# Webinar: How to Enhance Climate Scenarios for Investors

## 14 March 2024

Speakers:

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## General Considerations and a Big Thank You.

First of all, we would like to thank the delegates who have sent us really interesting questions. We have done our best to provide answers in this document. Some questions were rather similar, or called for a similar answer. So, we grouped them together.

**Q1: Aren't the UN probabilities a little optimistic (again)?**

We were not necessarily trying to opine on which projection is correct (after all it is impossible to validate) but that rather users of scenarios implicitly create a 'mean' and 'variance', despite the health warnings; furthermore, we can show that this is very different from a well-accepted estimated distribution.

To answer the point: up until 2010 most analysis of long-term population was conducted using scenario analysis or by expert judgement specifying future birth and death rates. It is only relatively recently that researchers have begun to apply probabilistic techniques. We reference the work of Raftery et al (see Adrian E. Raftery and Hana Ševčíková, Probabilistic population forecasting: Short to very long-term, International Journal of Forecasting 39 (2023), no. 1, 73–97 for a review) in particular; they have developed Bayesian models for statistically projecting the three components of population change: fertility, mortality and migration on a country-by-country basis. This approach - being probabilistic - enables the generation of country level population projections, age structure, profiles by sex as well as confidence intervals and importantly sensitivities to underlying assumptions and it now underpins the UN's forecasts. Their approach has undergone significant peer review, as well as extensive challenge by (local) experts (see e.g., analysis enclosed in the reference) - and as such we have no reason to doubt its veracity or to believe it to be an underestimate.

**Q2: Where does the relationship between carbon tax intake and emissions come from?**

We have developed this relationship by taking the data in the SSP/RCP simulated output – which for each SSP and (achievable) RCP lists the carbon tax required per time point. We also have the emission profiles in scenario – again from the SSP / RCP output.

We have taken a very basic approach to computing 'cumulative' tax (a more complete measure would be to assume much of the taxes are invested in capital and to associate a rate of depreciation and a cost to switching capital; however, we do not do this in the slide shown).

The impact of tax on emissions in the next period is parameterized through a range of IAMs by the IPCC. In our analysis we use these to provide some measure of the uncertainty in applying the benefits of taxes to the reduction of emissions.

**Q3: Have you any comment on the damage equation used by the IPCC to convert temperature into GDP? For example, under SSP5 has a temperature destination of 4.3c by 2100 (a temperature at which science suggest threatens Human existence) yet GDP is still growing?**

As per the presentation, the impact of climate feedback on the growth of economic activity is *not* included in the IPCC projections. This is obviously a concern: for example, a growing body of the academic literature explores how climate change has the potential to damage growth rates of in particular the developing world (see e.g., Marshall Burke, Solomon M. Hsiang, and Edward Miguel, Global non-linear effect of temperature on economic production, Nature 527 (2015), no. 7577, 235–239). The expectation is the developing world is where a significant amount of future economic activity will come from – and hence failing to incorporate climate damages is a (potentially) major 'model' risk.

On the substance of your point: understanding the behavior of climate damages for high values of the temperature anomaly is hugely challenging and potentially significantly underestimated – see work of Lenton et al.

More specifically SSP5 is deliberately perceived to be a scenario where there is a bargain to 'go for growth' through fossil fuel led growth, populations reduce and the aggressive future use of geo-engineering. While there are obvious challenges to a 4.5C world – it is possible to argue its plausibility through adaptation (e.g. mass emigration from coastal cities etc.). The point I guess is that having the scenario forces policy makers to consider implications – which as you point out are likely to prove somewhat unpalatable.

**Q4: So, is the best way to justify the investment in decarbonisation to link it to healthcare costs?**

I didn't really mean that. I simply presented how much we spend on healthcare as a comparison yardstick. I could be wrong, but I find it difficult to imagine the Western electorate accepting to spend more money than we do on healthcare on a regular basis (not in an emergency, such as a war). So, I look at this quantity as a reasonable upper bound. You may disagree, but, for any level of 'carbon tax' you may choose, please use the quick ready-reckoner on slide 30 of 52 to see what fraction of GDP that implies. This is not very precise, but it is ballpark correct. I reproduce it below for easy reference.

- As social cost of carbon is ultimately a tax imposed on the electorate.
- The level of taxation as percentage of GDP implied by a given SCC can be easily estimated from
  1. World GDP ($ 100 Trl)
  2. Current emissions $\approxeq 40$ Gton $CO_2$.[1]
  3. Proposed carbon tax of $ $X$ for Ton of $CO_2$.

  This gives that a carbon tax of $1/Ton is approximately equal to 0.04% of GDP.
- So, for instance, a tax of $100 /Ton corresponds to a tax of 4% of GDP.

**Q5: How are physical damages estimated, what is scoped in or out and why?**

This is a challenging question for which debate still continues. Historically, damage functions have been developed using the so-called enumerative approach (e.g., Nordhaus et al):

- stipulate sectors which would be affected by climate risk (alleviates potential of spurious identification) and analyse these.
- Typically assume only activities directly exposed to the weather (e.g., agriculture, forestry etc) would be affected by climate change; conversely sectors such as manufacturing and services, take place in controlled environments are assumed to be unaffected by climate change (~ 87% of US economy!).
- Regress 'one-off' estimated damages against temperature anomaly.

