Seeing through the smog:

Towards a more robust measure of climate transition risk

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Abstract

This paper proposes a new measure of climate transition risk – Climate Transition Value-at-Risk (CTVaR) – that estimates the effect of climate transition on the value of assets and businesses. CTVaR offers an estimate of transition risk to assets, firms and sovereigns that is more robust than those based on emissions, which are subject to systematic gaps and biases. In doing so, it has the potential to improve the measurement and management of climate transition risk across both the public and private sectors. By offering a granular assessment of the effects of transition at the level of individual assets, it could allow financial authorities to identify and mitigate concentrations of climate transition risk across assets held by financial institutions and their counterparties. It also offers a more robust means through which to assess the degree to which financial firms allocate capital to support the global transition to net-zero emissions in the real economy. This is because it can identify investments that are currently high emitting but that are likely to both profit from and enable the longer-run transition to lower emissions (such as the mining of transition-critical metals and minerals, such as lithium and copper).

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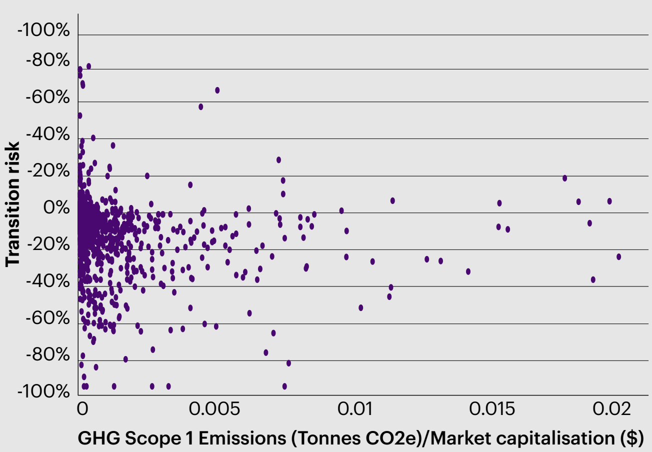
Executive summary

This paper proposes a measure of climate transition risk - that is, the risk of a reduction in an asset's value due to the global transition to net-zero emissions. This measure, which is termed Climate Transition Value-at-Risk (or 'CTVaR'), estimates the change in the value of an asset under a transition scenario, compared to its current market price. It does so by considering how changes in consumer preferences, technology and policy are likely to impact demand for, as well as the cost and price of, firms' products and services, and hence their future profitability.

CTVaR offers an estimate of transition risk that is more robust than those based on firms' emissions. This is partly because emissions reporting by firms tends to be backward looking, and subject to systematic gaps and biases (in particular, emissions arising from firms' customers and supply chains tend to be underreported). Firms in different sectors also differ in the degree to which they are likely to absorb any increase in the cost of their emissions (e.g., via the imposition of a carbon tax) or pass such costs on to their customers. As a result, there is little correlation between firms' current emissions and their transition risk (see figure).

There is little correlation between emissions and climate transition risk

Constituents of the MSCI World equity index: emissions versus transition risk



CTVaR has the potential to improve the measurement of climate transition risk across both the public and private sectors. It offers a highly granular measure of transition risk that estimates how a transition to lower emissions will affect the future cash flows of firms' individual business lines and assets. In doing so, it is able to identify concentrations of transition risk within the assets of financial institutions, their counterparties and the financial system more broadly. It can also estimate accurately the future profitability of firms that, whilst they may be highly emitting today, have robust plans to decarbonise their activities and operations (e.g. auto manufacturers that are committed to developing electric vehicles). In doing so, it allows financial firms to improve their measurement and management of transition risk, including by divesting or avoiding investment projects whose transition risk is large compared to their future profitability.

CTVaR also offers a more accurate means to assess which financial institutions are supporting the transition to net-zero emissions in the real economy. This is because it can identify firms that are undertaking innovation or extracting commodities that are necessary to support the transition elsewhere in the economy. Such firms may have high emissions today (e.g. those engaged in mining commodities for use in the generation and storage of renewable energy), but are likely to profit from and support the wider transition to net-zero emissions.

If adopted by the financial sector and its regulators, CTVaR could therefore improve the measurement and pricing of transition risk. It could also play a useful role in enabling the flow of investment to firms supporting, and likely to profit from transition, thereby driving the global transition to lower emissions in the real economy.

Introduction

The risks that climate change poses to the global economy are becoming ever more proximate. There is widespread recognition that financial firms and authorities need to develop data and tools to measure and manage the implications of climate change.[1] These include transition risk – that is, the risk of a decline in the asset values due to changes in consumer preferences, technology and official-sector policy designed to foster the transition to net-zero emissions. Measuring and managing transition risk is crucial if the financial sector is to support the reduction of emissions by businesses and households in the real economy.

Some financial institutions have started to reduce their exposure to emissions-intensive assets and firms. This does not, however, necessarily reduce their exposure to transition risk. This is partly due to shortcomings of firms' reporting emissions as a measure of their transition risk. Emissions tend to be reported on a backward-looking basis, thereby taking little account of steps being taken by firms to reduce their future emissions (e.g. steel or cement manufacturers that plan to shift operations towards renewable source of power). Reported emissions are also subject to systematic gaps and biases. For example, some companies may create very few emissions as part of their own operations (e.g., those in the service sector). However, if they serve customers in high emitting sectors (e.g., providing services to oil companies), they may experience a sharp decline in revenues due to the transition. On the other hand, some firms may currently have relatively high emissions, but might be likely to profit from the longer-term transition to lower emissions globally (e.g., if they are mining commodities for use in the generation and storage of renewable energy).

There is also likely to be considerable variation in how increases in the cost of emissions (e.g., due to a carbon tax) reduce firms' profitability. This is firstly because transition in some sectors is likely to be driven by changes in consumer demand that bear little relation to the changing cost of emissions. Some jurisdictions are, for example, likely to experience large declines in meat consumption driven not by an increase in the cost of emissions associated with animal grazing (which would be difficult to capture in a tax) but by changes in consumer preferences. Second, firms differ in the degree to which they are likely to absorb any increase in the cost of emissions. Firms in less (more) competitive sectors might be able to pass a large (small) proportion of these costs on to their customers. Together, this means that there is little correlation between firms' emissions, and their exposure to transition risk.

What is required, therefore, is a more robust measure of transition risk on which financial institutions can base their investment decisions. Such a measure should be based not on the cost of firms' emissions, but instead on a more robust estimate of how their future cash flows are likely to be impacted by the transition to net zero emissions.

This paper proposes such a measure of climate transition risk. This measure – which is termed 'Climate Transition Value-at-Risk', or 'CTVaR' – is defined as the expected future cash flows of an asset or firm under a climate transition scenario minus those expected under a business-as-usual scenario that is consistent with its market price.[2] CTVaR estimates the impact of transition through the in-depth estimation of the impact of the transition on the demand for firms' products and services, their input costs (including commodities prices) and prices, and their effect on profit margins. These estimates consider the effect of changes in consumer preferences, technology and regulation, and are carried out for over 500 segments of the economy, which vary by sector and/or geography.

In doing so, CTVaR improves upon other measures of transition risk – including those based on the cost of emissions – in three important respects:

- First, CTVaR overcomes the biases and gaps found in measures of risk based on emissions reporting. This is because it incorporates in-depth estimates of how transition is likely to impact firms' profitability – including those stemming from the effects of transition on their customers and supply chains – which are not captured by their emissions.
- Second, by focussing on *future* cash flows, CTVaR captures the degree to which assets and firms may *benefit* from the transition to net-zero emissions, even if they are currently high-emitting. This is because it accounts for the degree to which some industries – e.g., those that drive innovation in hard-to-abate sectors – may increase in profitability as part of the transition, even if they continue to be high emitting.

[1] See, for example, Financial Stability Board (2021), 'The availability of data with which to monitor and assess climate-related risks to financial stability'.
[2] CTVaR differs to standard measures of Value-at-Risk (VaR). In particular, whereas VaR estimate the change in the value of an asset that will occur with a given probability, CTVaR is the expected change in value under a given transition scenario.

- Third, CTVaR estimates the effect of transition risk on the future cash *flows at the level of individual assets or firms' lines of business*. The CTVaR of an overall portfolio or firm is then equal to the sum of the CTVaRs of their constituent assets or businesses.[3] This 'bottom up' approach allows CTVaR to capture the effects of future shifts towards lines of business that are lower emitting (such as a switch towards greener sources of power) and that will profit from the transition. It also means that the overall estimate of a firms' transition risk can 'net' across lines of business that will gain/lose from the transition, thereby forming a more holistic view of risk.

