **Step 3: Calculate each sectors total value-chain exposure:** To calculate the total value chain exposure of a sector, we sum the weighted physical climate risk exposures from all upstream sectors and the internal value chain to estimate the overall physical climate risk exposure inherited by a given sector from its value chain.

Building sector value chain models (step 1)

Input-output data provides insight into the economic relationships between sectors. Economic input-output data illustrate how sectors of the economy interact with one another, and specifically, how the output of one sector is used as an input by another sector for its own output. For example, the input-output data can show how much value the semiconductor industry contributes to the value of output from the consumer electronics industry.

Chart A1

A value-chain analysis is inclusive of value-added inputs beyond just the supply chain



Source: S&P Global Ratings.

In this analysis, we use the September 2023 update of the U.S. BEA input-output accounts supply tables. This dataset provides a detailed account of how 402 individual industries, based on the North American Industry Classification System (NAICS), interact with one another through the contribution to or use of economic value. We map each of the BEA industries into our own 32 sector classifications and then calculate each sector's use of value contributed from other sectors as a percentage of that sector's total output value. In doing so, we create 32 individual sector value-chain models based on each sector's economic relationships with other sectors (see Table A1 below for full detail on each sector's input percentages).

A value chain perspective is broader than a strictly supply chain approach. Because the data we use is based on value-added input, it is important to bear in mind that these value-chain models are broader in their perspective than a model that is strictly looking at the supply chain. The supply chain is more narrowly focused on the specific steps involved in transforming raw materials into finished goods and delivering those goods to market. Indeed, value can be added at all stages of a product or service lifecycle, including research and development at the early stages and business and customer service support in later stages (see chart A1).

Value can be added from upstream sectors or from within a sector. Because we are analyzing value-added input at all stages of the product lifecycle and not according to a typical supply-chain flow, we are concerned with the origin of value, whether from upstream sources, a sector's internal value chain, or its own value-add activities (see the Definitions box above).

As a consequence, each sector's value-chain model can be broken down into value originating from three sources: 1) The value from the inputs coming from upstream sectors (either directly or through other upstream sectors). 2) The value from the sector's internal value chain (such as an auto parts manufacturer supplying an auto manufacturer). 3) The value that entities within a sector originate directly (through, for instance, the assembly and marketing of a product).

A sector's total output value equals the sum of value coming from upstream inputs, internal sector value chain inputs, and the sector's own value-add activities. This output can then be used as input into further production by downstream sectors or for end use by final consumers.

Sectors exhibit varying degrees of economic dependency on upstream sectors relative to their own internal sector value chains and direct value add. Chart A2 breaks down the proportion each of our 32 sectors' total output by origin of value. As can be seen, a sector's reliance on value from upstream sectors can range substantially, from 55% of value from upstream sectors for the consumer (food) sector to just 13% for the pharmaceuticals sector. While some sectors are highly reliant on upstream value, sectors like pharmaceuticals, oil and gas, and technology hardware and semiconductors originate more value from within their own sector.

