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TRANSITION(S)

STRATEGY | FINANCE | TRAINING

Green Finance:
from concepts to advanced instruments

Session 2: the financial management of environmental risk

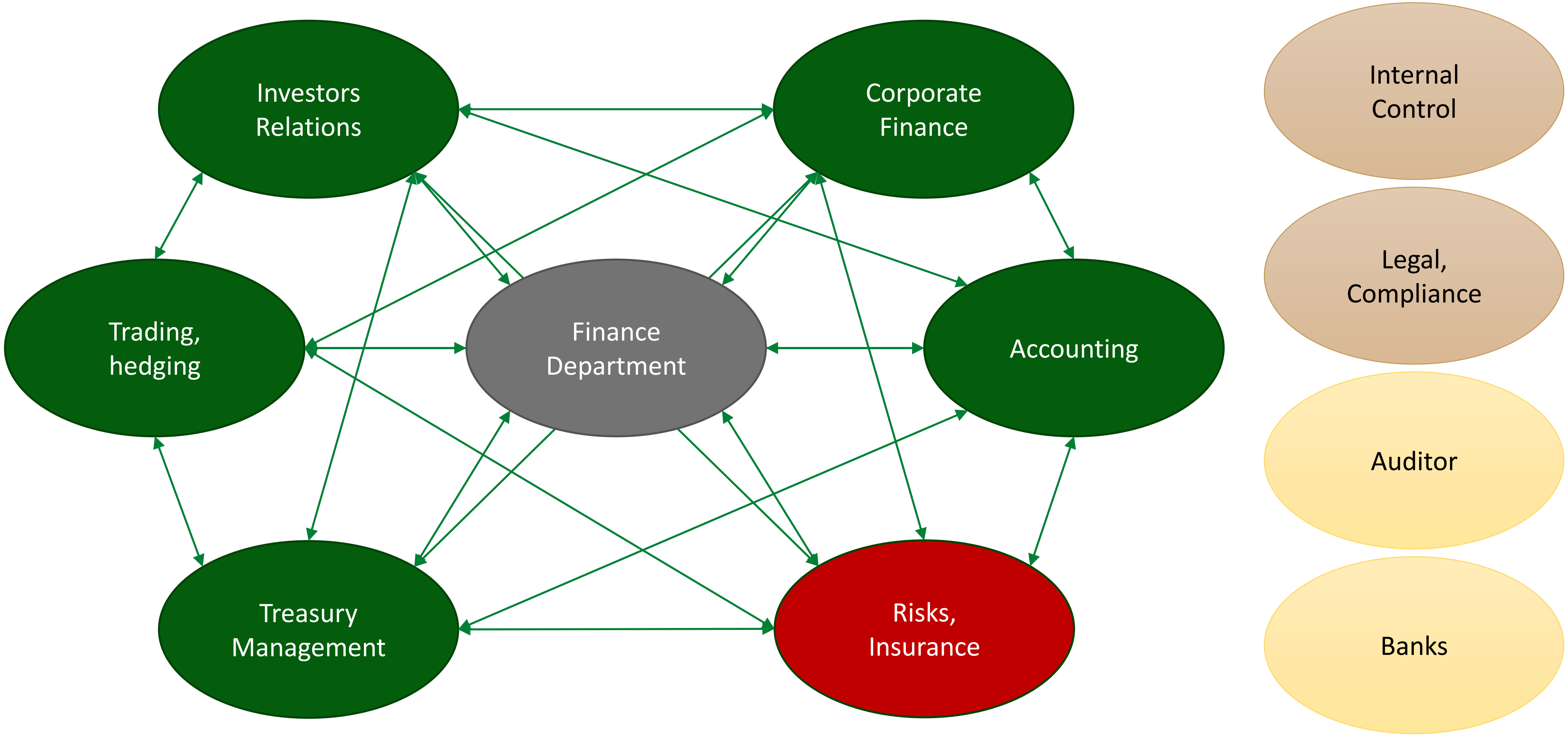
Refresher

Main messages from previous session

- Climate change and the green transition is the biggest economic challenge of the 21st century
- The fundamentals of our market economy do not allow for a full integration of this necessary effort without public intervention
- There is a radical uncertainty concerning both climate change and the policy measures that need to be deployed
- Currently the measures that are planned, even in the most optimistic scenarios, are insufficient to prevent dramatic evolutions
- Many (most) of the aspects of the current environmental crisis are left unaddressed

- At this stage, the main commitment is the Paris Agreement under which parties have agreed to implement national measures in order to limit temperature growth to 1.5ºC by the end of the century. For Europe, it means reaching **carbon neutrality** by 2050.

The many different jobs of a finance department



Is there a specificity to environmental risk?

Nothing can be more counterproductive than any certainty regarding complex affairs.
Uncertainty and unpredictability will always remain the most fundamental attributes of human existence.

Vaclav Smil, Energy Historian

https://www.latimes.com/business/story/2022-09-05/the-energy-historian-who-says-rapid-decarbonization-is-a-fantasy