CTVaR has the potential to improve the measurement and management of transition risk across both the private and public sectors. It allows private financial institutions to better measure and manage their exposure to transition risk. By estimating risk at the level of individual assets, it allows financial institutions to account for the effects of climate transition as part of their investment and expansion plans, including by divesting/avoiding investment projects whose transition risk is large compared to their future profitability. It also allows financial institutions to manage their individual exposures to transition risk in a manner that supports the transition to net zero, thereby reducing the exposure of transition risk of the overall financial system.

In addition, CTVaR also serves as a tool with which financial authorities can assess transition risks to the financial system and wider economy. CTVaR is able to provide a robust estimate of transition risk to financial institutions, including through changes in the value of their assets, and creditworthiness of their counterparties. By focusing on the level of individual assets, CTVaR is also able to identify concentrations of transition risk, including those that exist within some systemically important financial institutions and their counterparties.[4]

Using CTVaR as a lens through which to measure transition risk might also help ensure that the financial system enables transition to net-zero emissions in the real economy. This is because some firms that currently have high emissions (including on the basis of historical data) may plan to reduce emissions in future (e.g., those in the steel or cement industries). Others might be supporting innovation that will reduce future emissions in hard-to-abate sectors (e.g., mining lithium to accelerate the electrification of transportation), or developing solutions to replace high-emitting products and services.[5] Because CTVaR is able to identify high-emitting firms that are likely to enable (and profit from) transition, its use by financial firms to support their risk measurement and management – as well as their investment decisions – might help ensure that such firms continue to receive funding to support their activities.[6]

Going forward, CTVaR could also provide a tool with which to assess transition risks to sovereigns and public-sector financial institutions such as central banks and sovereign wealth funds. If left unmanaged, transition risks have the potential to negatively affect sovereign finances, via their impact on investment, economic growth and tax revenues. Governments in jurisdictions that are particularly exposed to transition risks – for example, where economies are reliant on the export of certain commodities – may face pressure to intervene to support stricken industries. CTVaR offers a means with which to capture this potential transfer of risk between the private and public sectors.

The paper proceeds as follows. The next section describes the shortcomings of estimates of transition risk that are based on firms' or assets' emissions. The third section describes how CTVaR assesses future changes in commodity prices under different transition scenarios. Such changes in commodity prices serve as a key driver of transition risk for firms in sectors most exposed to commodity prices, such as resources extraction. The fourth section describes how CTVaR assesses transition risks to firms in other sectors, including manufacturing and service industries. A fifth section describes how these estimates are brought together to form an estimate of CTVaR for different firms and assets. It also demonstrates some interesting properties of the CTVaR measure, including its low correlation with firms' emissions. A final section concludes and suggests some directions for further work.

[3] Unlike other more established measures of risk (including conventional measures of VaR), CTVaR is additive: that is the CTVaR of a collection of assets is equal to the sum of their CTVaRs under a given transition scenario.
[4] See Financial Stability Board (2020), 'The Implications of Climate Change for Financial Stability'.
[5] The importance of financial institutions extending funding to such firms as part of their support to transition to net-zero emissions in the real economy was noted in the work of the Glasgow Financial Alliance for Net Zero (GFANZ); see GFANZ (2022), 'Recommendations and guidance: financial institution net-zero transition plans'.
[6] In contrast, the divestment of such high-emitting assets by financial institutions on the basis of their emissions may - to the extent that such divestment increases these firms' cost of funding - may slow investment in low-emissions firms and technology. Divestment of such high emitting assets by prudentially regulated financial institutions (e.g., banks) may also cause these assets to be held and funded by alternative sources of non-bank finance that are less likely to encourage them to reduce emissions; see Breeden (2022), 'Balancing on the net-zero tightrope'.

The shortcomings of measures of transition risk based on emissions

There is a clear need to reduce emissions in the global economy to curb the effects of climate change.[7] Recent regulatory initiatives have also proposed that emissions be used as a measure of transition risk faced by individual firms and assets. Emissions are, for example, one of the metrics of climate-related risks that firms are required to report under the rulemaking proposed by the US Securities and Exchange Commission.[8] Part of the rationale for using emissions as a proxy for transition risk is that any increase in the cost of emissions under transition – for example, that brought about by the introduction of a carbon tax – will have a greater impact on the costs faced by higher-emitting firms, and thereby result in a greater reduction in their profitability and value.

This section begins by describing the shortcomings of emissions as a measure of transition risk to individual firms. It then goes on to discuss why using emissions as a proxy for transition risk may reduce the degree to which financial firms are willing or able to enable transition to net-zero emissions in the real economy.

Shortcomings of using the cost of emissions as a measure of transition risk to individual firms

The first shortcoming of emissions as a measure of transition risk stems from systematic gaps and biases in firms' reporting of emissions. There are only limited data on emissions from the entirety of firms' value chains – so called 'Scope 3' emissions.[9] Available Scope 3 emissions data that are available tend to also suffer from inconsistencies arising from differences in firms' calculation methodologies that prevent their comparison across firms and industries.[10] Together, these issues mean that firms lower down supply chains close to consumers tend to report emissions that give an unduly favourable view of their transition risks. For example, a software company serving firms in the oil and gas industry might have only very limited emissions; but to the extent that demand for its services is likely to reduce under transition, it might be exposed to substantial transition risk. Conversely, a firm higher up the supply chain – such as that manufacturing parts for wind turbines – might give rise to substantial emissions as part of its operations (and those of its supply chain) but stand to gain substantially from a shift to renewable energy.

Second, current and historical emissions give only very limited insight into future changes in firms' business models. Such changes can be a crucial determinant of transition risks. For example, a steel or cement manufacturer that is currently reliant on energy from oil and gas and therefore has high emissions, might have only limited transition risk if it plans to, in future, switch to using energy from renewable sources.

Even if these measurement issues were resolved and emissions available on a forward-looking basis, an increase in the cost of emissions – say from the introduction of a carbon tax – need not be associated with transition risks. This is partly because, at least in some sectors, transition is likely to be driven by changes in consumer sentiment and demand that bears little relation to the changing cost of emissions. Some jurisdictions are, for example, likely to experience large declines in meat consumption, as consumers decide to transition from eating meat to non-meat alternatives. This is likely to be driven not by an increase in the cost of emissions associated with animal grazing, the emissions from which would be difficult or impossible to capture in any tax on emissions. Rather, firms engaged in meat production would instead face transition risk stemming from a shift in consumer preferences.

Conversely, other firms might experience a large increase in the cost of emissions, but nonetheless still see robust (or increasing) consumer demand for their products. One example is firms working to reduce emissions in extractive industries, such as the mining and processing of lithium for use in electric car batteries, where emissions at one point in the supply chain avoid emissions elsewhere. Provided consumer demand for electric vehicles increases under transition, consumers may be willing to pay more for any increase in the cost of emissions associated with the mining of lithium, because doing so avoids emissions associated with the use of internal combustion engines.

[7] SeE IPCC (2022), 'Climate change 2022'.
[8] See SEC (2022), 'Proposed Rules to Enhance and Standardize Climate-Related Disclosures for Investors'.
[9] See FSB (2021), 'The availability of data with which to monitor and assess climate-related risks to financial stability'. Less than 25% of firms in a recent TCFD survey reporting Scope 1, 2 & 3 GHG emissions, with substantial variation across firm size and geography.
[10] For example, the same barrel of oil could be included in the Scope 3 emissions of multiple firms. It might also be absent from the Scope 3 emissions of other firms whose reporting does not yet extend along the supply chain of its input products.

Table 1: **The shortcomings of carbon emissions as a measure of transition risk to individual firms**

Problem: Measures of transition risk based on emissions…	**Examples of industries with…**	
	Low exposure to increasing cost of emissions; High exposure to transition risk	High exposure to increasing cost of emissions; Low exposure to transition risk
…are subject to measurement gaps and biases	Software supplier to oil & gas industry	Wind turbine manufacturer
…give little insight into firms' future transition plans	Software supplier to oil & gas that plans to shift its customer base to renewable energy firms	Construction firm that plans to transition to using green energy
…not informative as to impact of transition on changes in consumer preferences	Meat producer/ processor	Miner of lithium for electric car batteries
…do not account for how changes in the cost of emissions will affect costs and prices (and hence profit margins)	Plastic bag manufacturer	Long-haul air travel

Finally, firms also differ in the degree to which any increase in the cost of emissions is likely to be passed on to consumers, thereby impacting their profitability and exposure to transition risk. This is likely to depend on the relative competitiveness of different industries, as well as the ease with which consumers can substitute towards different, lower-emitting products and services. Higher emitting firms in less competitive industries with few ready alternatives to their products might face relatively little transition risk. Consumers are likely, for example, to continue to use long-haul air travel despite the higher cost due to the lack of low-emission alternatives (at least in the short-to-medium term).[11] High emitting firms in less competitive industries – or those for which there exist few low-emission alternatives to products – are therefore relatively shielded from transition risk.