There are then obvious issues – e.g., extrapolation using a low order polynomial which means damages are very sensitive to extrapolation.

While this avoids issues such as spurious association it clearly misses more general impacts (for example cost of adaptation, long term growth effects).

This has led to burgeoning research using spatial econometrics – see survey reference (Temperature and GDP: A review of climate econometrics analysis, Jun-Jie Chang, Zhifu Mi, *, Yi-Ming Wei, Structural Change and Economic Dynamics 66 (2023) 383–392) for more details.

**Q6: How do you do a reality check for the abatement that can be achieved (i.e. by throwing more money do you reach an upper limit of how much technology to abate one can install)?**

It is possible to develop estimates in two ways:

1. We can do back of the envelope 'feasibility' estimates – e.g., by considering the amount of raw materials (e.g., rare earth metals needed to make the high density magnets for wind turbines) or by considering how much 'space' is required for green technology generation. Such estimates follow in the spirit of Mackay (Sustainable Energy without the hot air).
2. We can also look at current marginal cost curves for particular technologies and make assumptions about the pace of technological change, while respecting constraints imposed by e.g., thermodynamics and future cost of energy.

**Q7: What do figures 17-20 look like for the world?**

Here are some of the figures, so that everyone can see what the question refers to.

### Developed Countries

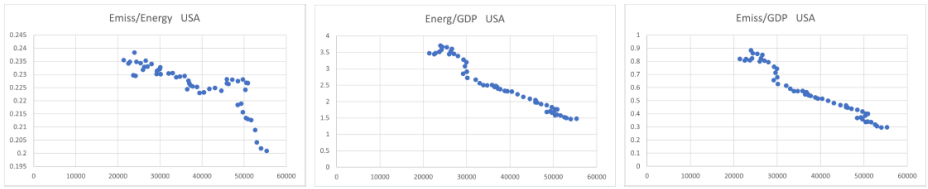



Figure 17: *Emissions per unit energy (top left), energy required to obtain one unit of GDP (top right) and emissions per unit of GDP (bottom) for USD. GDP/person in USD $ on the $x$ axis.*

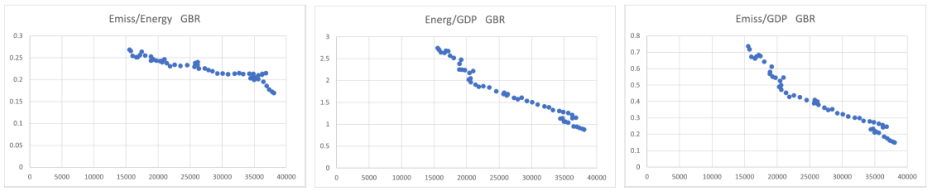



Figure 18: *Emissions per unit energy (top left), energy required to obtain one unit of GDP (top right) and emissions per unit of UK (bottom) for the UK. GDP/person in USD $ on the $x$ axis.*

### Developing Countries

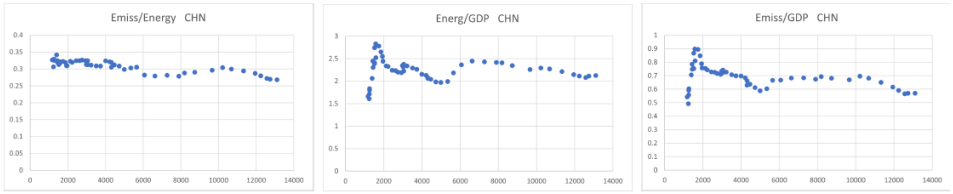



Figure 19: *Emissions per unit energy (top left), energy required to obtain one unit of GDP (top right) and emissions per unit of GDP (bottom) for China. GDP/person in USD $ on the $x$ axis.*

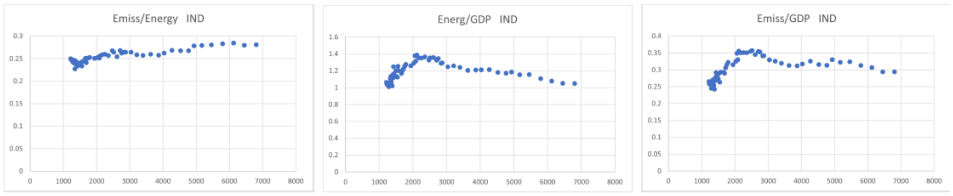
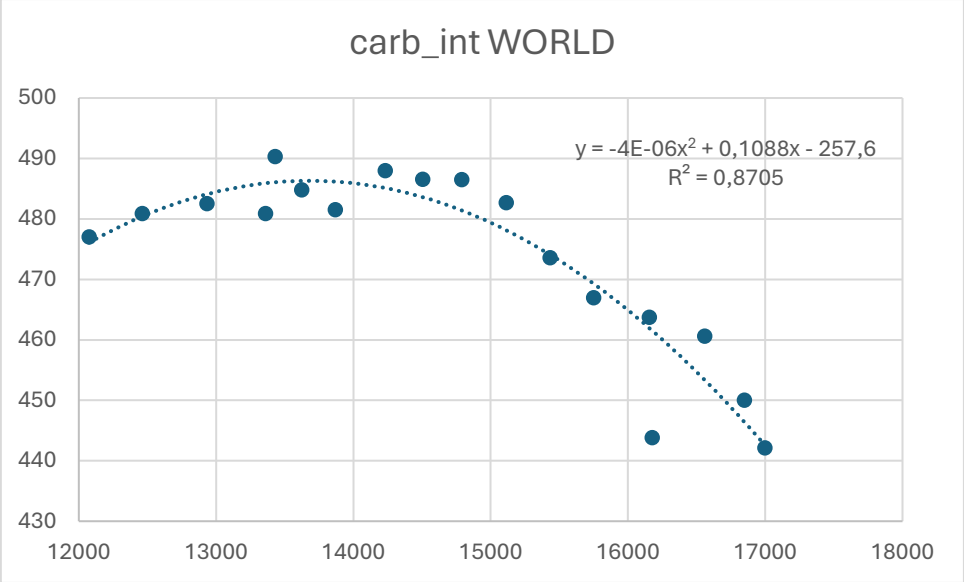