Risk stems from the changing nature of the world

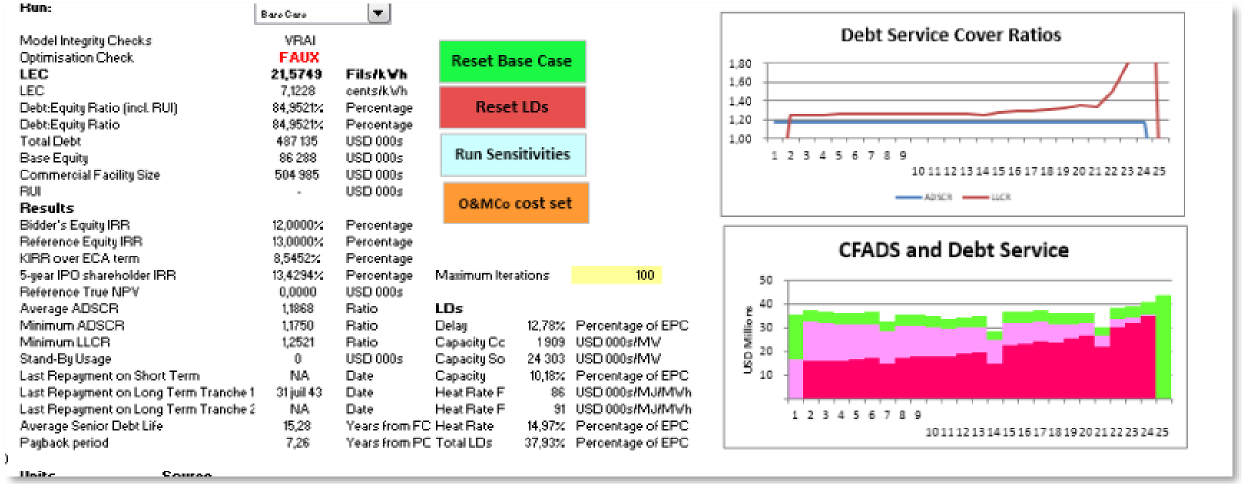
- Decision-making for the future depends on our ability to anticipate change
- Conduct is forward-looking and the problem of knowledge is prediction
- Knowledge of the future depends on our ability to analyse past behaviours to isolate recurrences and that these properties maintain over time
- Too many variables to handle, so we depend on **inference** from other behaviours, i.e. in the **constancy of the properties**
- Fully deterministic analysis is impossible, leading to estimations and probabilities attached to different outcomes
- Statistics are historical observations, probabilities are forward-looking models
- Past performance is not representative of future performance

Source: Franck Knight, Risk, Uncertainty, and Profit, 1921,

The difference between risk and uncertainty

- According to Knight (1921) arises when we cannot predict the outcome of a situation but are able to attach probabilities to the different scenarios
- On the other hand, uncertainty means that we do not have the ability to infer these probabilities (*Knightian uncertainty*)
- In practice, the distinction is a bit hazardous as all situations potentially present unquantifiable variables

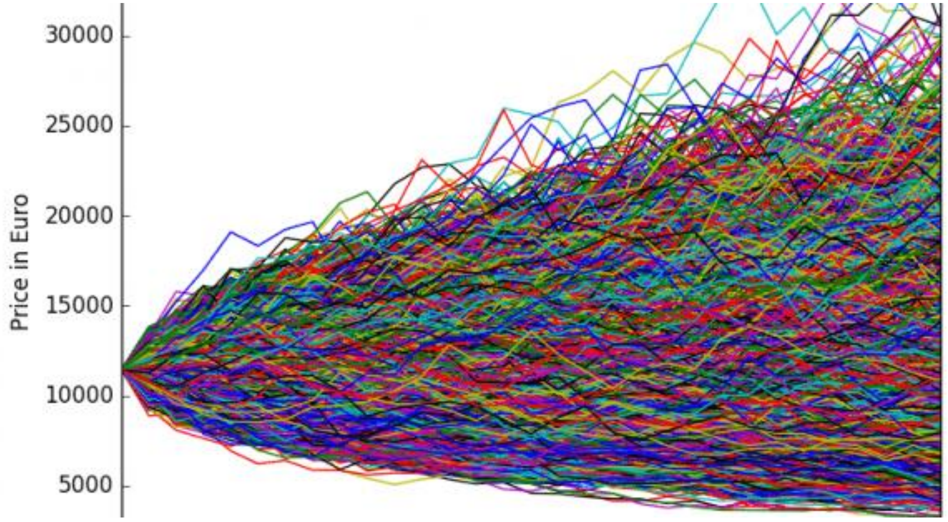
- In order to anticipate risks, the financial industry has developed always more sophisticated modelling techniques
- **Deterministic models** assign fixed probabilities to different events and explore a limited range of outcomes : a business plan is a deterministic model
- These models have strong limits :
  - Simple and explainable
  - Heavily rely on quality of hypothesis
  - Provide false sense of certainty, i.e. do not cover the full range of outcomes

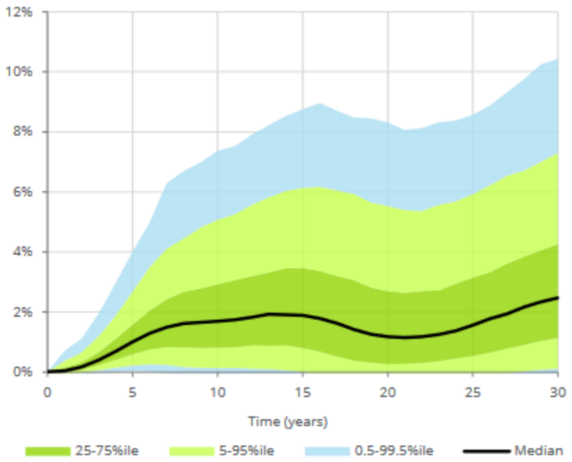


Source: Franck Knight, Risk, Uncertainty, and Profit, 1921,

The statistical treatment of uncertainty

- **Stochastic (probabilistic) models** use randomness to assess the different probability scenarios
- Stochastic models still rely on hypothesis and on the capacity to generate random variables (Brownian motions are frequently used)
- Black & Scholes option pricing model is one of the most famous examples in finance of stochastic modelling (and it relies on both Brownian motion and the assumption of a log-normal distribution of returns)
- **Monte-Carlo simulations** (von Neumann, Ulam) allow repetitive iterations of the same randomness-based calculation in order to assess the actual probability distribution of the outcome
- Monte-Carlo simulations will provide estimates of probabilities and of a cone of possibilities, which can then be used in deterministic modelling





Source: https://datascience.eu/fr/mathematiques-et-statistiques/definition-de-la-simulation-de-monte-carlo/ | https://www2.deloitte.com/content/dam/Deloitte/za/Documents/financial-services/ZA_XSG-information-pack_151116.pdf