Conversely, firms in more competitive industries with relatively low emissions may be exposed to substantial transition risk, particularly if there are readily available alternatives to their products. There might be – and in some jurisdictions there already is – a shift by consumers away from using plastic bags, in favour of non-petrochemical alternatives. This effect is – at least thus far – not driven by an increasing cost of emissions per se, but more by consumer adoption of a readily available alternative products.

These effects and examples are summarised in **Table 1.**

Possible unintended consequences of using emissions to guide investment/divestment decisions by financial firms

Whilst there is a clear need to reduce emissions at the level of the global economy, the divestment of high-emitting assets by any *individual* investor or financial institution also risks having unintended consequences – including those that are to the detriment of economy-wide transition.

This is partly because – as discussed in the previous section – some individual firms that currently have high emissions may play a crucial role in enabling the economy-wide transition to net-zero. Some firms that currently have high emissions (including on the basis of historical data) may be invested in a manner designed to reduce emissions in future (e.g., those firms that plan to shift operations towards renewable sources of power). Others might be supporting innovation that will reduce future emissions in other sectors (e.g., mining lithium for use in electric car batteries).

In either case, the divestment of such assets by financial institutions on the basis of their emissions does little to support transition to net-zero emissions in the real economy.[12] In fact, to the extent that such divestment increases these firms' cost of capital and funding, it might slow such transition.[13]

[11] See Brons et al (2001), 'Price Elasticities of demand for Passenger Air Travel: a meta-analysis', Tinbergen Institute Discussion Paper.
[12] See Breeden (2022), 'Balancing on the net-zero tightrope'.
[13] Divestment of high emitting assets by banks may also cause these assets to be held and funded by alternative sources of non-bank finance which are less likely to encourage them to reduce emissions. This may also increase the total future emissions that are funded by the overall financial system. Ibid.

Furthermore, rebalancing investment portfolios by increasing investment into service sector companies (such as technology stocks or consulting firms), to meet portfolio decarbonisation targets, may not necessarily be effective in reducing emissions in the real economy. For example, an investor that divests away from high emitting firms that are playing a critical role in enabling transition and instead invests into service providers to the oil and gas sector would likely lower the emissions embodied in (or carbon intensity of) their portfolio. But such 'paper decarbonisation' does little to enable progress in reducing global emissions.[14]

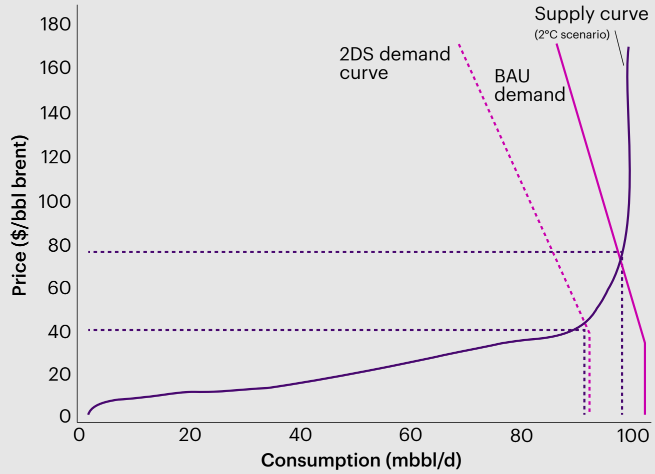
Estimating the future price of commodities

This section describes the first step in estimating CTVaR – that is, an estimate of transition risk that is robust to the issues described in the previous section. It describes the method used to estimate the future price of commodities under different climate transition scenarios. Such commodity prices are used to estimate the effect of transition to firms in sectors most exposed to commodity prices, such as extractive industries (e.g., oil, gas and mining). A large part of transition risk to firms in these industries stems from changes in the market for commodities themselves, as the price of commodities (and the quantity in which they are consumed) changes over time.

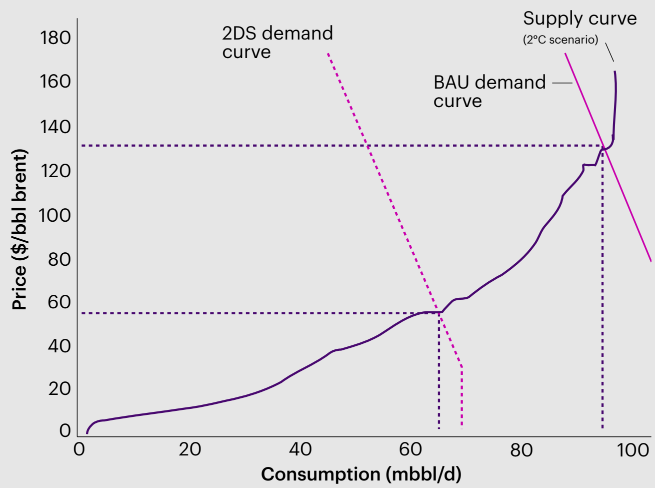
The methodology estimates the price at which it will be economic to supply different quantities of each commodity under a business-as-usual (BAU) and different transition scenarios. It does so by using detailed data on the future costs of extracting each commodity from different sources (e.g. mines or oil fields) worldwide.[15] These data allow for the construction of 'supply curves' that show the quantity of each commodity that it will be economic to supply at a given price.[16] Two such supply curves for crude oil are depicted by the dark purple lines in **Figure 1**. The top chart shows that estimated for 2025; the bottom chart for 2040. Note that the supply curve for 2040 is 'higher'– that is, a given quantity of oil is supplied at a higher price – than that for 2025. This is because by 2040, under transition, oil wells with a lower cost of extraction are expected to have been exhausted, leaving the supply of oil reliant on fields with a higher cost of extraction.

Figure 1: **Estimated prices at which different quantities of crude oil will be supplied and demanded, under BAU a (2°C) transition scenario**

...In 2025
2025 demand and supply equilibrium



...In 2040
2040 demand and supply equilibrium



[14] See Caldecotte et al (2022), 'How can Net Zero Finance best drive positive impact in the real economy'.
[15] CTVaR's focuses on the effect of transition risk to the future cashflows of assets and firms. As such, this calculation captures only the future operating costs of extracting commodities that have already been discovered (capital expenditure that has already been undertaken as part of the development of these sources of commodities is a sunk cost that can be ignored for the purposes of this calculation). On the other hand, the cost of extracting commodity supplies that have been discovered but that have yet to be developed includes the capital expenditure expected to be required for their development, including exploration costs.
[16] These data are provided by commodity industry data providers including Rystad, CRY, Wood Mackenzie and S&P Global.

CTVaR also uses forecasts of the scale of future demand for a given commodity at a given price.[17] The pink lines in **Figure 1** show the resulting 'demand curves', which chart the relationship between the quantity of, and price at which, a given commodity is demanded, at different points in the future. Note that, under transition a lower quantity of crude oil is demanded at a given price further into the future, as the global economy shifts towards net zero emissions (that is, the demand curve 'shifts left' over time).[18]

Importantly, this methodology is agnostic as to *what drives* changes in demand for a given commodity. Demand for a given commodity is determined by the cap on future emissions associated with a given transition. Such changes in demand could occur for a variety of reasons during transition, including changes in emissions prices, technological innovation, changes in consumer demand or regulation. However, it is not necessary to capture these drivers at part of this estimation process.

Commodities differ in terms of the granularity with which their future supply and demand is estimated. This is designed to balance the need for parsimony with the importance of capturing differences in the supply of, and demand for, different variants of the same commodity. For example, the relative homogeneity of crude oil, iron ore and copper across geographies means that a single global supply curve can be constructed for these commodities. But multiple supply curves are constructed for commodities whose markets are more segmented. For example, demand for thermal coal (used to generate power) and coking/metallurgical coal (used in the production of steel) are estimated separately due to differences in the likely path of transition across these two markets. Similarly, supplies of liquified natural gas (LNG) and pipeline gas are estimated separately given differences in their transportation and supporting infrastructure, and the costs these entail.

Table 2: **List of commodity supply curves, their scope and granularity of data used in their estimation**

Commodity	Scope of estimation	Granularity with which supply curves are estimated
Crude oil	Global	Individual oil fields[1]
Liquid natural gas	Global	Individual LNG terminals
Pipeline gas	Regional	Split by geography, lifecycle (current/future) and segment (e.g. on/offshore)
Thermal coal	Global seaborne	Individual mines[2]
Coking coal	Global seaborne	Individual mines[2]
Iron ore	Global seaborne	Individual mines[2]
Steel	Global	Individual steel plants
Copper	Global	Individual mines[2]

[1] Supply of oil from individual fields above a certain threshold output capacity is captured separately. This threshold is typically around 50 000 barrels/day for assets that are currently in production, and 10 000 barrels/day for future production.
[2] Some mines with very low relative output volumes (and/or with limited information as to their potential future commodity supply volume) are grouped together for the purposes of estimating their future commodities supply.