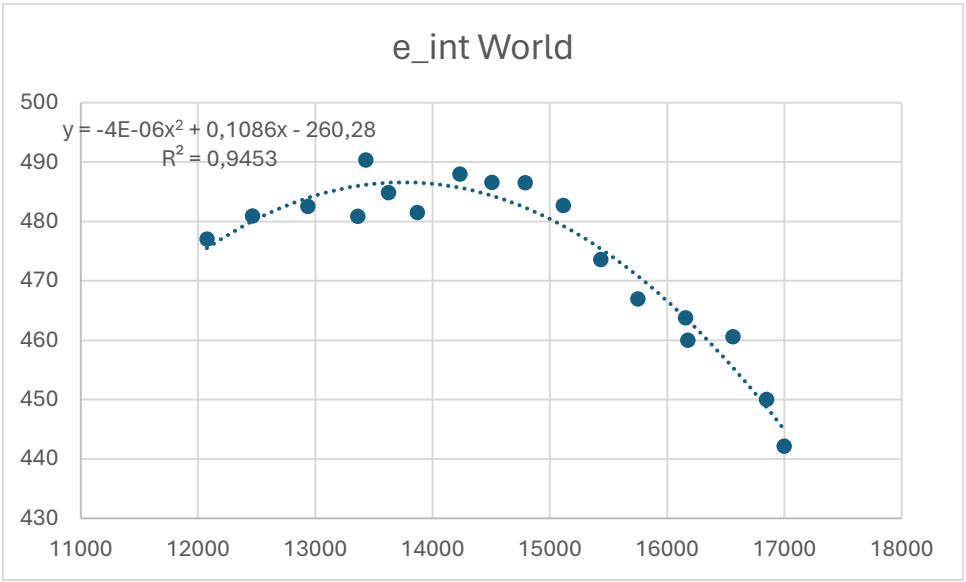

Figure 20: *Emissions per unit energy (top left), energy required to obtain one unit of GDP (top right) and emissions per unit of GDP (bottom) for India. GDP/person in USD $ on the $x$ axis.*

When we look at the whole world, the structure can become difficult to see because the various ‘humps’ are common for many developing countries, but they occur at different levels of GDP/pp, as you can see just from the two cases of India and China. However, there is still a very discernable pattern, as the figure below neatly shows.




The figure shows the carbon intensity (CO2 emissions per unit of GDP) for the whole world. Keep in mind that we have used data only since 2004 – so the left (upward-climbing) side of the curve is partially missing.

A very similar relationship holds for world energy intensity (energy/GDP).




The strong decline in the developed economies is not (all) due to ‘exported emissions’, because energy and emission intensity declines also for China and India.

**Q8: Given carbon taxes could be introduced in a fiscally neutral way (eg other taxes are lowered to offset) would you be better looking at (cumulative) marginal abatement costs?**

Our argument is that GHG emission impacts is an unpriced externality. We then want to use the amount required to decarbonize to a certain level to determine feasibility and hence determine whether a particular abatement is plausible. At the margins substitution against other taxes is possible – however, for serious abatement, the amounts required are more analogous to expenditure on big ticket items e.g. health / defence. I would suggest that this is challenging to raise through “efficiency” or substitution.

**Q9: Do you have a view on the probability of the NGFS scenarios? Or the SSP or RCP scenarios? If so, please share.**

No, we have not determined probabilities for the SSP/RCP scenarios or indeed the NGFS scenarios. As we said – this is probably an ill-defined exercise. However, it is possible to highlight SSP/RCP scenarios which are unlikely to occur – see figure below.


Figure 3: Numbers of applications of SSP–RCP combinations in 715 total studies applying integrated scenarios, published over the period 2014–2019. Each cell represents an SSP–RCP combination, with colours indicating the number of applications. White cells indicate no applications. Green rectangles along the right side of the figure indicate totals for each RCP (rows); those along the bottom of the figure indicate totals for each SSP (columns). Unlikely SSP–RCP combinations indicate those in which integrated assessment models found the outcomes infeasible under the SSPs and SPAs assumed. Reproduced in accordance with the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/legalcode) from [OCE+20]. No changes were made to the figure.