Getting it wrong

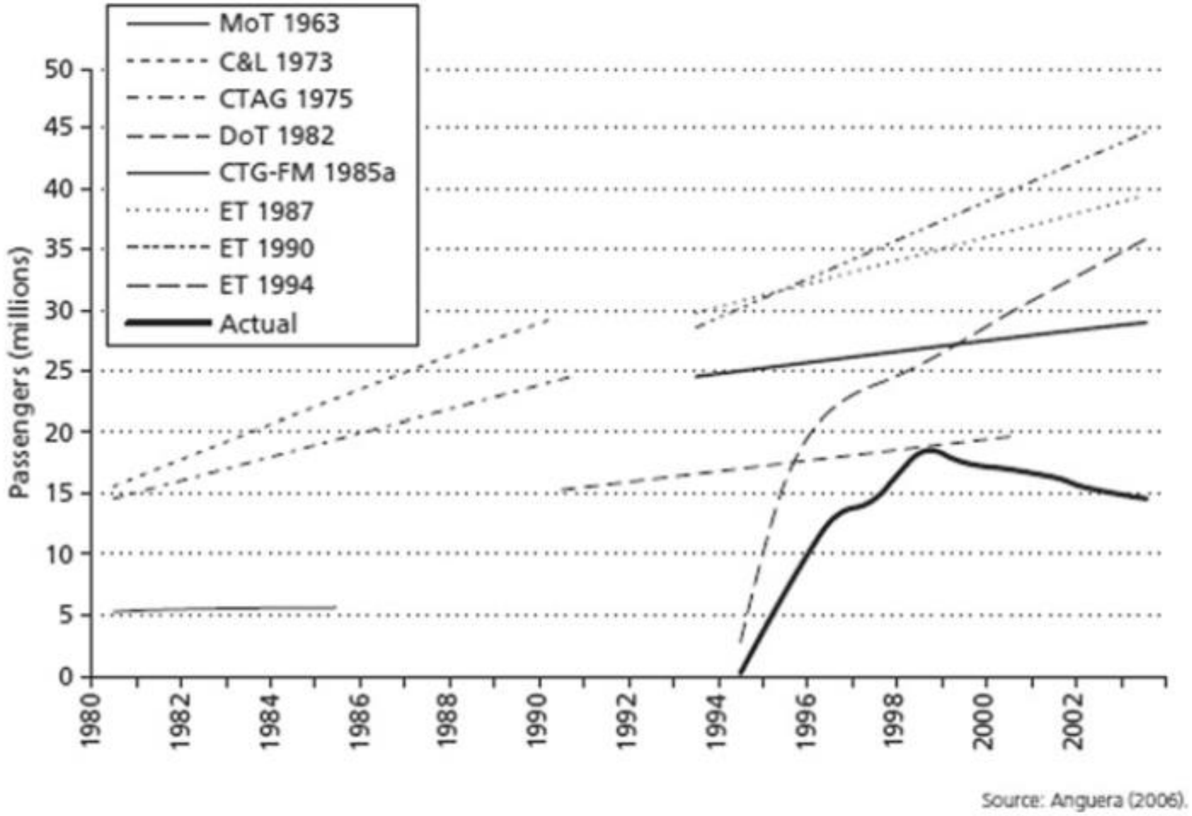
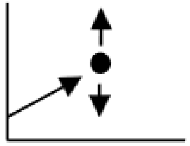
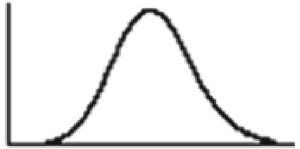
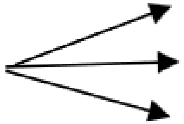
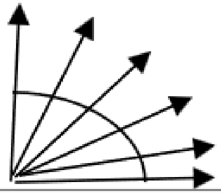
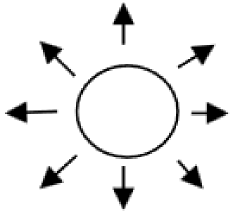


Fig. 1.1 Channel Tunnel passenger traffic forecasts and actual results

Source: Marchaux et al., Decision Making under deep uncertainty, From Theory to Practice, DMDU, Springer, 2019, 418 pages

The different levels of uncertainty

Table 1.1 Progressive transition of levels of uncertainty

	Complete determinism	Level 1	Level 2	Level 3	Level 4 (deep uncertainty)		Total ignorance
					Level 4a	Level 4b	
Context (X)		A clear enough future 	Alternate futures (with probabilities) 	A few plausible futures 	Many plausible futures 	Unknown future 	
System model (R)		A single (deterministic) system model	A single (stochastic) system model	A few alternative system models	Many alternative system models	Unknown system model; know we don't know	
System outcomes (O)		A point estimate for each outcome	A confidence interval for each outcome	A limited range of outcomes	A wide range of outcomes	Unknown outcomes; know we don't know	
Weights (W)		A single set of weights	Several sets of weights, with a probability attached to each set	A limited range weights	A wide range of weights	Unknown weights; know we don't know	

Source: Marchaux et al., Decision Making under deep uncertainty, From Theory to Practice, DMDU, Springer, 2019, 418 pages

Deep uncertainty and its consequences

- Deep uncertainty has **three unknowns** (Lempert et al., 2003) :
  - The external context of the system
  - The functioning and the boundaries of the system
  - The outcomes and their relative importance
- Climate –related decisions are highly sensitive to catastrophic events, even if they occur with extremely low, but 'fat-tailed', probability (**Dismal theorem**, Weitzman, 2009)
- The **exact quantification of the damages of these events is impossible**
- This is a structural result of our uncertainty as to the effects of GHG emissions
- The cost of those catastrophes is so important that it dwarfes discounting and should make our willingness to pay for their avoidance **infinite** (Weitzman, 2009)
- The main question becomes: **how should we value catastrophic events as a society ?**

Rumsfeld: Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know. And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones.