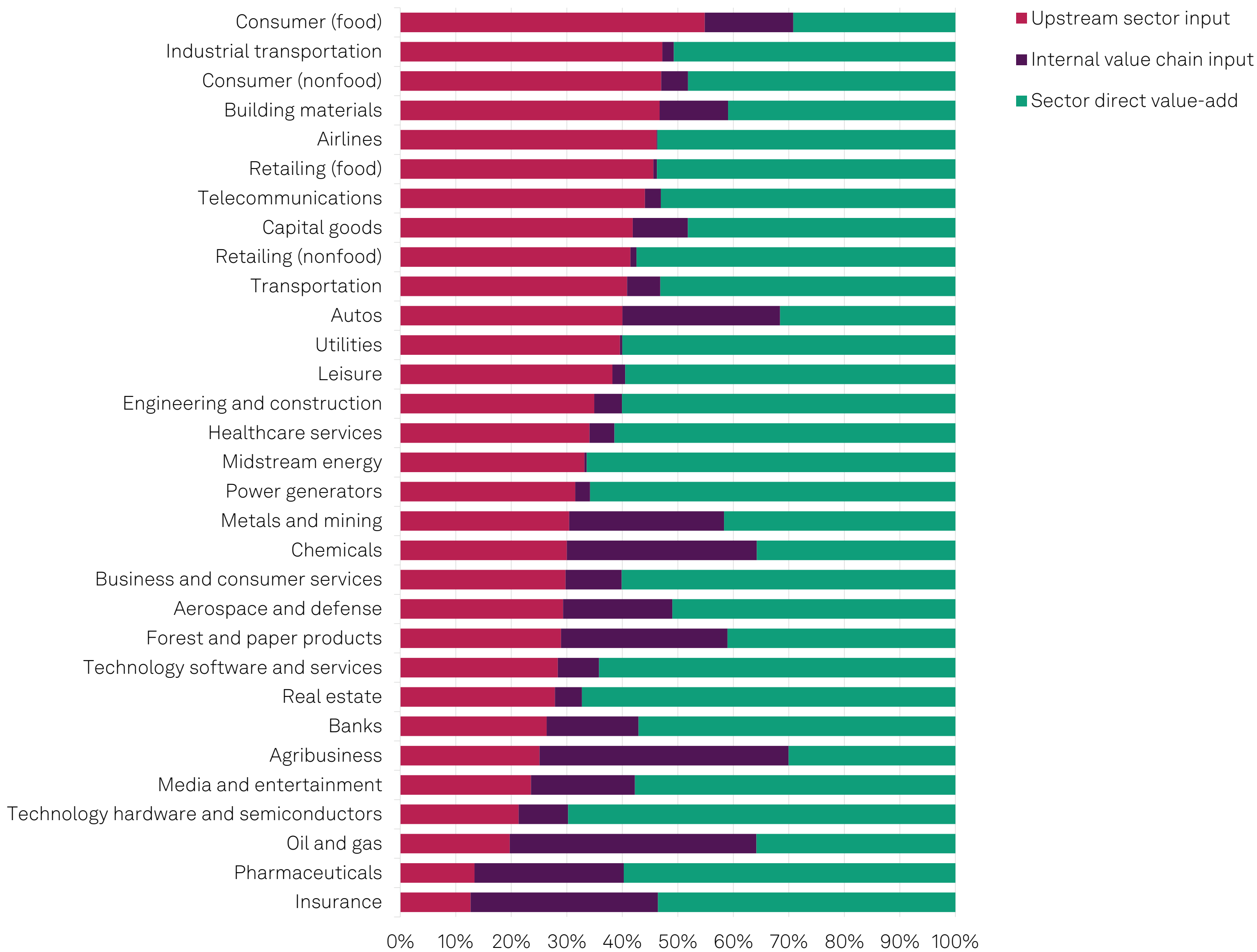
Value also originates from a sector's internal value chain and its direct value-add activities. For instance, the autos sector derives 60% of the value of outputs from within the sector. The origin of that 60% own-sector value contribution, however, is split almost evenly between the internal sector value chain (e.g. value from auto parts supplied to auto manufacturers) and the sector's direct value-add activities (e.g. value from an auto manufacturer's assembly of a finished car). By comparison, the technology software and services sector generates 64% of its output value from direct value-add activities, relying on the sector's internal value chain for just 7.4% of value-add and the remaining 28.6% from upstream sectors.

For each sector, we also derive the specific value contributions from other sectors. This approach allows us to break down the proportion of value contributed by other sectors. In the autos sector example presented in chart A3 below, for instance, we find that 40% of value comes from upstream sectors, most notably metals and mining (7.5%), capital goods (6.7%), building materials (3.5%), and chemicals (3.4%). And within each of these sectors we can take a more granular view on the specific commodity categories that are being utilized by the autos sector. From minerals and mining, for instance, the predominant upstream input into the Autos sector is steel flowing to automotive parts manufacturers.

Chart A2

Sectoral dependence upon other sectors for the value of inputs into their output varies

Sectoral source of value chain inputs (as a % of total sector output)

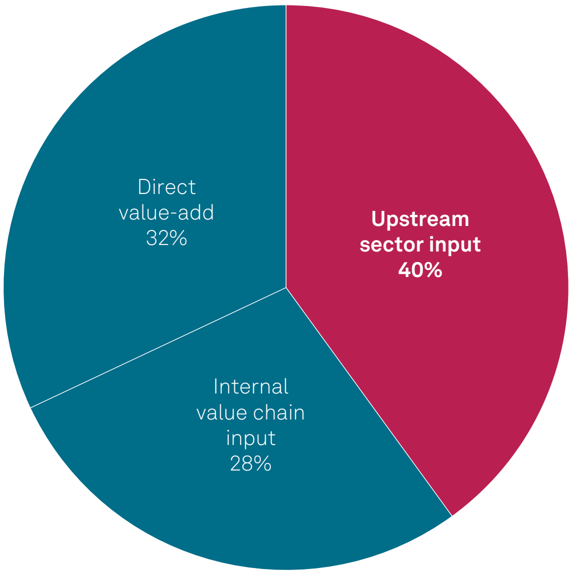


Source: U.S. BEA, S&P Global Ratings.