**Q10: Can I summarise the approach to actually get to the probabilities is to "ask a load of experts"? Perhaps I missed something? How to avoid the "experts bias" of Freakonomics fame?"**

**and**

**The answer to the first question concerns me, we drifted very quickly into frankly spurious precision about the probability of cashflows inferred from what is basically a survey-based, potentially biased distribution.**

Sorry for not explaining this well. We do not ask 'loads of experts' to get to the probabilities. We make use of

1. carefully cleaned and scrutinized empirical relationship – that we assume will hold in the future (such as the fact that, as countries become richer, fertility declines);
2. the best physics models, with the attending uncertainty (we have re-implemented all the 17 IPCC climate models;
3. theoretical models (such for GDP growth) that have a strong empirical record.

When there are different models which are equally respectable, we use both to reflect the uncertainty.

Then we combine all these ingredients in a (Monte Carlo) simulation, and we record the distribution of outcomes.

If you refer to the survey of social cost of carbon, please remember that we only use the *shape* of the distribution, and we shift it to match actually observed behavior. But remember that, if you don't believe in the distribution, you can perfectly use a 'totally diffuse prior' – i.e., saying that everything is possible within the feasibility bounds. The bounds are far more important than the shape of the distribution they encompass. The expert distribution is almost a distraction – it is the cherry on top of the cake, not the take. Perhaps I should not have mentioned it.

**Q11: Carbon tax is only one out of a range of tax instruments available to governments. As long as the total tax burden is more or less constant, why should there be a maximum to carbon tax? under a balanced budget approach, you can increase carbon tax while at the same time reducing other taxes.**

You raise a very good point. However, it is not easy to cut on other services so as to keep the tax burden constant. Suppose that the carbon tax *were* similar to the expenditure on healthcare. What other government expenditure is the government going to cut to keep the tax burden constant. Canada is experimenting with a carbon tax which is rebated to taxpayers. But, if the carbon tax is really spent on abatement, the rebate is a fall in available tax for other expenditures. The Western electorate does not seem to like that.

**Q12: Do you have a view on how likely it is that there will be a climate-driven catastrophe that causes (say) a 50% decline in equities?**

I have been looking at this type of question. I can give you an indirect answer. From our best estimates, to get a 50% fall in equity we 'need' tipping points with a threshold around 2.5 C, *and* we need to be abating slowly in the decades to come. See the table below, perhaps focusing on

| $EIS$ | $\kappa = 0.001$ | $\kappa = 0.01$ | $\kappa = 0.02$ | $\kappa = 0.03$ | $\kappa = 0.04$ |
|---|---|---|---|---|---|
| 0.875 | 55% | 65% | 70% | 85% | 90% |
| 0.925 | 55% | 60% | 70% | 80% | 90% |
| 0.975 | 50% | 55% | 65% | 80% | 90% |
| 1.025 | 50% | 55% | 65% | 80% | 90% |
| 1.075 | 45% | 50% | 60% | 75% | 90% |
| 1.125 | 45% | 50% | 60% | 70% | 90% |
| 1.075 | 40% | 45% | 55% | 75% | 90% |
| 1.125 | 40% | 45% | 55% | 75% | 85% |
| **average** | **45%** | **55%** | **65%** | **80%** | **90%** |

Table 3: The loss ratio (defined as the ratio of the value of equity stock with climate damages to its value in the absence of climate damages) for the values of the abatement speed, $\kappa$ displayed in the top row, for the values of the EIS shown in the first column, in the presence of tipping points, and in the case of the leverage exponent, $\lambda$, equal to 2. The bottom row shows the loss ratio averaged across different values for the EIS.

the bottom row. These are loss ratios, so a number such as 80% means a fall in equity prices of 20%.

The various columns correspond to speeds of abatement, slow to fast from left to right. The slowest corresponds roughly to the RCP8.5 scenario; the fastest implies a temperature in 2100 just above 2 C.

**Q13: How is this functionally different from investors looking at multiple scenarios (e.g., SSP1-26, SSP2-45, and SSP5-85)? Isn't it already understood a general "likelihood" of these scenarios?**

There are two problems with the reasonable approach you suggest:

1) the combinations SSP/RCP do not 'span the sample space' - meaning that they do not cover all reasonable combinations of economic, population and technological growth. This also means that you cannot just assign probabilities to the various SSP/RCP combinations, because they would not add up to 1.
2) Some of the scenario's combinations are almost impossible, so they should not be used unless one wants to study really 'tail' events. But investors do not know which combinations are almost impossible. As Dherminder said, for some combinations the models used to match SSP and RCP 'do not compute', meaning that there is no carbon tax that can link the two. So, these combinations are 'impossible'. However, the SSP/RCP does not tell you which combination 'just made it' – i.e., had a tiny probability of occurrence.

**Q14: Is it important to separate physical and transition risk, or combine them for final metrics?**

You raise a very good point here. One has to estimate both physical and transition risk, but one cannot just 'add them up' because they tend to be negatively correlated. So, yes, at the end of the day one is interested in valuation purposes in the combined (physical + transition costs), but these have to be estimated consistently, preferably from the same model (so that errors will cancel out).