Source : https://archive.ph/20180320091111/http://archive.defense.gov/Transcripts/Transcript.aspx |Millner, On Welfare frameworks and catastrophic climate risks, in Journal of Environmental Economics and Management, 2013 | Weitzman, On modelling and interpreting the economics of catastrophic climate change, in The Review of Economics and Statistics, 2009

From Black Swans to Green Swans

- A **Black Swan** (1) has a probability of occurrence outside of realistic expectations, (2) have extreme impacts and (3) can only be explained ex post (Taleb, 2007)
- **Fractal mathematics** and **conter-factual reasoning** can be used to reduce the importance of black swans. Fat-tail risk is an argument for the need of regulation on financial markets. Historical data and normal distributions are irrelevant.
- **Three differences with Green Swans :**
  - There is certainty about the coming materialization of climate risk
  - Climate change is the “mother of all systemic risks” because it can trigger extinction-level events
  - The level of complexity is far higher than for “traditional” Black Swans

Source : Bolton et al., The Green Swan, Central Banking and financial stability in the age of climate change, BIS, Banque de France, 2020, 115 pages

The different natures of environmental risk

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- Climate change affects prices through two channels : **physical risks** related to climate damages, and **transition risks** related to mitigation strategies
- Distinctive features of climate change include physical and transition risks that interact with complex, far-reaching, nonlinear, chain reaction effects

Framework for physical and transition risks — Graph 5

	Low-carbon scenario ← More transition risk			Hothouse Earth scenario More physical risk →
Scenario	**Rapid Transition**	**Two-degree**	**Business-as-intended**	**Business-as-usual**
Corrective transition response	Very strong	Strong	Substantial	Limited
Change in temperature, 2100 vs pre-industrial era	1.5°C	2°C	3°C	4°C

Source: adapted from Oliver Wyman (2019); authors' elaboration.

Risks affected	Physical: Climate-related	Physical: Environmental	Transition: Climate-related	Transition: Environmental
	• Extreme weather events • Chronic weather patterns	• Water stress • Resource scarcity • Biodiversity loss • Pollution • Other	• Policy and regulation • Technology • Market sentiment	• Policy and regulation • Technology • Market sentiment
Credit	The probabilities of default (PD) and loss given default (LGD) of exposures within sectors or geographies vulnerable to physical risk may be impacted, for example, through lower collateral valuations in real estate portfolios as a result of increased flood risk.		Energy efficiency standards may trigger substantial adaptation costs and lower corporate profitability, which may lead to a higher PD as well as lower collateral values.	
Market	Severe physical events may lead to shifts in market expectations and could result in sudden repricing, higher volatility and losses in asset values on some markets.		Transition risk drivers may generate an abrupt repricing of securities and derivatives, for example for products associated with industries affected by asset stranding.	
Operational	The bank's operations may be disrupted due to physical damage to its property, branches and data centres as a result of extreme weather events.		Changing consumer sentiment regarding climate issues can lead to reputation and liability risks for the bank as a result of scandals caused by the financing of environmentally controversial activities.	
Other risk types (liquidity, business model)	Liquidity risk may be affected in the event of clients withdrawing money from their accounts in order to finance damage repairs.		Transition risk drivers may affect the viability of some business lines and lead to strategic risk for specific business models if the necessary adaptation or diversification is not implemented. An abrupt repricing of securities, for instance due to asset stranding, may reduce the value of banks' high quality liquid assets, thereby affecting liquidity buffers.	

Source: ECB.

Source: Bolton et al., The Green Swan, Central Banking and financial stability in the age of climate change, BIS, Banque de France, 2020, 115 pages | ECB, Guide on climate-related and environmental risks

A focus on stranded assets

- **Stranded assets** are assets who are no longer economically useful or whose economic value is lesser than anticipated despite not being fully depreciated
- In financial terms, these assets need to be written-down to reflect their loss of value, this impacts both the balance sheet (reduction of tangible assets) and the income statement (non-cash loss)

$$Impairement = Book\ Value - Max(Selling\ Value; Usage\ Value)$$

With :

$Selling\ Value = Fair\ Value - Cost\ to\ sell$

$Usage\ Value = Present\ Value\ of\ Future\ Cash\ Flows$

- To keep in line (50% prob.) with a 2°C scenario, 80% of coal reserves, 50% of gas reserves, 33% of oil reserves should remain in the ground
- This is not priced-in as it relies on political choices, i.e. the related asset classes are susceptible to be affected by « **unanticipated and sudden writedowns, devaluations or conversion to liabilities** »
- Studies estimate the value of potentially stranded assets in fossil fuel anywhere **from $1 trillion to $18 trillion**

In addition, in line with its new Climate Ambition announced on May 5, 2020, which aims at carbon neutrality, Total has reviewed its oil assets that can be qualified as "stranded", meaning with reserves beyond 20 years and high production costs, whose overall reserves may therefore not be produced by 2050. The only projects identified in this category are the Canadian oil sands projects Fort Hills and Surmont.