Chart A3

Sectoral origin of value for the autos sector

Origin of value as a percent of the auto sector's total output



Upstream sector	% of total output
Metals and mining	7.5%
Capital goods	6.7%
Building materials	3.5%
Chemicals	3.4%
Business and consumer services	3.3%
Banks	3.0%
Technology hardware and semiconductors	2.2%
Consumer (nonfood)	1.7%
Real estate	1.3%
Media and entertainment	1.2%
Transportation	1.2%
Forest and paper products	1.0%
Insurance	0.9%
Leisure	0.6%
Power generators	0.6%
Airlines	0.5%
Engineering and construction	0.4%
Technology software and services	0.3%
Retailing (nonfood)	0.3%
Healthcare services	0.2%
Oil and gas	0.2%
Retailing (food)	0.1%
Utilities	0.1%
Telecommunications	0.1%
Aerospace and defense	0.1%
Agribusiness	0.0%
Consumer (food)	0.0%
Industrial transportation	0.0%
Midstream energy	0.0%
Pharmaceuticals	0.0%

Source: U.S. BEA, S&P Global Ratings.

These sectoral value-add contributions form the basis for weighting and estimating value-chain exposures to physical climate risks. To apply these value chain models to the question of value chain physical climate risk exposure (which includes exposures from upstream sectors and the internal value chain), we weight risk exposure contributions from each upstream sector and the internal value chain by their percent value contribution to a sector's total output. The aggregate of these exposures form the sector's total value-chain physical risk exposure.

Value-added inputs into sector outputs (%)

Summary statistics of the value-added input percentages by sector are provided in table A1.