The granularity with which each of these individual commodities' supply curves is estimated varies depending on the homogeneity of commodities across different sources. For example, crude oil varies markedly in quality and in the cost of its extraction across different oil fields. For this reason, the future supply of crude oil is estimated using data that distinguishes between the supply of oil from individual fields. In contrast, natural gas is relatively homogeneous across different sources. Its future supply is estimated by aggregating across different sources according to their geography, lifecycle (current/future) and segment (e.g. on/offshore). Full details are given in **Table 2.**

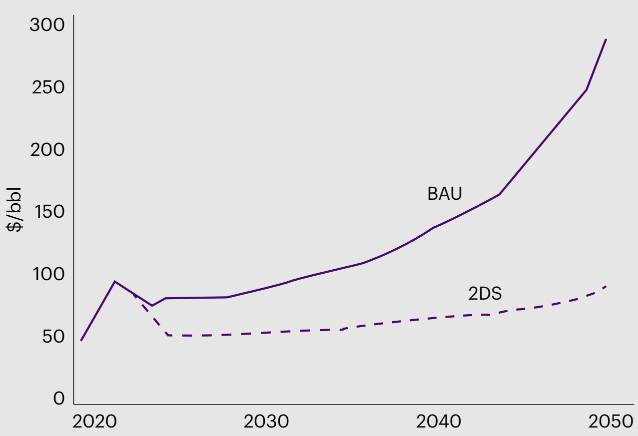
[17] These forecasts of demand for each commodity under different scenarios are derived from research by the International Energy Agency, European Commission as well as various academic research.
[18] Demand curves for some commodities – e.g, crude oil – are adjusted to account for how consumers may, in future under transition, react to rising commodity prices by introducing improvements to the efficiency with which they use commodities, or substituting to other (less polluting) sources of power. This results in a 'flattening' of the future demand curves for these commodities under transition.

The future price of each commodity – and the quantity in which it is consumed – are estimated as the price and quantity at which estimates of supply and demand are equal. For some commodities such as crude oil, where global trade in commodity is relatively integrated and takes place at relatively homogenous prices, this price and quantity are obtained by balancing the global schedules of supply and demand described above (these prices and quantities equate to the intersection of the supply and demand curves in **Figure 1**). With other commodities, whose consumption and pricing are more heterogenous across geographies (for example due to constraints and costs associated with transport and infrastructure), prices and quantities are those that equilibrate supply and demand across different regions, subject to constraints arising from the cost and availability of infrastructure and transport.[19]

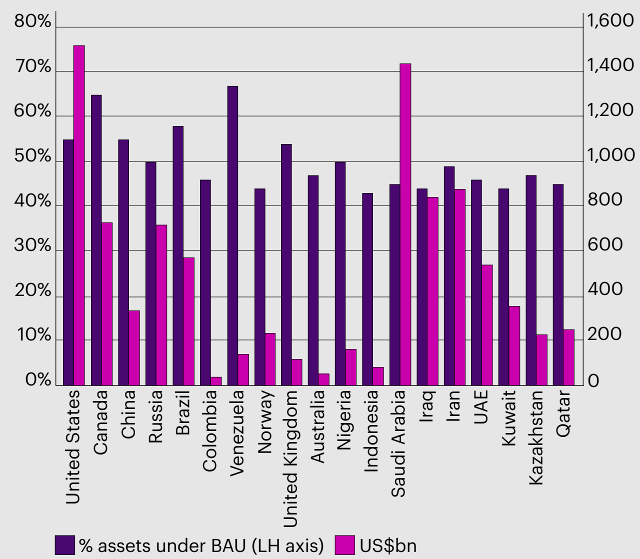
These estimates of the equilibrium price of each commodity – that is the price and quantity of production in which estimates of supply and demand are equal – allow for to the construction of price forecasts for each commodity under a given transition scenario. **Figure 2** compares the current estimate of the future price of crude oil both under a BAU and scenario consistent with 2 degrees of global warming (2DS).

Figure 2 **Estimated future crude oil prices, and stranded assets and production, by country**

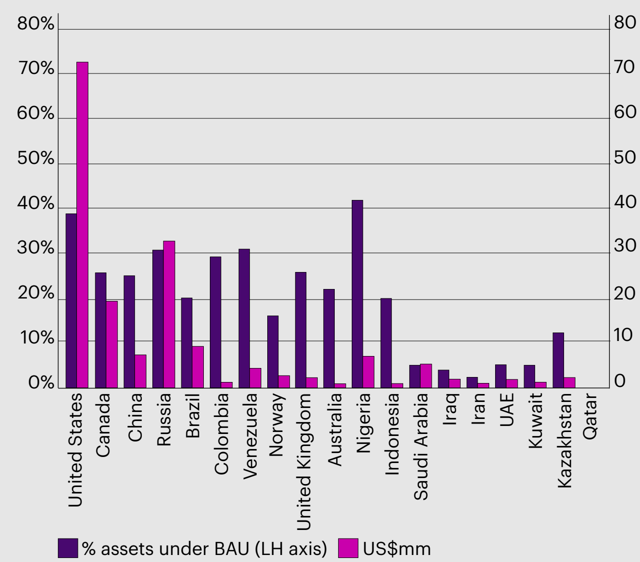
Brent oil price forecast



Value of stranded assets, by country



Volume of stranded production, by country



It is also possible to estimate of the quantity of each commodity that are 'stranded' under a given transition scenario – that is, end up being uneconomic to extract. Figure 2 (middle and bottom charts) shows the quantity of oil – both in terms of volume and value – that is stranded under a 2DS scenario, split by jurisdiction. Countries experiencing higher (lower) volumes of stranded assets (middle chart) tend to be those whose oil fields are less (more) economic to extract. That said, some countries with low volumes of stranded oil (e.g. Saudi Arabia) are forecast to experience a high value of stranded oil; that is their oil markets are exposed to material transition risk. This is due to the reduction in profit margins of their oil extraction driven by falling prices.

[19] Prices and quantities of commodities in each region are obtained through a constrained optimisation that seeks to maximise commodity producers' profits, whilst minimising the costs to consumers along with other constraints arising from the availability of a commodity in different regions, as well as well as the cost of its transport and associated infrastructure.

The impact of transition on manufacturing and service industries ('Climate Transition Controversies')

This section describes how CTVaR captures the impact of transition on firms in the manufacturing and service industries. Whereas changes in the price of, and demand for, commodities closely track the profitability of firms in the extractive industries, their relationship with manufacturers' profitability is more complex. Firms in the manufacturing and service industries convert commodities (or other manufactured products or human capital) into other products and services. In doing so they derive a profit margin equal to the difference between the price at which they sell their products and their costs of production (both of their inputs, as well as their operating expenses and capital intensity).[20] Profits are then equal to the value of this margin, multiplied by the volume of sales.[21] This calculation is depicted in **Figure 3**.

Calculating CTVaR for firms in the manufacturing and service industries therefore requires estimating how the transition will affect each of these determinants of future profitability (that is their prices and costs, as well as sales volumes), compared to a business-as-usual scenario. To do so, the impact of transition is estimated for around 500 different sectors of the global economy which differ by their product or service. Some sectors also differ by geography (e.g. consumption of poultry in Europe, or adoption of electric vehicles in Asia). This is in order to capture differences in the pace of transition (in this case the consumption of meat or switch to electric transport) in different jurisdictions. The effects of the transition on the aggregate profitability of firms in each sector (determined by changes in their prices, costs and sales) are then estimated separately, depending on that sector's individual characteristics and the dynamics of the market in which it operates. We term these estimates 'climate transition controversies', or CTCs.

The estimation and application of CTCs underpins the ability of CTVaR to overcome the shortcomings of other metrics of transition risk that are based on emissions. By its nature, the estimation of CTCs is forward looking – that is, it estimates changes to firms' future cashflows under transition, and hence their profitability. By applying CTCs to firms that are active in multiple sectors, CTVaR is able to account for how shifts in firms' activities across these sectors – including from high to low emitting activities, and those exposed to more/less transition risk – affect its overall transition risk. In addition, by focussing on consumer demand – as well as firms costs and prices – CTVaRs are able to account for how changes in consumer preferences, as well as differences in market structure and competitiveness, affect firms profitability.

The subsections that follow describe the estimation of CTCs for sectors in the manufacturing and service industries. A detailed example of the estimation of one such CTC, which pertains to the manufacture of cars, is given in **Box 1** (pages 14 and 15).