The relationship is shown below – from a forthcoming publication. Notice how low transition costs implied high physical damages, and vice versa.

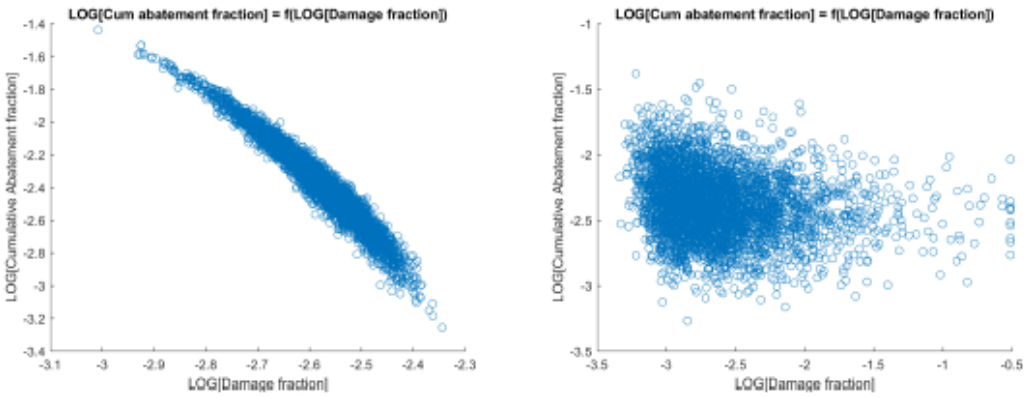



Exhibit 1: Left panel: the relationship between the logarithm of the fraction of GDP lost to physical damages ($x$ axis) and the logarithm of the cumulative abatement fraction ($y$ axis) when the only uncertainty is about the exact pace of the abatement policy. Right panel: The same quantities when the state variables of the problem are allowed to be stochastic.

**Q15: You say that physical and transition risks go together, but there is an important temporal lag due to the accumulation of GHG concentrations as the driver of physical risks. Do you plan to account for that in future iterations?**

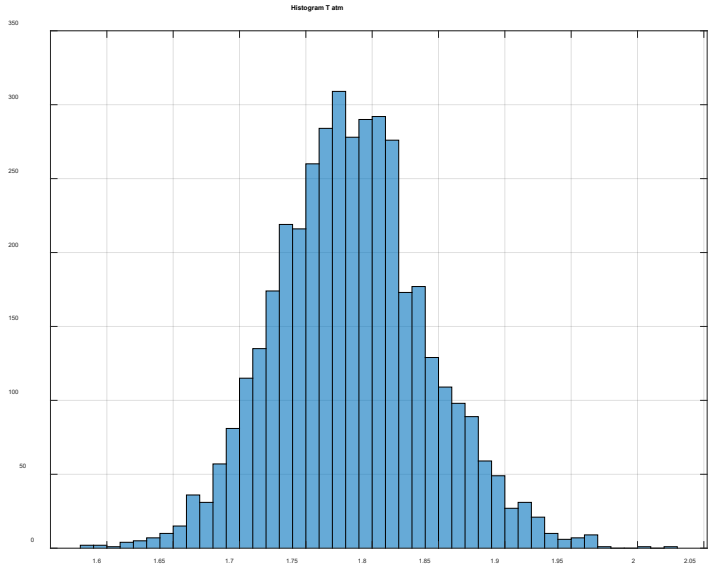
Excellent questions, but we already (try to) account for this, because we have calculated transition costs and physical damages as they evolve over time. So, if I abate little today, I have small transition costs and small physical damages *tomorrow*, but I can expect large physical damage in the future. Our models already know about the lags.

For a future Webinar…?

**Q17: Is the temperature anomaly that you presented referring to temperature in 2100? How does that distribution look like for temperature in 2050?**

Yes, the histogram I showed was for 2100. Please see the consistent distribution for 2050 – I stress that this is indicative, it is a bit on the pessimistic side, and should be looked at in the light of the assumptions made. So, please don't read too much into the fine details.

Careful, though. When equity analysists do their equity valuations, they project cashflows for a firm max 10-15 years, and then typically 'flat line' after that. The fact that we cannot guess what the cashflows *an individual firm* will be in the distant future, doesn't mean that those cashflows don't matter. With a not-particularly-low real-rate of discounting (without the risk premium) of 2.5%, cashflows in 50 years' time do not 'disappear' – they become 30% of their face value. Careful therefore in assuming that only the distribution of temperatures in 2050 matters because cashflows *of an individual firm* are never projected that far.



**Q18: How does this work compare to what Venmans & Carr did on the unconditional probability distribution of future emissions and temperatures?**

Thank you for pointing out the reference – it was one that I was unaware of. This is a different way to do the same calculation that we talk about. While we determine abatement profiles using the SCC, they argue that scenarios with emissions largely beyond current policy scenarios and largely below current pledge scenarios are relatively unlikely. They then put (arbitrary as far as I understand) weights on the scenarios and develop an unconditional temperature distribution.

**Q19: What is the probability of SSP1-26, SSP2-45, and SSP5-85? Is the quantified % much different than what is already expected?**

See answer to Q9.