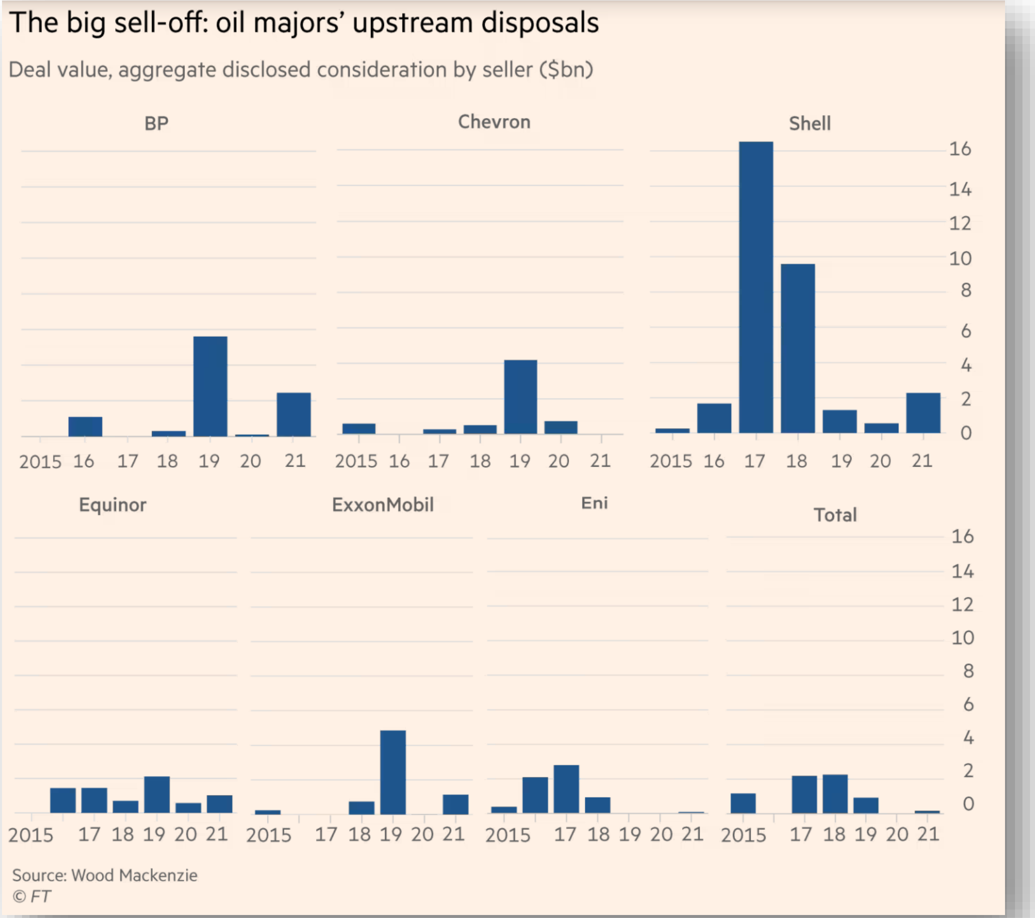
For impairment calculations, Total's Board of Directors has decided to take into account only proven reserves on these 2 assets – unlike general practice which considers so-called proven and probable reserves. **This leads to an additional exceptional asset impairment of 5.5 B$**. Consequently, Total will only take into account for its proven and probable reserves in Canada the proved reserves. And the proved and probable reserves life of the Group is thus reduced from 19.0 to 18.5 years. In addition, Total will not approve any new project of capacity increase on these Canadian oil sands assets. Finally, still consistent with the Climate Ambition announced on May 5, 2020, Total decided to withdraw from the Canadian association CAPP considering the misalignment between their public positions and the Group's ones.

Overall, the exceptional asset impairments that will therefore be taken into account in the 2nd quarter of 2020 amount to 8.1 B$, including 7 B$ on Canadian oil sands assets alone, impacting the gearing ratio of the Group by 1.3%.

Sources: Bolton et al., The Green Swan, Central Banking and financial stability in the age of climate change, BIS, Banque de France, 2020, 115 pages | https://corporatefinanceinstitute.com/resources/knowledge/accounting/stranded-assets/

Unintended consequences

- Faced with the prospect of significant losses, some companies actually prefer to **divest** from the threatened assets before the losses materialise
- This has a double benefit since it avoids losses and frees-up cash to invest in other energy projects, mainly to finance the pivot to renewable energy
- **Shift of ownership** to private and/or State-owned investors with much less scrutiny and public pressure (and no investor activism), reduces overall impetus to cut emissions