Climate transition controversies for firms in the manufacturing sector

The estimation of CTCs for firms in the manufacturing sector begins by estimating the change in demand for firms' products under the transition. Included in this estimate are the effects of changes in:

- **Consumer preferences –** for example, consumers may choose to eat less meat, reducing demand in certain areas of the food industry.
- **Technology –** for example, certain industries are likely to witness a shift in demand towards products powered by lower-emissions technology (e.g., demand is likely to increase for electric vehicles).
- **Regulation –** in some jurisdictions, regulation may directly or indirectly require some manufacturers (e.g., those in the fast fashion industry) to increase the durability of their products to reduce supply chain emissions. Demand for products with greater lifespans may increase.

It is then necessary to calculate the degree to which demand for a given product is likely to decrease (or increase) without any adjustment to manufacturing processes. In some high relatively high emitting sectors, consumers might be relatively willing and able to substitute much of their demand for products with lower emissions alternatives – for example, the switch away from the use of plastic bags, or meat consumption. In other sectors, demand reductions might result from efficiency gains in the way products are used – for example, the introduction of carpools might reduce demand for internal combustion engines, as the same vehicle is used more

[20] Capital intensity is defined as firms' cost of capital – that is interest or depreciation – per unit of production.
[21] Firms' volume of sales, operating expenses and capital intensity roughly correspond to their revenue, earnings before interest, tax, depreciation and amortization (EBITDA) and earnings before interest and tax (EBIT) given on their accounting statements. This is useful because it allows the figures in firms' accounting statements to be used to estimate CTVaR.

efficiently across a greater number of drivers. In other sectors – particularly those in which such substitution to other products or efficiency gains in their use are relatively scarce (e.g. the use of cement) – this 'natural' reduction in demand may be far less.

The next step in the estimation is to consider how residual demand for the products – over and above the reduction in demand described above – will be decarbonised. This requires an estimate of the changes in manufacturing processes that will be required to meet residual consumer demand for a given product to ensure that its emissions reduce in line with a given transition scenario. Such changes might include electrification (over the use of oil and gas, for example in some parts of the transport industry), or the introduction of green hydrogen (for example as aircraft fuel). Some sectors in which emissions are particularly hard-to-abate might also rely on the use of carbon capture and sequestration (CCS), in which their residual emissions are removed from the atmosphere.

The next step in the estimation is to consider who meets the cost of this decarbonisation of the residual demand for products and services. Such costs might include additional investment required to adopt new technology or meet regulatory requirements (including the introduction of a carbon tax) or adopt new technology. They might also include changes in operating costs, as firms adopt cleaner forms of energy. Firms in different sectors are likely to vary in terms of whether, and the degree to which, they pass through any change in their costs to their customers. In most industries it is assumed that any increase (decrease) in costs is passed fully on to firms' customers in the firm of higher (lower) prices, meaning that firms' profit margins remain constant. That said, in some industries – for example in markets where prices are regulated, or markets are less competitive and firms have higher margins – firms may not change prices, and instead absorb more of the increase in their costs.[22]

The final step in calculating the CTC is to consider the sum total of these changes in demand, and on firms' prices and margins, on the profitability of firms in each sector. The overall estimation process is depicted in **Figure 3**. **Boxes 1 and 2** give examples of the calculation of CTCs for the airtravel and car manufacturing industries.

Figure 3: **Estimating the impact of transition on the profitability of firms in the manufacturing and service industries (Climate Transition Controversies).**

(1) What drives climate transition? E.g.,

- Changes in consumer sentiment
- New regulation
- New technology

(2) How does this affect demand for products? E.g.,

- Are there readily available substitutes?
- Can products be used with increased efficiency?

(3) How will residual demand be decarbonised? E.g.,

- Changes to manufacturing processes
- Introduction of new technology (e.g. carbon capture and sequestration)

(4) Who will meet the cost of this decarbonisation? E.g.,

- Consumers
- Firms
- Governments

(5) What is the overall impact of these changes on firms' profitability?

- Generally equal to the change in overall demand multiplied by the change in firms' margins

[22] A further consideration is that, particularly in industries benefiting from the transition, any increase in firms' profit margins is likely to be relatively short-term. This is because – all else equal – higher profit margins are likely to encourage other firms to enter the market, returning margins to around their original level.

Box 1: Climate Transition Controversy (CTC) for air travel

This CTC analyses the effect of the energy transition on the air travel industry.

Demand for some air travel is likely to decline naturally as part of climate transition. This is likely to take place due to an increase in the availability and use of high-speed rail, as well as reductions in business and leisure travel. The degree to which such reductions in demand occur naturally is likely to vary across geographies and with the length of journeys. For example, in a transition scenario more European short-haul flights are forecast to be substituted with rail travel than are those in Africa. A combination of third-party data and in-house analysis is used to estimate the likely degree of demand reduction and how this varies across each region and across different air travel distances (see Figure A).[23]

Residual demand air travel will still have to be decarbonised in order for the airline industry to conform to a given transition scenario. Some of this decarbonisation will take place via the introduction of hydrogen and electric aircraft; however, given the large number of technical complications these face' it is expected that such technology will not become available before 2035.[24] In the short-to-medium term, it is likely that carbon emissions of existing aircraft will be reduced through the use of Sustainable Aviation Fuel (SAF) (see Figure B). These fuels can be biofuels or synthetic kerosene made from hydrogen and carbon dioxide. SAF has the advantage that it requires little or no modification of existing aircraft. However, there is likely to be a considerable cost involved in introducing the necessary infrastructure to supply it at airports. The CTC therefore models the capital expenditure required to build this infrastructure and roll out SAF across the aviation industry.

The analysis also considers which party will pay for the decarbonisation of this residual demand for aircraft. The additional costs are faced by all airlines, and there doesn't tend to be substitute forms of transport on at least medium and long-haul routes. It is therefore expected that the majority of additional costs will be passed on to travellers via higher airfares.[25]

The aircraft CTC therefore yields a detailed estimate of flight demand across regions and flight distances. This also has implications for how certain other industries will be affected by a transition scenario.

For example, the breakdown of short, medium, and long-haul flights allows for an analysis of how different aircraft manufacturers will be affected by a decrease in demand for aircraft models designed for these distances.

Finally, it is important that the estimates of demand and costs embodied in different CTCs are consistent across the global economy. For example, estimates of future demand in the CTC for rail travel are linked to those used in the air travel industry.

Figure A **Air travel (in passenger kms)**

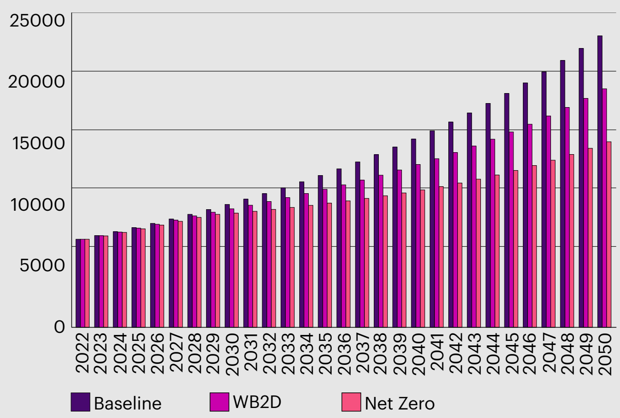
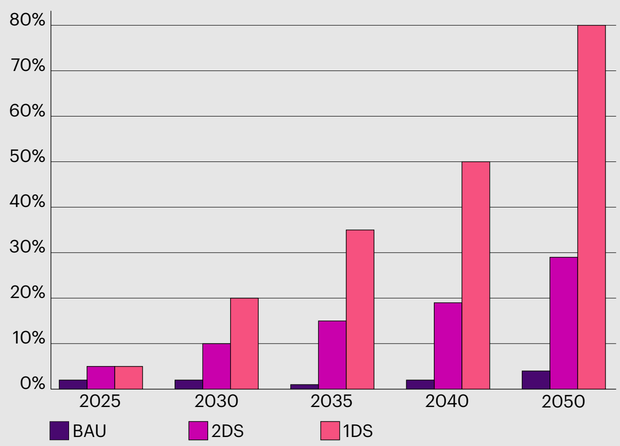


Figure B **Forecast use of sustainable aviation fuel**



[23] International Energy Association (2022), 'Aviation'.
[24] IATA 'Aircraft technology roadmap to 2050'.
[25] See Brons et al (2022).

Box 2: Climate Transition Controversy (CTC) for the car manufacturing sector

This box sets out the details of the calculation of the climate transition controversy for the car manufacturing sector. This controversy is calculated separately across electric vehicles (EVs) and internal combustion engine cars (ICEs), and by region. This is to reflect differences in the current - and future - projected change in the relative market for such vehicles across different geographies.