**Q20: Do you have any thoughts on the impact of climate change on interest rates?**

Another super question. Let's take it in stages.

1) Suppose that there is robust abatement (little physical damage). This (study by the IMF) is likely to entail large public borrowing to finance this – an increase globally of ~ 40%. This in itself can put upward pressure on rates – albeit in a rather erratic way. Watch out for emerging markets (with small debt room) and for countries such as Italy.
2) Suppose now that there is slow abatement and therefore significant climate damage. This can depress economic activity (reduce consumption growth), and this typically induces central banks to cut rates. However, the fly in the ointment is inflation, which is difficult to associate with climate outcomes.

There are models (neo-Keynesian) that handle this stuff, and we are beginning to work with them, but, as you can imagine, it is all rather complicated.

**Q21: How would figure 16 be updated on an ongoing basis. At the moment it says something like "abandon all hope"?**

Since my family is of Italian origin, I am pleased that you quote Dante – alas, your quote stands at the entrance to his Inferno.

This figure (that, as I warned you during the presentation, is ballpark correct, but on the pessimistic side and at this stage only indicative – I wouldn't trust it to a resolution finer of 0.25 C), and must be continuously updated as we learn more:

1) about the damage function, and the possible location of tipping points;
2) about technological developments;
3) about the willingness of the electorate to divert consumption to climate abatement – in plain English, to pay more taxes to control climate change: we are already observing backlashes, and the rise of populists parties all over the world does not help;
4) about the economic models of GDP growth.

So, it is a continuous work in progress – at any stage it is a reflection of our state of knowledge *and of our ignorance*.

**Q22: How do you resolve the time horizon issue that physical risks impact on cash flows are so long term that they can be seen as irrelevant in the normal investment time horizon that fiduciary duty is concerned with? Is transition risk and hence divestment from the emitters going to be always overwhelming the risk assessments?**

Very good question. I would answer in two ways.

First, the investment horizon does not matter: even a long-term strategic investor can buy and sell her securities every month or week. So, what matters is how much distant cashflows impact current valuations, and this boils down to choosing the correct discount rate (and this is my second point).

We are running this type of calculations, and we find that medium-term cashflows can already be affected by physical damages, especially if we abate very little, and that the discounting is far from cancelling these impairments. We are using a range of discount rates, but the most important thing is to make the discount rate *state dependent:* low rates in states of low economic activity, and vice versa. Please see the answer to the question above.

**Q23: I have trouble seeing how financiers might estimate their asset portfolio (and hence exposure) at timescale beyond even 15 to 20 years?**

Our results refer mainly to equities as a whole, not to individual securities or sectors. Projecting cashflows for a company beyond 15 to 20 years is extremely difficult, but, for the market as a whole, we can make reasonable guesses about the distribution of economic output. What security holders receive is the fraction of what the economy produces that is paid out to the providers of capital – according to the seniority of their claim (equity or debt). So, the first and most important effect is the size of the pie. How the pie is shared also matters, but perhaps not so much.

**Q24: What prior probability distribution are you using for climate sensitivity (ie the temperature response to emissions)?**

Algorithmically:

- We work with the entire suite of CMIP6 models
- We then remove the so called hot tail of models (see eg Hausfather et al )
- We then parameterise all of the existing models using a 2 box EBM in the spirit of de Goeffroy (as per DICE)
- There is then an empirical distribution of parameters – for each model once can imply an ECS and TCR.
- We sample from the empirical distribution (effectively using a kernel density / gaussian copula type approach). *Hence we sample over the ECS distribution*.

**Q25: There is literature that distinguishes between long-term and short-term investors. Would you argue that these two classes of investors would look at scenarios differently (in particular with respect to pricing)?**

Not really – see also my answers above. Again, a price is a price, and a fall in price is going to hit you irrespective of whether you are a long- or short-term investor. Long-term investors do not have to keep their positions for years: their holding period need not match their horizon. And exceedingly few long-term investors have the ability to hold on to their positions if they show a fall in MTM because, given time, they will recover. They are exposed to stop losses like everyone else.

The real issue is whether physical damages in the medium-term future can affect valuation *today*. Please see my previous answer on this.

**Q26: If I'm understanding correctly, your analysis assumes that an increase in GDP per capita results in reduced carbon emissions as manufacturing transitions to services within a developing country. However, it seems like that manufacturing would simply transfer to less developed countries, so is it appropriate to assume that carbon emissions truly decrease worldwide absent a decrease in goods consumption per capital? Or are there other factors at play which might reduce emissions globally (perhaps carbon tax transfers from developed countries to developing countries)?**

and

**Energy / GDP intensity decreases in part because developed countries delegate production to developing country. At some point, China and India will delegate to let say Africa/Asia. But we will all want to consume more stuff (China, India, OECD). Someone will have to produce all this stuff… Is it really possible to decrease the Energy / GDP intensity at the global level? We could not all be in the service sector…**

You both raise a good point, but the trends I show in Figures 17 to 20 remain valid even if we account for 'exported emissions'. Ultimately it is down to the fact that, as people become richer, they do not want a fourth refrigerator, but a nice restaurant meal. The shift from manufacturing to services as people become richer is a robust finding, and globally this remains true even if some of the manufacturing is outsourced.