Sources: https://www.ft.com/content/4dee7080-3a1b-479f-a50c-c3641c82c142

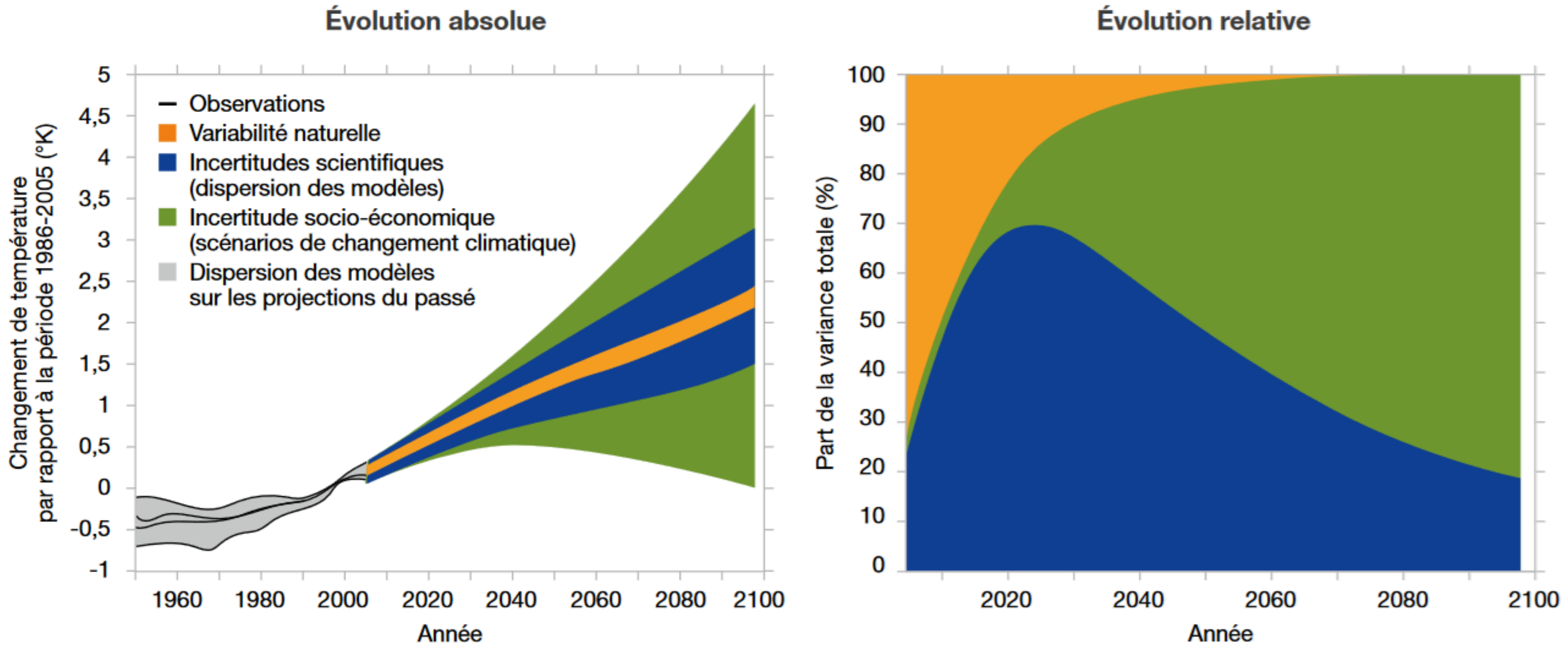
The sources of climate uncertainty

Sources of uncertainty	Natural variation of climate (stochastic / ontological uncertainty)	Scientific uncertainty (or epistemological)	Socio-economic uncertainty
Associated risks	Physical risk	Physical risk	Physical and transition risk
Origin and nature of uncertainty	Climate is a chaotic system with a non-linear, non-deterministic behaviour Differences in model outcomes using same inputs and model	Climate is a complex system that we can only partially describe and represent Limits to modelling Differences in model outcomes using identical scenarios but different models	Inherent to the global GHG reduction trajectory (which low carbon transition?)
Perspectives on the evolution of uncertainty level	By essence, unreducible uncertainty	Some uncertainties could be reduced through improvements in modelling (both in terms of computing power and understanding of dynamics) Scientific progress is not linear however	Depends on political and economic scenarios and on their interpretation (perceived credibility) by economic actors
Time horizon for the prevalence of this uncertainty	Short term	Medium term	Long term
Ability to manage uncertainty	Known unknowns: for some variables and dimensions, we know the intrinsic limits or the errors in our understanding/modelling choices that have been made Unknown unknowns: parts of the system could display disruptive behaviours, surprises, especially when straying away from average variability domains		Scenarios can be used to limit the field of possibilities but not to assign probabilities

Source: Dépoues et al. Pour une autre approche du risque climatique en finance, Tenir compte des incertitudes, I4CE, Nov. 2019, 20 pages. Translation by the author.

Weight of the difference sources of uncertainty

FIGURE 1. IMPORTANCE RELATIVE DE CHAQUE SOURCE D'INCERTITUDE DANS LES PROJECTIONS DE CHANGEMENT DE LA TEMPÉRATURE AU COURS DU 21ÈME SIÈCLE



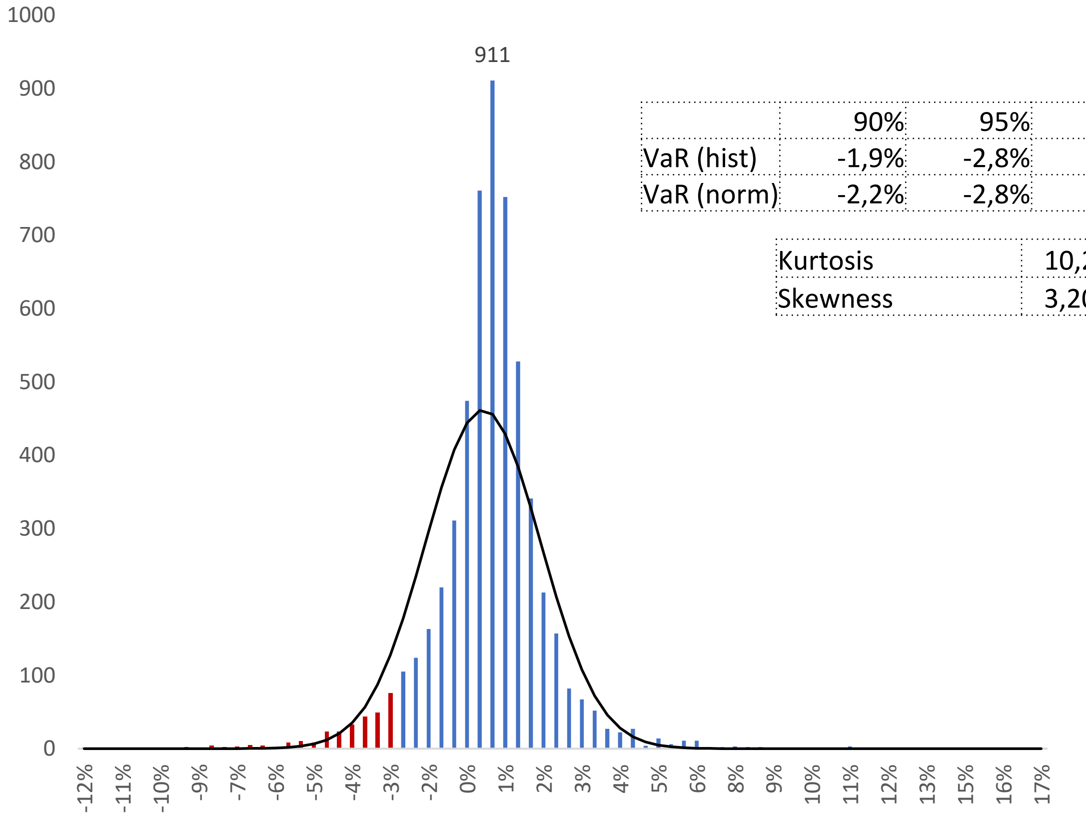
Source : (Hawkins and Sutton 2009) - Traduction : auteurs

Source: Dépoues et al. Pour une autre approche du risque climatique en finance, Tenir compte des incertitudes, I4CE, Nov. 2019, 20 pages. Translation by the author.