Table A1

Value contribution by sector of origin as percent of use sector total output

	Use sectors																														
Supply sectors	Aerospace and defense	Agribusiness	Airlines	Autos	Banks	Building materials	Business and consumer services	Capital goods	Chemicals	Consumer (food)	Consumer (nonfood)	Engineering and construction	Forest and paper products	Healthcare services	Industrial transportation	Insurance	Leisure	Media and entertainment	Metals and mining	Midstream energy	Oil and gas	Pharmaceuticals	Power generators	Real estate	Retailing (food)	Retailing (nonfood)	Technology hardware and semiconductors	Technology software and services	Telecommunications	Transportation	Utilities
Aerospace and defense	19.7	0.0	0.9	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0
Agribusiness	0.0	44.9	0.0	0.0	0.0	0.2	0.2	0.0	5.9	32.2	0.9	0.0	0.5	0.3	0.0	0.0	1.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	3.9	0.2	0.0	0.0	0.0	0.0	0.1
Airlines	0.0	0.0	0.2	0.5	0.5	0.2	0.4	0.3	0.1	0.1	0.2	0.4	0.1	0.2	0.0	0.0	0.3	0.2	0.2	0.1	0.0	0.0	0.3	0.4	0.2	0.2	0.0	0.7	0.2	0.6	0.2
Autos	1.3	0.5	0.2	28.4	0.0	0.8	1.6	3.5	0.5	1.2	0.7	0.3	1.5	0.2	0.1	0.0	0.6	0.2	1.1	0.9	0.2	0.0	0.0	0.0	0.5	1.2	0.2	0.0	0.1	2.4	0.0
Banks	2.1	1.1	2.9	3.0	16.6	2.9	3.1	5.1	3.0	3.5	8.4	2.2	1.3	4.0	1.4	1.5	4.5	2.4	4.7	4.5	3.2	3.6	2.3	5.3	6.6	4.8	2.2	2.2	2.2	3.9	4.9
Building materials	1.4	0.3	0.0	3.5	0.0	12.3	3.1	2.1	2.0	2.3	1.2	1.9	1.7	1.0	14.0	0.0	1.2	0.6	1.6	1.7	0.2	0.4	0.0	2.9	0.9	0.8	2.4	0.8	2.2	0.6	0.0
Business and consumer services	3.5	1.3	2.1	3.3	9.3	4.5	10.1	6.6	3.2	2.4	7.7	10.2	3.3	7.5	3.2	4.9	5.9	8.4	4.6	4.4	2.9	3.3	10.4	8.1	5.5	10.1	3.4	10.4	8.7	6.4	8.7
Capital goods	3.9	1.0	6.3	6.7	0.2	3.7	2.0	10.0	2.2	1.3	1.8	1.9	2.4	0.6	6.6	0.3	1.5	1.4	4.9	6.1	1.4	0.1	0.9	1.0	0.2	0.5	3.7	0.6	2.7	2.7	1.5
Chemicals	0.7	4.4	0.0	3.4	0.1	11.8	1.1	1.0	34.2	3.3	4.3	1.6	6.0	1.0	1.8	0.0	0.5	0.2	2.2	0.3	5.1	1.7	0.6	0.6	1.6	0.3	0.9	0.2	0.3	0.1	0.3
Consumer (food)	0.0	5.7	0.4	0.0	0.0	0.0	0.1	0.0	0.3	16.0	0.0	0.0	0.1	0.5	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	0.3	0.0	0.0	0.0	0.1	0.3
Consumer (nonfood)	0.4	0.2	0.0	1.7	0.0	0.6	0.6	0.9	0.3	0.0	4.8	0.1	1.6	0.4	1.2	0.0	1.3	0.1	0.2	0.8	0.1	0.0	0.0	0.7	0.3	0.9	0.2	0.1	0.4	0.1	0.0
Engineering and construction	1.1	0.1	0.1	0.4	0.3	0.6	1.2	0.8	0.3	0.3	0.3	5.0	0.6	0.5	8.0	0.0	0.4	0.2	0.8	2.6	0.3	0.5	0.3	1.4	0.2	0.3	2.4	1.3	4.0	0.5	2.3
Forest and paper products	0.0	3.7	0.0	1.0	0.1	0.8	1.2	0.4	0.7	1.3	1.5	0.2	30.0	0.2	2.4	0.0	0.8	0.2	0.4	0.2	0.1	0.0	0.0	0.9	0.4	0.4	0.5	0.2	0.3	0.5	0.0
Healthcare services	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Industrial transportation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Insurance	0.2	0.7	0.3	0.9	1.2	0.4	0.8	1.4	0.4	0.6	1.3	0.9	0.3	1.4	0.1	33.7	1.5	0.4	1.0	1.2	0.7	0.2	0.5	1.6	0.8	1.4	0.1	0.4	0.1	2.8	0.4
Leisure	0.1	0.0	13.0	0.6	1.0	0.6	1.2	0.9	0.2	0.2	1.0	1.2	0.4	0.6	0.0	0.4	2.3	1.9	0.3	0.4	0.2	0.0	2.8	0.5	0.6	1.5	0.0	1.3	0.7	6.5	1.4
Media and entertainment	0.5	0.2	0.8	1.2	2.9	0.7	2.2	1.4	0.5	1.0	2.6	0.9	0.4	1.3	0.3	1.9	3.6	18.7	0.4	0.4	0.2	0.6	0.8	0.6	3.2	4.3	0.3	3.5	9.7	0.8	0.7