And, yes, you are right, we cannot all be in the service sector, but the mix of manufacturing/services *can* change globally if the world (globally) becomes richer. Once the roads and the bridges and the dams are built, you are done for a long time – witness the Roman roads 😊.

**Q27: How is the uncertainty of the temperature anomaly as a risk driver correlated to traditional financial risk, or is this viewed separately?**

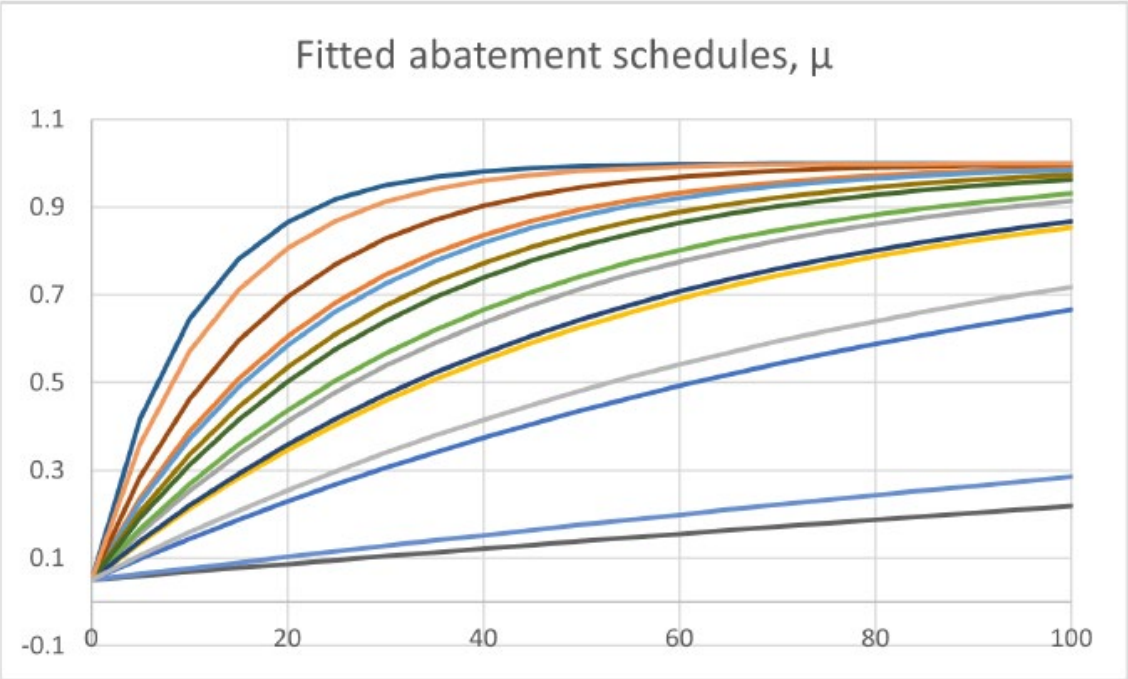
The logical flow within our model is:

Economic output ➔ emissions ➔ concentrations ➔ temperature ➔ economic damages.

The last link comes from the damage function, that I discussed above. So, temperature is a fully integrated risk factor in our approach.

**Q28: Is Figure 16 associated to one SSP path? What's are the assumptions for this model?**

I should have made this clearer: the distribution in Fig 16 (which, I stress again, is indicative) covers all the abatement scenarios in Fig 13, which I reproduce below. So, it comes from combining very fast and very slow abatement patterns. The demographic, economic and technological distributions are also all included. So, this is a probability-weighted average of all the SSP/RCP combinations, and more.



**Q29: How do you factor in the temperature uncertainty into the histogram of temperate anomalies, e.g. RCP gives a likelihood of limiting outomes to given temp, which is not certain**

**Q30: Does this model also assume that there is a pre-defined climate sensitivity distribution that fully determines radiative forcing with increases in temperature? There are controversies around using this as the basis for further analysis.**

See answer to Q 24

**Q31: What is the principal risk factor affected by climate risk? market risk, credit etc?**

and

**Once the distribution of the temperature is obtained, how to convert this information to impact on asset class returns?**

To me the really important thing to look at is the seniority of your financial claim (equity versus debt, for instance). Equity will take the first hit.

Careful, however, when people leverage debt (eg, via securitization – junior, mezzanine, etc). Then things can get very messy, very soon.

As for the second, related, question, from the temperature the damage function gives you the loss in economic output, that then you have to cascade down according to the seniority of the claim to the economy produces. Apart from risk premium effects, if securities do badly is because the economy will have been founding to produce less than it was expected to. Remember that we are doing a top-down approach.

**Q32: What sources do you use apart from geographic data to assess company-level physical risk?**

To be clear we have not done this for the exercise under discussion. The answer would be very company / asset specific: for example, for an electricity generator we might consider risk to physical infrastructure which is a function of future climate and resilience (eg some infrastructure may be designed / adapted to run in warmer conditions) as well as potential future demand (which may be higher than today).