How does finance manage risk and uncertainty?

Measuring risk: Value at Risk

- **Volatility** is a traditional measure of risk but it does not tell you which side of volatility you are exposed to (+/-) as risk should not be symetrical
- **Value at Risk** is the minimum value of losses expected during a specified time period at a given level of probability
- Here we have different values for the VaR of the Nasdaq 100, based on historical and normalised data
- For 100$ invested over a day, you stand to lose 2,8$ with a 5% probability, conversely, your returns are expected to be superior to -2,8% with a 95% confidence level
- Monte Carlo simulations can also be used to approximate VaR on a forward-looking basis
- VaR is the work horse of risk management with various levels of sophistication in its modelling
- VaR is structurally incapable of valuing potential losses linked to climate change



	90%	95%	99%
VaR (hist)	-1,9%	-2,8%	-4,9%
VaR (norm)	-2,2%	-2,8%	-4,0%

Kurtosis	10,23501
Skewness	3,202567

Modern portfolio theory and diversification

- **Modern Portfolio Theory** (Markowitz, 1952) distinguishes between **unsystematic risk** (linked to a specific security) and **systematic risk** (linked to the market)
- Using the **Capital Asset Pricing Model** (CAPM), investors are able to build a theoretically efficient portfolio and to diversify their exposure to systematic risk through management of the β

$$E[r_i] = r_f + \beta_i * (E[r_m] - r_f)$$

With :

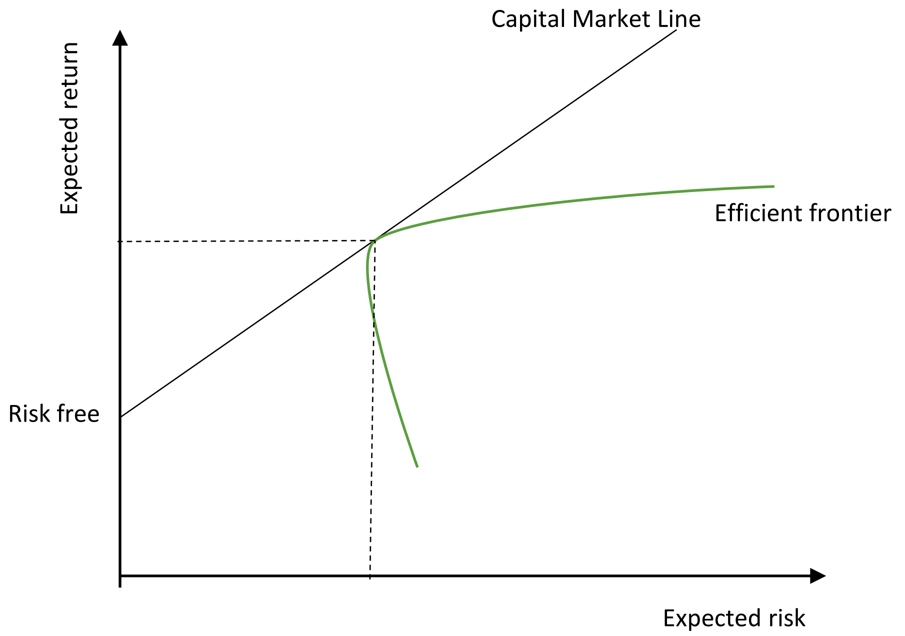
$E[r_i]$ the expected return of asset i

r_f the risk-free rate

$\beta_i = \frac{Covariance\ (r_i, r_m)}{variance\ (r_m)}$

$E[r_m]$ the expected return of the market

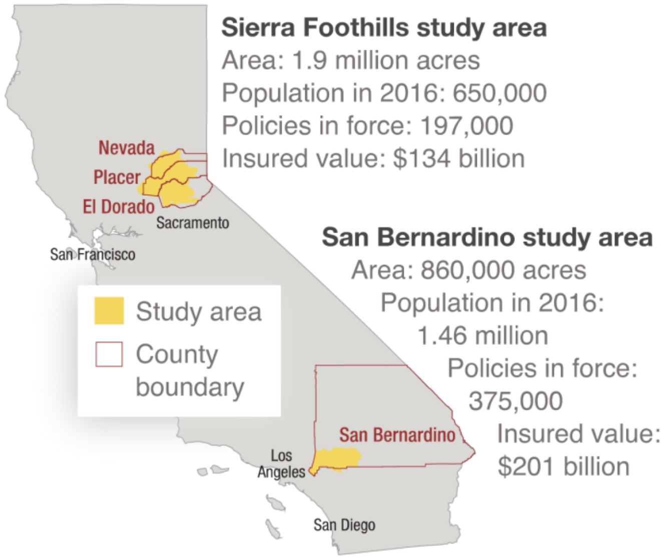
- Β is a measure of the sensitivity of the portfolio to systematic risk
- CAPM assurmes that variance is a good descriptor of risk and a normal distribution of returns



Insurances

- Companies use insurance policies to cover themselves against certain risks (drought, fires, etc)
- Insurance policies have a cost (**premium**) and **deductibles**
- Insurances create **moral hazard** by providing negative incentives against mitigation behaviours
- Insurance companies refuse to cover some assets:
- Insufficient data / low volume – high cost / danger areas
- Increasing risk levels will mean either increasing cost (premium/deductible) or reducing coverage
- Increasing insurance costs amplifies **adverse selection** whereby only the most exposed actors suscribe insurance coverage

The Sierra Foothills and San Bernardino Study Areas



By 2055 :