	Use sectors																													
Supply sectors	Aerospace and defense	Agribusiness	Airlines	Autos	Banks	Building materials	Business and consumer services	Capital goods	Chemicals	Consumer (food)	Consumer (nonfood)	Engineering and construction	Forest and paper products	Healthcare services	Industrial transportation	Insurance	Leisure	Media and entertainment	Metals and mining	Midstream energy	Oil and gas	Pharmaceuticals	Power generators	Real estate	Retailing (food)	Retailing (nonfood)	Technology hardware and semiconductors	Technology software and services	Telecommunications	Transportation	Utilities
Metals and mining	4.3	0.4	0.0	7.5	0.0	11.1	0.4	8.0	2.0	1.0	2.0	4.9	2.4	0.2	1.8	0.0	0.3	0.3	27.9	6.0	2.2	0.0	1.4	0.2	0.2	0.1	2.1	0.1	0.3	0.3	0.3
Midstream energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil and gas	0.1	1.8	13.9	0.2	0.7	2.3	0.9	0.3	3.6	0.5	0.5	0.4	1.1	0.2	2.9	0.0	0.6	0.1	2.0	0.9	44.4	0.1	6.3	0.5	0.5	0.4	0.7	0.3	0.1	8.0	9.9
Pharmaceuticals	0.0	0.4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.3	0.4	2.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	26.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Power generators	0.6	0.7	0.1	0.6	0.4	1.9	0.5	0.7	1.9	0.9	0.8	0.3	2.4	0.8	0.5	0.1	1.1	0.5	2.4	0.9	0.9	0.4	2.7	1.0	2.8	1.6	0.5	0.3	0.4	0.6	2.2
Real estate	0.4	0.8	0.1	1.3	3.6	1.0	3.9	1.9	0.3	0.7	5.8	2.9	0.4	6.1	0.6	2.0	6.7	2.4	0.5	0.5	0.3	1.0	1.6	4.9	7.2	6.2	1.1	2.0	5.4	1.8	1.8
Retailing (food)	0.0	0.1	3.7	0.1	0.9	0.1	0.8	0.3	0.1	0.1	0.3	1.1	0.1	1.5	0.1	0.3	1.1	0.2	0.2	0.1	0.0	0.0	0.6	1.0	0.7	0.5	0.0	1.0	0.2	0.3	0.4
Retailing (nonfood)	0.0	0.3	0.0	0.3	0.1	0.4	0.3	1.3	0.6	0.6	0.6	0.1	0.4	0.1	0.1	0.1	0.3	0.3	0.2	0.1	0.1	0.0	0.0	0.1	0.2	1.1	0.0	0.1	0.2	0.7	1.8
Technology hardware and semiconductors	6.5	0.0	0.0	2.2	0.5	0.9	0.7	1.3	0.9	0.5	0.8	0.9	0.7	1.6	1.3	0.0	0.4	1.2	0.9	0.6	0.2	0.4	0.0	0.1	0.1	0.3	8.9	1.6	3.0	0.1	0.0
Technology software and services	1.8	0.1	0.5	0.3	3.0	0.6	2.0	1.2	0.2	0.3	1.3	1.2	0.4	0.6	0.5	0.8	1.1	1.4	0.5	0.1	0.5	0.1	1.7	0.2	1.2	1.6	0.4	7.4	2.0	0.4	1.2
Telecommunications	0.1	0.0	0.1	0.1	0.5	0.1	0.4	0.2	0.0	0.0	0.2	0.3	0.0	0.2	0.2	0.1	0.3	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.1	0.4	2.9	0.1	0.1
Transportation	0.1	0.2	0.4	1.2	0.7	0.2	1.0	1.6	0.1	0.1	2.2	0.6	0.2	0.9	0.1	0.2	0.9	0.8	0.2	0.2	0.3	0.0	0.3	0.3	1.0	2.8	0.1	0.8	0.7	6.0	1.0
Utilities	0.1	1.0	0.0	0.1	0.2	0.3	0.1	0.1	0.7	0.2	0.1	0.0	0.4	0.1	0.1	0.0	0.4	0.0	0.2	0.2	0.4	0.1	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.2	0.4
Total value chain	**49.0**	**70.0**	**46.3**	**68.4**	**42.9**	**59.1**	**39.9**	**51.8**	**64.2**	**70.8**	**51.8**	**40.0**	**59.0**	**38.6**	**49.3**	**46.4**	**40.5**	**42.3**	**58.3**	**33.6**	**64.2**	**40.2**	**34.2**	**32.7**	**46.3**	**42.6**	**30.3**	**35.8**	**47.0**	**46.9**	**40.0**
Direct value add	51.0	30.0	53.7	31.6	57.1	40.9	60.1	48.2	35.8	29.2	48.2	60.0	41.0	61.4	50.7	53.6	59.5	57.7	41.7	66.4	35.8	59.8	65.8	67.3	53.7	57.4	69.7	64.2	53.0	53.1	60.0
Total output	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: S&P Global Ratings.

Origin of physical climate risk exposure by sector

Summary statistics of the physical climate risk exposures by sector, including value-chain exposures and direct exposures, are provided in the table below.