The first step in calculating these CTCs is to estimate future changes in the demand for EVs versus cars more broadly. Future growth in demand for EVs is based on forecasts provided by third parties.[26] These estimate demand for EVs under different transition scenarios in different jurisdictions. They account for changes in regulation (i.e. government mandates to remove ICEs from the road) as well as shifts in consumer preferences.

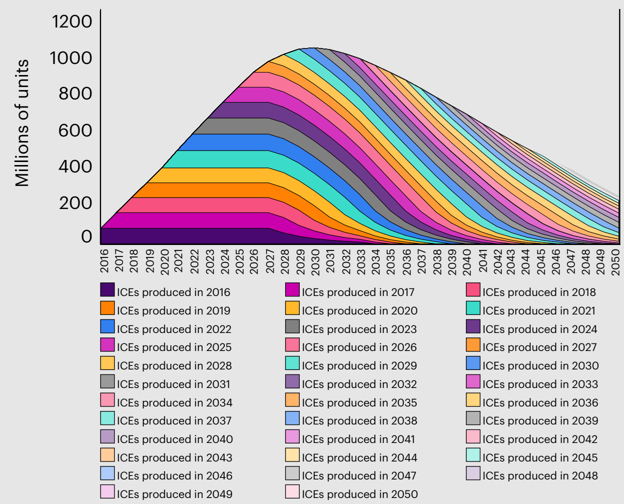
The second step in the calculation is to estimate changes in future demand for all cars (EVs and ICEs). This is a function of a broader variety of factors, some of which are assumed to be unaffected by transition (e.g. population growth, or increases in the average useful life of EVs) and some of which differ depending on the pace of transition to EVs (such as increases in the average useful life of a car, or changes in car ownership and uptake of ride sharing).

These calculations allow for the modelling of future changes in ownership of EVs and ICEs by region. This gives an estimate of how the market for EVs is likely to expand over time and across geographies under both a baseline and transition scenario. Figure C shows the estimated aggregate worldwide value of cars in existence to 2050, split by year of production, in both a baseline and transition scenario.

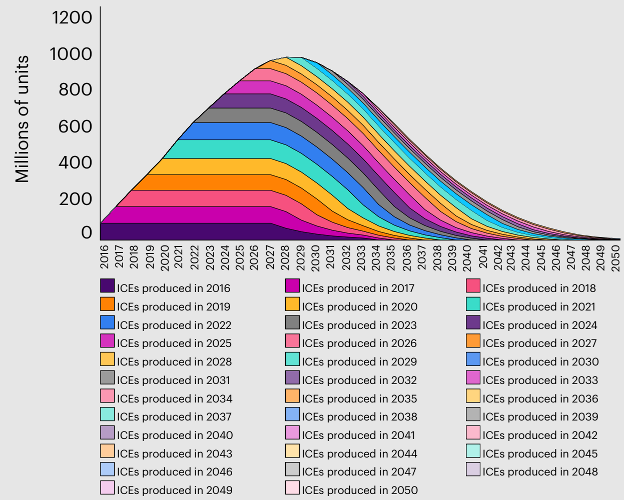
The difference between EV sales in the transition scenario relative to the baseline scenario captures the risk/opportunity associated with climate transition for ICEs and EVs, across each geography.

Figure C**: Estimated worldwide stock of internal combustion engine cars (ICEs) split by production year**

In a baseline scenario:



In a climate transition scenario:



[26] International Energy Agency and Bloomberg NEF.

Note that the change in demand estimated at the start of this calculation is assumed to be fixed in the calculations of costs and prices that follow. Put differently, changes in demand for firms' products is assumed to be an exogenous variable, that is determined by the path of the transition. Other variables that determine firms' profitability – that is their costs and prices - are assumed to be affected by, but not themselves affect, changes in demand. This is a simplifying assumption given that, in reality, any change in price is likely to itself affect demand. That said, the notion that changes in demand are fixed is consistent with the estimation being undertaken conditional on a given transition scenario.

Climate transition controversies for firms in service industries

The impact of transition on firms in service industries differs from those in the manufacturing sector. Unlike with the refinement of commodities and product manufacture, profit margins from human labour in service industries are unlikely to change substantially due to transition.[27]

Instead, the impact of transition on service industries is likely to stem more from changes in the demand for services under transition. These impacts may differ substantially across a given industry. For example, a software manufacturer who sells its services to renewable energy firms is likely to experience an increase in demand under the transition. Conversely, a firm that targets the oil exploration sector may see a decrease in demand for its products.

Estimating the effects of transition on firms in service industries therefore amounts to using CTCs to estimate the change in their potential revenues from the industries they serve. This sometimes requires applying a number of different CTCs, particularly if a firm provides services across a number of sectors (e.g. both the oil exploration and other manufacturing indices).

Applying climate controversies to manufacturing and service industry firms

The estimation described in the sections above – whereby different CTCs are calculated for different manufacturing and service industries – yields the impact of transition on the average firms' cash flows in each sector. CTVaRs are then calculated as the net present value of cash flows under the business-as-usual scenario minus those under transition scenario. A positive CTVaR corresponds to firms that are estimated to increase in value under the transition, and a negative CTVaR to those firms that are estimated to decrease.

Importantly, the application of CTCs to firms to determine the impact of transition on their cash flows takes place at the level of individual business segments within a company. For example, a car manufacturer that sells both cars with internal combustion engines and those with electric motors will have two CTCs applied to these separate business units. The overall CTVaR of the manufacturing firm is then equal to the sum of the CTVaRs of its individual business lines.[28]

[27] Average wages might, however, change between different service industries. For example, increased demand for electric vehicles may mean that mechanics with the skills and knowledge to service them can command a premium for their labour over and above that charged by mechanics servicing internal combustion engines. However, such effects are likely to be relatively short term (as eventually workers will reskill or retire as new labour comes online) and so relevant in only the most sudden transition scenarios.

[28] Applying CTCs to firms' lines of business in the manner described here would implicitly assume that the impact of transition on every firm in a given sector was identical. In reality, the impact of transition across firms in a given sector is likely to vary to that captured by the CTC. For example, firms that already invest in technology such as carbon capture and storage or that supply products that are more energy efficient of its peers are likely to be exposed to lower transition risk. To reflect these differences, the impact on changes in revenue and margins on some firms are adjusted to reflect these specific facts, such as their geographic presence, cost and emissions intensity, and mitigation measures.

Climate transition controversies for financial institutions

Transition risk to financial institutions – eg. banks and insurance companies – is estimated by calculating its effect on these firms' assets. The effects of transition are not calculated on financial firms' liabilities. This is because such liabilities are either sufficiently short-term that they are assumed not to be affected substantially by transition (e.g., those of general insurance firms which have a relatively short duration) or are longer-term (e.g., life insurance policies) but have cash-flows that are assumed not to be affected by transition risks.[29]

Some types of bank assets are assumed to have only minimal overall exposure to transition risk and are therefore excluded from the CTVaR estimate. Assets held as part of banks' trading and market-making operations, for example, are typically held on a relatively short-term basis and relatively well hedged – that is, neutral in their exposure to overall changes in market prices.[30] Similarly, banks' retail lending is assumed to be largely neutral in its exposure to transition risk. Retail borrowers' ability to repay loans secured on specific assets – e.g., on homes (in the case of mortgages), or cars (in the case of auto loans) – may also be affected by changes in the value of collateral. For example, policies to increase the energy efficiency of homes or catalyse a move towards electric vehicles may affect the value of these assets. Over time, however, these transitions are likely to have only minimal effect on borrowers' creditworthiness. The cost faced by consumers, for example, of increasing home energy efficiency or investing in an electric vehicle are likely to be recouped over time by the savings made in energy bills. To the extent, therefore, that these transitions are staggered over time – that is, they don't affect each of a banks' borrowers simultaneously – their overall effect on the value of retail lending is likely to be minimal.[31]

The effect of transition on banks and insurers is therefore assumed to occur mainly via their exposure to corporate borrowers. In the case of banks, these exposures occur via corporate lending, and the impact of transition risk on firms' ability to repay these loans. With insurers, they are assumed to occur via holdings of both equities and corporate bonds. Unlike for banks (see above), insurance firms hold these securities on a long-term basis and may take directional positions in some securities as part of their investment strategy.[32] Their value may therefore be affected by transition risk.