**Q33: besides looking at impact ic climate change on the CFs, how are alternative data such as climate could be used to create a sustainable portfolio. for example by looking at the impact of weather patterns on different regions.**

We are actively looking into this. We are exploring climate data over the whole world with a 3 km x 3 km spatial resolution. We are still in the early stages of this. Watch this space…

**Q34: How might you apply this framework at a total portfolio level (ie at a strategic asset allocation level, how can you distribute the transition costs across asset classes)?**

At the moment the only asset classes we can 'resolve' cleanly are equities and government debt. With a bit of work, we could add corporate debt, but we are not there yet. Remember, this is a top-down approach.

**Q35: Thank you for the very insightful presentation. I have a question regarding the use of such scenarios (or at least same reasoning/methodology) to assess place-based/asset level investments. Is it possible?**

This is challenging and not really what is discussed here. One would need to understand future climate at a given point (e.g., there are detailed projections within the CMIP6 datasets using the SSP / RCP frameworks for example); in the framework discussed here, you would need to downscale the global temperature anomaly into a spatially resolved temperature and climate. Once done this would then be translated into an impact on the asset; presumably one would build some form of regression model of the asset and look at its history or analyse the asset to understand how it might fail if eg the number of heating degree days exceeded a certain level.

**Q36: This GDP/pop and CTax driven approach is neat, but it works because you have collapsed all climate related policies to a single lever CTax and rely on the identity. Sadly, the real world is way more nuanced and other policies (with considerably more uncertainty). This is a simple model and I don't really know if an investor (I have been on the front line on this regard) would find this useable on this. I would love to work with you on enhancing this.**

**The biggest providers of capital (banks/insurers/pension funds) have to demonstrate the robustness of assumptions/models. If we move to a useable model, we would need many more survey-based distributions about even more nebulous things (date of coal phase out in US, date of ICE cars being <20% stock in China). So, how to make this approach "validatable"?**

You raise interesting points, but, again, I think that some of the misunderstanding comes from the confusion between bottom-up and top-down approaches.

First, I come from physics. It is not true that simple models are just toy models. It depends on what questions you want them to answer. At the aggregate level, simple models often give much better, and more 'auditable', answers than complex ones.

You say that you are on the frontline. I assure you that I have been as well, both on the sell- and buy-side. My last job in the industry was head of fixed-income research at PIMCO. I can assure you that they are very interested in the bottom line, and that they take simple, top-down models very seriously. Bill Gross always used to start from 30,000 feet up – perhaps even higher.

Of course, the top-down approach does not have all the answers, and a bottom-up approach is very important as well. But the two have to meet in the middle. Both approaches miss important parts of the puzzle. At the moment, we are providing one set of answers.

Very happy to talk to you separately om all of this.

**Q37: Is this work published and citable?**

Yes, this work has just been published and is citable:

Rebonato, R., D. Kainth, and L. Melin. (2024) Climate Scenario Analysis and Stress Testing for Investors: A Probabilistic Approach. EDHEC-Risk Climate Impact Institute, EDHEC Business School (January).

**Q38: How do SSP scenario uncertainties compare with climate risks uncertainties?**

You put your finger right on the problem. For a given narrative, there is no uncertainty in a given SSP/RCP scenario, only a most likely path.

Many SSP/RCP scenarios do create a fan of outcomes, but there is no probabilistic dimension to this fan. This is what we are trying to fix.

**Q39: Does the damage function map the temperature into economic damage on the overall economy, or sector-specific?**

Good question. Currently globally, but we are doing a lot of work (with extremely high spatial resolution data: 3 km x 3 km covering the whole globe), to get regional damage functions.

**References:**

Rebonato, R., D. Kainth, and L. Melin. (2024) Climate Scenario Analysis and Stress Testing for Investors: A Probabilistic Approach. EDHEC-Risk Climate Impact Institute, EDHEC Business School (January).

Viewpoint: Investor climate scenarios need to be probability-aware"), op-ed, Investment & Pensions Europe

About Riccardo Rebonato:

Riccardo Rebonato is Scientific Director of EDHEC-Risk Climate Impact Institute and Professor of Finance at EDHEC Business School. He heads EDHEC-Risk Climate Impact Institute's "Impact of Climate Change on Asset Prices" research programme. Riccardo holds doctorates in Nuclear Engineering and Condensed Matter Physics. He has held senior positions at Edinburgh University, Oxford University and Imperial College, London, as well as at some of the world's leading international financial institutions, and served on the boards of ISDA and GARP. He has written 10 books on finance and political economics; his latest book "How to Think About Climate Change" (Cambridge University Press) deals with using economics to tackle climate change. The Journal of Portfolio Management named him 2022's "PMR Quant Researcher of the Year".

About Dherminder Kainth:

Dherminder Kainth is a Research Director at the EDHEC-Risk Climate Impact Institute, working on the impact of climate change on asset prices and investment management. After obtaining a PhD in condensed matter physics from Cambridge University and conducting post-doctoral research there, he spent the majority of his career in the banking industry, working extensively in derivative pricing, risk management and prudential capital requirement, before taking on the role of Head of Model Risk at RBS. Subsequently he worked for three years within the Prudential Regulation Authority at the Bank of England, where he was involved in the LIBOR phase out and the development of industry wide model risk management principles. His financial research has appeared in Risk and The Journal of Portfolio Management.