Table A2

Total physical climate risk exposure contribution by sector of origin

	Sector physical climate risk exposures																												
Contributing sectors	Aerospace and defense	Agribusiness	Airlines	Autos	Building materials	Business and consumer services	Capital goods	Chemicals	Consumer (food)	Consumer (nonfood)	Engineering and construction	Forest and paper products	Healthcare services	Transportation infrastructure	Leisure	Media and entertainment	Metals and mining	Midstream energy	Oil and gas	Pharmaceuticals	Power generators	Real estate	Retailing (food)	Retailing (nonfood)	Technology hardware and semiconductors	Technology software and services	Telecommunications	Transportation	Utilities
Aerospace and defense	9.7	0.0	0.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Agribusiness	0.0	26.5	0.0	0.0	0.1	0.1	0.0	3.5	19.0	0.5	0.0	0.3	0.2	0.0	0.6	0.0	0.0	0.0	0.1	0.1	0.0	0.0	2.3	0.1	0.0	0.0	0.0	0.0	0.1
Airlines	0.0	0.0	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.2	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.3	0.1	0.2	0.1
Autos	0.7	0.3	0.1	15.4	0.4	0.9	1.9	0.3	0.7	0.4	0.2	0.8	0.1	0.1	0.3	0.1	0.6	0.5	0.1	0.0	0.0	0.0	0.3	0.7	0.1	0.0	0.1	1.3	0.0
Banks	0.8	0.4	1.1	1.1	1.1	1.1	1.9	1.1	1.3	3.1	0.8	0.5	1.5	0.5	1.6	0.9	1.7	1.6	1.2	1.3	0.8	1.9	2.4	1.7	0.8	0.8	0.8	1.4	1.8
Building materials	0.8	0.2	0.0	2.0	7.0	1.8	1.2	1.1	1.3	0.7	1.1	1.0	0.6	7.9	0.7	0.3	0.9	1.0	0.1	0.2	0.0	1.6	0.5	0.5	1.4	0.5	1.2	0.3	0.0
Business and consumer services	1.7	0.6	1.0	1.6	2.2	5.0	3.3	1.6	1.2	3.8	5.0	1.6	3.7	1.6	2.9	4.1	2.3	2.2	1.4	1.6	5.1	4.0	2.7	5.0	1.7	5.1	4.3	3.2	4.3
Capital goods	1.9	0.5	3.1	3.3	1.8	1.0	4.9	1.1	0.6	0.9	0.9	1.2	0.3	3.2	0.7	0.7	2.4	3.0	0.7	0.0	0.4	0.5	0.1	0.2	1.8	0.3	1.3	1.3	0.7
Chemicals	0.4	2.5	0.0	1.9	6.7	0.6	0.6	19.5	1.9	2.5	0.9	3.4	0.6	1.0	0.3	0.1	1.3	0.2	2.9	1.0	0.3	0.3	0.9	0.2	0.5	0.1	0.2	0.1	0.2
Consumer (food)	0.0	3.2	0.2	0.0	0.0	0.1	0.0	0.2	9.1	0.0	0.0	0.1	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.2	0.0	0.0	0.0	0.1	0.2
Consumer (nonfood)	0.2	0.1	0.0	0.9	0.3	0.3	0.5	0.2	0.0	2.4	0.1	0.8	0.2	0.6	0.7	0.1	0.1	0.4	0.1	0.0	0.0	0.4	0.2	0.5	0.1	0.1	0.2	0.1	0.0
Engineering and construction	0.5	0.0	0.0	0.2	0.3	0.5	0.4	0.1	0.1	0.1	2.3	0.3	0.2	3.7	0.2	0.1	0.4	1.2	0.1	0.2	0.1	0.6	0.1	0.1	1.1	0.6	1.8	0.2	1.1
Forest and paper products	0.0	2.1	0.0	0.6	0.5	0.7	0.2	0.4	0.7	0.9	0.1	17.2	0.1	1.4	0.5	0.1	0.2	0.1	0.1	0.0	0.0	0.5	0.2	0.2	0.3	0.1	0.2	0.3	0.0
Healthcare services	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Insurance	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.0	0.2	0.0	0.2	0.1	0.1	0.2	0.1	0.0	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.4	0.1