In order to estimate CTVaR for financial institutions' assets – that is corporate loans, as well as corporate bonds and equities – it is necessary to adjust the estimates of transition risk described in the previous section to account for the relative indebtedness of firms in each industry. This is crucial because the level of firms' indebtedness has bearing on the relative risk of their debt and equity, including that held by financial institutions. A given transition scenario impacts not just the overall value of a firm, but also its ability to service its debts. The impact of a given transition scenario on interest coverage ratio (that is the ratio of free cash flow to debt service payments) is used to estimate the impact of transition on the firms' credit rating and value of its debt.[33] The impact of a given transition on a firms' debt – which we term 'Debt CTVaR' – then corresponds to the difference between the value of their debt under that transition scenario and that under BAU.

The remaining transition risk to which a firm is indebted is borne by equity holders. This we term the 'Equity CTVaR'. This is equivalent to the difference between the market capitalisation of the average firm in a given sector under business-as-usual and that under a given transition scenario.

A full list of debt and equity CTVaRs applied to the assets of financial intermediaries is given in **Table 3**. These are listed at the level of the industry segments at which financial firms' assets are typically given in their public reports. The granularity of such reporting (e.g., aerospace and defence) is generally less than that of the business segments at which CTCs are calculated (see above). An average CTC for firms in that sector is obtained by averaging across the CTCs of firms in each of its constituent business segments (calculated using the CTCs described in the previous sub-section).

[29] Further work may be necessary to determine whether some climate transition scenarios might impact the value of some long-term liabilities of some financial firms, for example those of life insurance companies. For example, the effects of climate change on mortality, morbidity and longevity could materially impact the value of life insurers' liabilities.

[30] Other approaches of transition risk exclude such assets that typically comprise banks' trading books; see for example Bank of England (2021), 'The 2021 biennial exploratory scenario on the financial risks from climate change'.

[31] It is possible that a sudden transition to a low emissions economy might trigger a widespread depreciation of some assets used to collateralise bank lending (for example less energy efficient homes or cars). It might also have a wider depressing effect on the macroeconomy – for example reducing prospects for growth and increasing unemployment - that might cause a widespread reduction in the creditworthiness of banks' borrowers. The latter effect might be particularly pronounced in certain geographic regions, such as those where economic activity is concentrated in emissions-intensive sources of energy.

[32] See, for example, Geneva Association (2021), 'Climate risk'.

[33] This estimation is based on the historical relationship between firms' interest coverage ratios, credit ratings and debt valuations across different sectors and jurisdictions.

Table 3: **List of Financial intermediation CTCs**

Sector	Industry Group	Equity CTVaR	Corporate Debt CTVaR
Energy	Integrated Oil & Gas CTC	-46%	-35%
Energy	Non-Integrated Oil and Gas CTC	-31%	-20%
Materials	Chemicals CTC	-6%	-7%
Materials	Metals, Mining and Miscellaneous Materials CTC	-4%	-9%
Industrials	Aerospace & Defence CTC	-9%	-8%
Industrials	Commercial and Professional services CTC	-2%	-3%
Industrials	Industrial conglomerates, Machinery & Equipment CTC	0%	-3%
Industrials	Transport, Infrastructure, Construction CTC	-6%	-5%
Consumer Discretionary	Automobiles CTC	-2%	-5%
Consumer Discretionary	Consumer Durables CTC	-2%	-2%
Consumer Discretionary	Consumer Services CTC	-5%	-4%
Consumer Discretionary	Non-food Retail CTC	-3%	-3%
Consumer Staples	Food & Staples Retail CTC	-5%	-3%
Consumer Staples	Food, Beverages & Tobacco CTC	-2%	-2%
Consumer Staples	Household and Personal Products CTC	-1%	-1%
Health Care	Health Care Equipment, Supplies and Services CTC	0%	0%
Health Care	Biotechnology CTC	0%	0%
Health Care	Pharmaceuticals CTC	0%	0%
Financials	Banks CTC	-1%	-1%
Financials	Financial Services CTC	-1%	0%
Financials	Insurance CTC	-1%	0%
Financials	Real Estate CTC	-2%	-1%
Communication Services	Interactive Media CTC	0%	0%
Communication Services	Media CTC	0%	0%
Communication Services	Telecommunication Services CTC	0%	0%
Information Technology	Semiconductors CTC	3%	0%
Information Technology	Software & IT Services CTC	0%	0%
Information Technology	Tech Hardware & Communications Equipment CTC	-1%	0%
Utilities	Utilities CTC	-4%	-4%

The CTVaR for any individual bank or insurer is then estimated by applying these debt and equity CTCs to its equity and debt holdings across each of these sectors.

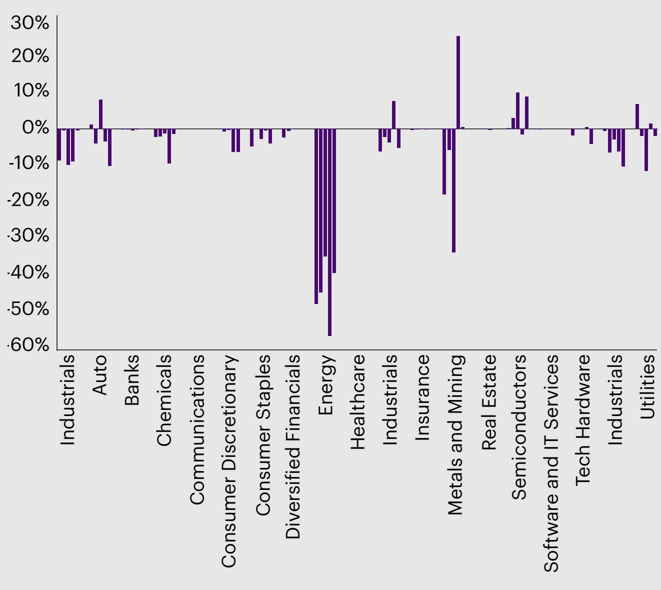
Applying CTVaR to companies and sovereigns

This section applies the methodology described in the previous sections to estimate CTVaR across different sectors, firms and countries. CTVaR is obtained as the difference between the current value of firms' future cash flows (as reflected in their market prices), and the value of the same cash flows adjusted for the effect of changes in commodity prices and relevant CTCs. This represents the transition risk, under a given scenario, to a company's economic value (an 'EV' CTVaR).

For the purposes of the results that follow, CTVaRs are calculated under a '2DS' transition scenario;[34] that is, an orderly transition in which average global temperature increases by 'well below' 2°C by 2100. This scenario – which requires rapid and widespread changes across economies – is aligned to the goals of the Paris Agreement. In principle, CTVaR could also be calculated for a range of other scenarios, including those used by the NGFS.

The bars in **Figure 5** show estimates of CTVaR under this scenario. CTVaRs are shown for the five largest firms (by market capitalisation) in each sector within the MSCI world equity index. Negative values indicate those sectors (such as oil & gas) whose value is estimated to fall under the transition; positive values indicate those sectors where this is estimated to increase.

Figure 5 **CTVaR of firms in MSCI world equity index (largest five firms by market capitalisation, per sector)**

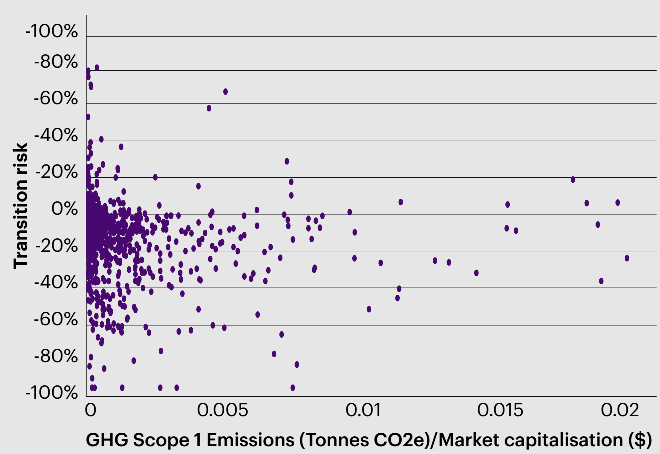


One of the benefits of CTVaR is its ability to offer a more robust estimate of transition risk than do estimates of transition risk based on firms' emissions. **Figure 6** compares firms in the STOXX Europe 600 index with their emissions intensity (that is, their emissions of carbon per unit economic value). Sectors that stand to benefit from the transition – those that have positive CTVaR – generally have zero (or close to zero) emissions, at least on a Scope 1 basis. However, sectors with negative CTVaR – that is, where firms' economic value is likely to fall in transition – have a range of emissions, which are close-to uncorrelated with their CTVaRs. This underlies the shortcomings of metrics based on emissions as a measure of transition risk.

Note that Scope 1 emissions tend to underestimate the transition risk associated with sectors that are further 'down' supply/value chains.[35] Sectors that are closer to consumers – such as consumer discretionary and consumer staples – have very low emissions but substantial negative CTVaR. This is due to emissions being concentrated higher up their supply chains in their manufacturers, for example. Some such firms are nonetheless exposed to transition risk, given the reconfiguration of their supply chains – and subsequent changes in their profitability – that are likely to occur as a result of transition. On the other hand, sectors such as energy, metals and mining, that are themselves a source of emissions, have both high emissions and high (negative) CTVaR.

Figure 6 **CTVaR vs Scope 1 emissions for constituents of the STOXX Europe 600 equity index**

...at the level of individual firms



[34] These scenarios broadly align with those used by the International Energy Agency and Network for Greening the Financial System; see for example NGFS (2022), Scenarios Portal.
[35] Data constraints make it possible to compare CTVaR only to Scope 1 emissions, which are those emissions bought about by firms' own activities. The results shown here might change if CTVaR were compared to Scope 2 or Scope 3 emissions, which aim to account for emissions brought about by firms' energy supply and those of its broader supply chain. Scope 3 emissions are, however, not reported by firms in all sectors, and may suffer from other shortcomings that prevents their comparison across firms and sections; see Section 2.

Emissions and transition risk also bear little correlation at country level. **Figure 7** compares countries' CTVaR (estimated at industry level for firms in those countries) and emissions. Some countries such as the US are estimated to have relatively high transition risk despite having relatively low emissions. Such countries typically have supplies of commodities and sources of energy (such as shale oil and gas) that are most costly to produce, making their supply less economic in transition. Other countries such as Norway supply commodities that are relatively economic under transition; they are therefore less exposed to transition risk (despite having relatively high emissions).

Figure 8 illustrates how CTVaR, as a highly granular measure of risk, can guide investment decisions (including those of financial institutions) based on their relative transition risk. It compares the proportion of the overall CTVaR of an energy company contributed by each business line (horizontal axis), to that business line's economic value (as a proportion of that of the overall company) (vertical axis). This allows a comparison of each business lines' contribution to the overall firms' transition risk, versus its enterprise value. Those business lines below the 45-degree line have high transition risk relative to their economic value and be might considered for lower investment; those above it might be considered for increased investment.

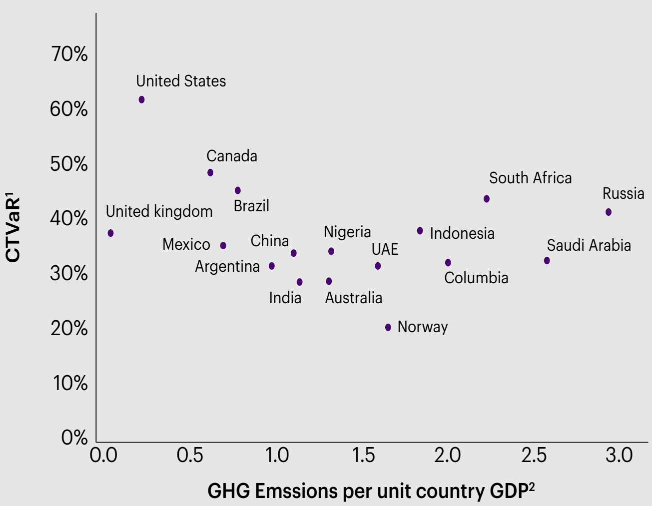


Figure 7 **Emissions intensity versus CTVaR for countries' commodity extraction sectors**

Finally, by providing a granular measure of risk based on future cash flows, CTVaR is also able to estimate the future time at which transition risk is likely to crystallise on a given asset. **Figure 9** illustrates a hypothetical break down of the reduction in free cashflows that will occur across the different business lines of a major oil & gas firm. The majority of transition risk crystallises between 2030 and 2050 as oil and gas are replaced by renewable alternatives. By providing an estimate as to the horizon over which transition risk might crystallise, CTVaR also has the potential to provide financial institutions (and their regulators) with a guide as to when to exit certain investments to ensure their profitability and soundness.

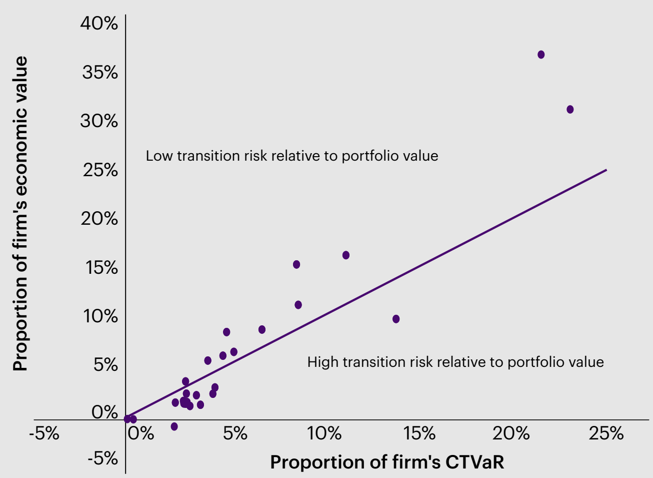


Figure 8 **CTVaR vs economic value, by business line, of a major energy company**

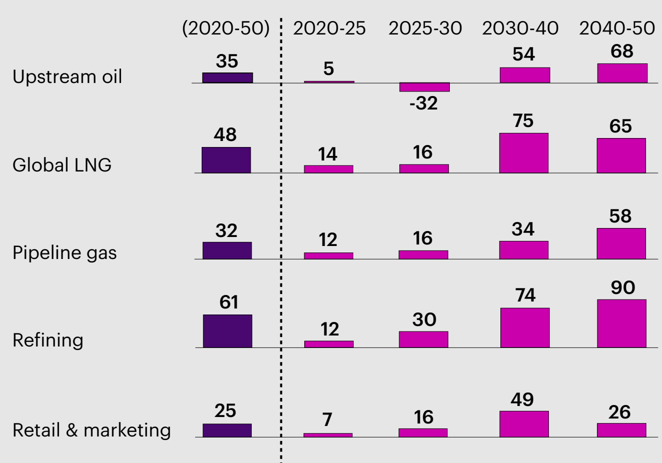


Figure 9 **An illustration of the horizon over which transition risk is likely to crystallise across the business lines of an oil and gas firm**

CTVaR by horizon (%)

Conclusion and further work

This paper proposes a new measure of transition risk – CTVaR – that estimates the impact of different climate scenarios on the value of firms across a range of sectors. By focussing on future changes to firms' cash flows – including those stemming from changes in both the demand for products and services and changes in profit margins under transition – CTVaR overcomes the shortcomings of measures of transition risk based on firms' emissions.

CTVaR has a range of applications that increase the ability of the financial system to better price transition risk. It can be applied on a very granular level across firms' activities and business segments, and thereby identify investment opportunities that are resilient to transition risk, including those that are likely to appreciate as a result of transition. This has the potential to improve the risk measurement and management of transition risk by individual firms. By distinguishing those assets that, despite being high emissions, stand to profit from/support transition, it also has the potential to help ensure the financial system supports the transition to net zero emissions in the real economy.

There are a number of possible areas for further work.

First, CTVaR could be used to capture some of the unintended consequences of transition to net zero. There is a growing risk of imbalance between the pace of growth in investment in – and changes in demand for, and technology/policy to support – low emissions products and services. One concern is that the reduction of investment in high emitting sectors (including fossil fuels) could outpace growth in alternative sources of energy. This could lead to acute energy shortages, as well as high and volatile commodity prices. Such a 'disorganised' transition could have a destabilising effect on the financial system and macroeconomy. By capturing the effect of transition on individual sectors CTVaR would be able to capture the risk of such a mismatch between investment in, and demand for, low-emissions products and services, and how this might vary across different transition scenarios.

Second, the estimation of CTVaR could be refined and expanded across certain industries. The range of assets and liabilities that are included in the estimation of CTVaR for financial institutions could be increased. In particular, CTVaR could be estimated for other bank assets, including its retail lending, which might be affected by transition (particularly that which is relatively sudden or disorderly, and that led to the widespread depreciation of collateral or deterioration in household creditworthiness in certain geographies). It could also be expanded to include the long-term liabilities of insurance firms, particularly those – such as those of life insurers – that might be impacted in some climate transition scenarios.

Finally, CTVaR could also provide a tool with which to assess transition risks to sovereigns and public-sector financial institutions such as central banks and sovereign wealth funds. If left unmanaged, transition risks have the potential to impact sovereign finances, via their impact on investment, economic growth and tax revenues. Governments in jurisdictions that are particularly exposed to transition risks – for example, where economies are reliant on the export of certain commodities – may face pressure to intervene to support stricken industries. By assessing the scale of these risks, CTVaR offers a means with which to capture this potential transfer of risk between the private and public sectors.

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