Sector physical climate risk exposures

Contributing sectors	Aerospace and defense	Agribusiness	Airlines	Autos	Building materials	Business and consumer services	Capital goods	Chemicals	Consumer (food)	Consumer (nonfood)	Engineering and construction	Forest and paper products	Healthcare services	Transportation infrastructure	Leisure	Media and entertainment	Metals and mining	Midstream energy	Oil and gas	Pharmaceuticals	Power generators	Real estate	Retailing (food)	Retailing (nonfood)	Technology hardware and semiconductors	Technology software and services	Telecommunications	Transportation	Utilities
Leisure	0.1	0.0	7.3	0.3	0.3	0.7	0.5	0.1	0.1	0.6	0.7	0.2	0.3	0.0	1.3	1.1	0.2	0.2	0.1	0.0	1.6	0.3	0.3	0.8	0.0	0.7	0.4	3.7	0.8
Media and entertainment	0.2	0.1	0.3	0.4	0.2	0.8	0.5	0.2	0.4	0.9	0.3	0.1	0.5	0.1	1.3	6.6	0.1	0.1	0.1	0.2	0.3	0.2	1.1	1.5	0.1	1.2	3.4	0.3	0.2
Metals and mining	2.4	0.2	0.0	4.1	6.1	0.2	4.4	1.1	0.5	1.1	2.7	1.3	0.1	1.0	0.2	0.2	15.3	3.3	1.2	0.0	0.8	0.1	0.1	0.1	1.1	0.1	0.2	0.2	0.2
Midstream energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil and gas	0.0	0.8	5.8	0.1	1.0	0.4	0.1	1.5	0.2	0.2	0.2	0.5	0.1	1.2	0.3	0.0	0.8	0.4	18.6	0.0	2.6	0.2	0.2	0.2	0.3	0.1	0.0	3.4	4.2
Pharmaceuticals	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.2	0.2	1.2	0.0	0.1	0.0	0.0	0.0	0.0	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Power generators	0.3	0.4	0.1	0.3	1.0	0.3	0.4	1.0	0.5	0.4	0.2	1.2	0.4	0.3	0.6	0.3	1.2	0.5	0.5	0.2	1.4	0.5	1.4	0.8	0.3	0.2	0.2	0.3	1.1
Real estate	0.2	0.3	0.0	0.6	0.4	1.7	0.8	0.1	0.3	2.5	1.2	0.2	2.6	0.3	2.9	1.0	0.2	0.2	0.1	0.4	0.7	2.1	3.1	2.7	0.5	0.9	2.3	0.8	0.8
Retailing (food)	0.0	0.0	1.8	0.0	0.0	0.4	0.1	0.0	0.0	0.1	0.5	0.0	0.7	0.0	0.5	0.1	0.1	0.0	0.0	0.0	0.3	0.5	0.3	0.2	0.0	0.5	0.1	0.1	0.2
Retailing (nonfood)	0.0	0.1	0.0	0.1	0.2	0.1	0.6	0.3	0.3	0.3	0.0	0.2	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.1	0.3	0.8
Technology hardware and semiconductors	3.2	0.0	0.0	1.1	0.4	0.3	0.6	0.4	0.2	0.4	0.4	0.3	0.8	0.6	0.2	0.6	0.4	0.3	0.1	0.2	0.0	0.0	0.0	0.1	4.4	0.8	1.5	0.0	0.0
Technology software and services	0.7	0.0	0.2	0.1	0.2	0.8	0.5	0.1	0.1	0.5	0.5	0.2	0.2	0.2	0.4	0.6	0.2	0.0	0.2	0.0	0.7	0.1	0.5	0.6	0.2	2.9	0.8	0.2	0.5
Telecommunications	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	1.1	0.0	0.0
Transportation	0.0	0.1	0.2	0.6	0.1	0.5	0.8	0.0	0.0	1.0	0.3	0.1	0.4	0.0	0.4	0.4	0.1	0.1	0.1	0.0	0.1	0.1	0.5	1.3	0.0	0.4	0.3	2.9	0.5
Transportation infrastructure	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Utilities	0.1	0.5	0.0	0.1	0.2	0.1	0.1	0.4	0.1	0.1	0.0	0.2	0.1	0.1	0.2	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.2
Total value chain exposure	**24.0**	**39.4**	**21.9**	**35.3**	**30.7**	**18.8**	**24.7**	**34.3**	**39.0**	**23.8**	**19.0**	**32.0**	**17.6**	**25.0**	**18.4**	**17.6**	**29.3**	**15.9**	**28.3**	**20.2**	**15.7**	**14.7**	**21.9**	**18.9**	**14.7**	**15.9**	**20.6**	**21.2**	**17.8**
Direct exposure	49.5	59.0	39.9	54.3	56.7	49.4	49.1	57.0	57.0	50.9	45.7	57.3	43.8	50.8	56.4	35.2	54.7	44.1	41.9	52.9	51.3	42.9	49.5	42.9	49.9	39.6	38.5	47.6	50.9

Source: S&P Global Ratings.

Limitations

We describe some of the limitations and assumptions of our analysis below. This list is not exhaustive.

- **Economic dependency is just one measure of sectoral value chain relationships.** We use value contribution in these models to provide the foundation for value chain exposures. We recognize, however, that this is just one perspective on and mechanism for measuring relationships between sectors and the likelihood that a risk embedded in a sector's value chain might be transmitted to cause a meaningful impact. In some instances, economic value contribution may understate (or potentially overstate) real risk exposures. Take, for example, a sector that may only rely on a particular upstream component for a small percentage of the value-add in its final products, but without that component, or a viable substitute, the product is unworkable and cannot go to market. A disruption in the supply of that component can have substantial negative consequences, irrespective of its economic value contribution.
- **U.S. BEA input-output data is centered on the U.S.** The BEA use tables provide information on input sectors globally. However, they are reflective of how sectors in the U.S. use those inputs from a value-add standpoint. While sectors in other geographic regions may exhibit different use patterns, we believe that U.S. sector use is broadly representative of global patterns, particularly given the U.S. economy's relative size, complexity, diversity, and openness. While sectors in other locations may exhibit different patterns, we assume that they may not differ too much from the U.S. on average. That said, differences in regional company structures and business models are still likely. This reflects historical differences in local industry networks, and market and regulatory dynamics specific to each country.
- **Input-output data does not shed light on which phase in the value chain the value originates.** While we can identify the sector of value origin, we cannot necessarily determine whether that value (and by extension, the value chain physical climate risk exposure) comes from, for example, tier 1 suppliers or further up the chain. Where the exposure originates has important implications for the degree to which an entity can actively and effectively manage that risk. If the risk is from a tier 1 supplier, with which an entity has a direct contractual relationship, the entity has more visibility into that risk and more levers at its disposal to manage the risk. If, on the other hand, the risk exposure resides with a tier 2 supplier or above, the entity may not have similar visibility and ability to manage.
- **U.S. BEA input -output data does not include the geographic origin on input.** The BEA data used in this analysis is valuable for its level of commodity disaggregation. This allows us to map to our own sector classifications and view sector relationship dynamics at a more granular level. In contrast to other input-output datasets, this data does not include the geographic origin of input. The physical climate risk data we use from S&P Global Sustainable 1 inherently embeds geographic exposures to physical climate hazards. However, we recognize that having data on the geographic origin of value (in addition to the sectoral origin of value) could further enhance our analysis and would be crucial for any issuer level analysis of value chain physical climate exposures.
- **Our analysis considers the exposure of entities to physical climate risks, but it does not capture the adaptation and resilience interventions either planned or in place.** Due to data availability and the lack of comparable metrics, the measures that may be taken by companies to adapt and build resilience to the physical impacts of climate change are not factored into our analysis.

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- Assessing How Megatrends May Influence Credit Ratings, Apr. 18, 2024
- Risky Business: Companies' Progress On Adapting To Climate Change, April 3, 2024
- ESG In Credit Ratings Deep Dive: ESG Factors Drove 13% Of Corporate And Infrastructure Rating Actions Since 2020, Mar. 13, 2024
- TSMC And Water: A Case Study Of How Climate Is Becoming A Credit-Risk Factor, Feb. 26, 2024
- Tear Sheet: Autoridad del Canal de Panama S.A., Dec. 23, 2024
- Lost GDP: Potential Impacts Of Physical Climate Risks, Nov. 27, 2023
- Supply Chain Risks: A Credit Perspective, Oct. 17, 2023
- Is Climate Change Another Obstacle To Economic Development, Jan. 16, 2023
- ESG Materiality Map: Health Care Services, Oct. 27, 2022
- Carbon Pricing, In Various Forms, Is Likely To Spread In The Move To Net Zero, Aug. 9, 2022
- Corporate Physical Assets Increasingly In Harm's Way As Climate Change Intensifies, Oct. 1, 2021
- Germany And Affected States Can Absorb Response To Devastating Floods, Jul. 21, 2021
- Strong Connections Or Weak Links: How Global Supply Chains Affect Credit Quality, Oct. 4, 2011

External Research

- Ademmer, M., Jannsen, N. and Meuchelböck, S. (2023) Extreme Weather Events and Economic Activity: The Case of Low Water Levels on the Rhine River. German Economic Review, 24 (2), 121-144.
- EMDAT (2019) The emergency events database.
- EventWatch (2018) 2018 Annual Report. 33pp.

- Munich Re (2025) Climate change is showing its claws: The world is getting hotter, resulting in severe hurricanes, thunderstorms and floods.
- Network For Greening The Financial System (NGFS) (2024) Acute physical impacts from climate change and monetary policy. 45pp.
- Reuters (2023) Low Water Again Hampers Rhine River Shipping In Germany.
- UN Office for Disaster Risk Reduction (2022) Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk: Transforming Governance for a Resilient Future. Geneva.
- World Bank (2021) The Trade And Climate Change Nexus: The Urgency And Opportunities For Developing Countries. 141pp.
- World Meteorological Association (WMO) (2023) The Global Climate 2011-2020. A decade of accelerating climate change. 60pp.
- World Meteorological Associated (WMO) (2023) Economic Costs Of Weather-Related Disasters Soars But Early Warnings Save Lives.