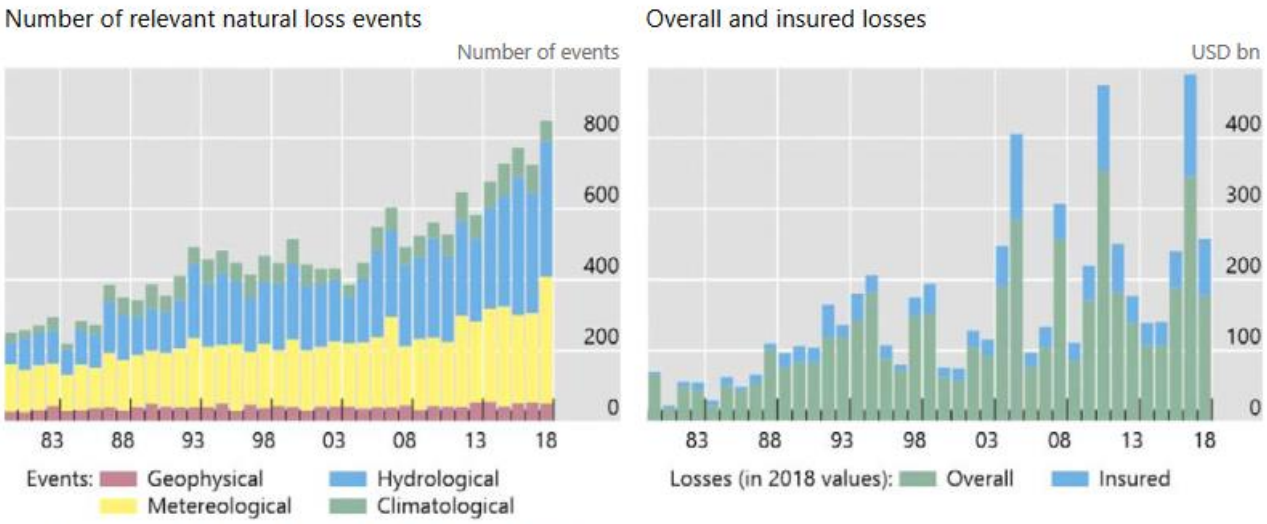
- a 5 percentage point drop in the market share of admitted insurers, reducing their market share vis-à-vis surplus lines and the FAIR Plan
- an 18 percentage point increase in premiums in the admitted market per $1,000 coverage, reflecting higher risk and potentially creating affordability issues for homeowners; ZIP codes with the greatest risk show significantly higher increases
- a 6.5 percentage point drop in the ratio of coverage amounts to property value, potentially exacerbating under-coverage issues for homeowners
- an increase of $121 in deductibles per $1,000 of coverage.

Source: https://www.rand.org/pubs/research_briefs/RBA635-1.html

The insurance sector is under increasing pressure

Increase in the number of extreme weather events and their insurance,[15] 1980–2018

Graph 4



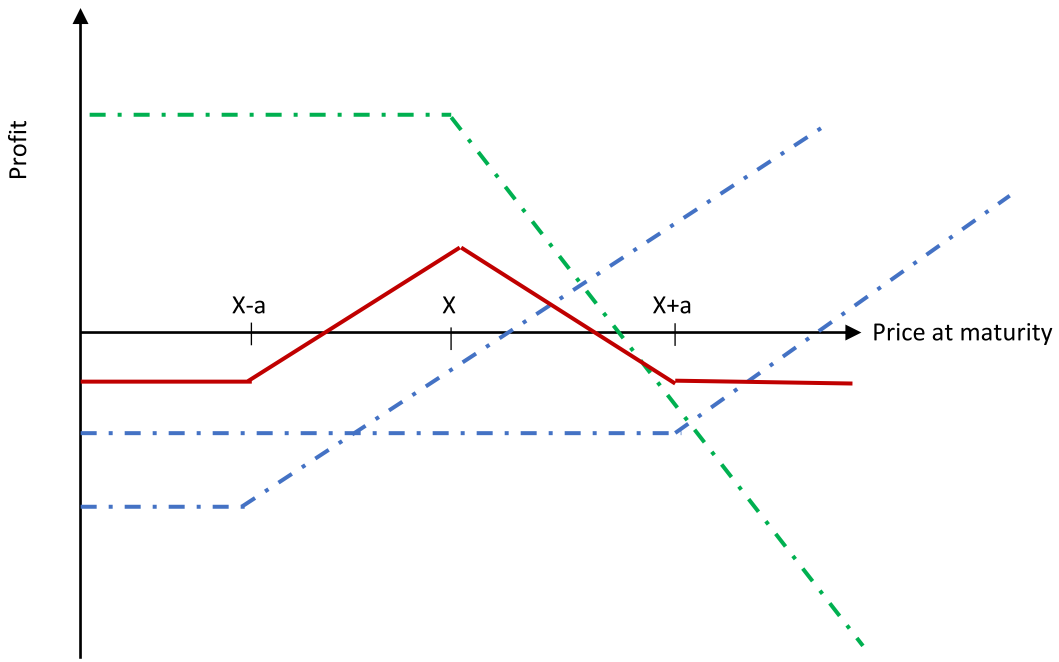
Includes copyrighted material of Munich Re and its licensors.

Source: MunichRe (2018).

Sources: Bolton et al., The Green Swan, Central Banking and financial stability in the age of climate change, BIS, Banque de France, 2020, 115 pages

Hedging through financial products

- Financial instruments can be used to partially cover some of the risks companies are exposed to
- **Credit Default Swaps** (CDS) are contracts by which a third party agrees to repay the lender if the borrower defaults on his debt. In exchange, the third party receives a stream of cash flows for the length of the contract
- CDS are an example of **hedging strategies** by investing in derivatives whose risk profile is inversely correlated to the initial investment (put / call options, forwards, swaps…)
- **Securitisation** is a financial technique that allows a company to isolate some of its assets within **Special Purpose Vehicles** (SPVs). This technique can be used to ring-fence bankruptcy risk, to rationalise activities according to their risk profile or to dispose of or deconsolidate some assets
- All these techniques present significant advantages but (1) are expensive, (2) require financial sophistication, (3) are not exempt from risks (most notably basis risk and counterparty risk)[1] and (4) are often unavailable in many geographies / on longer time scales

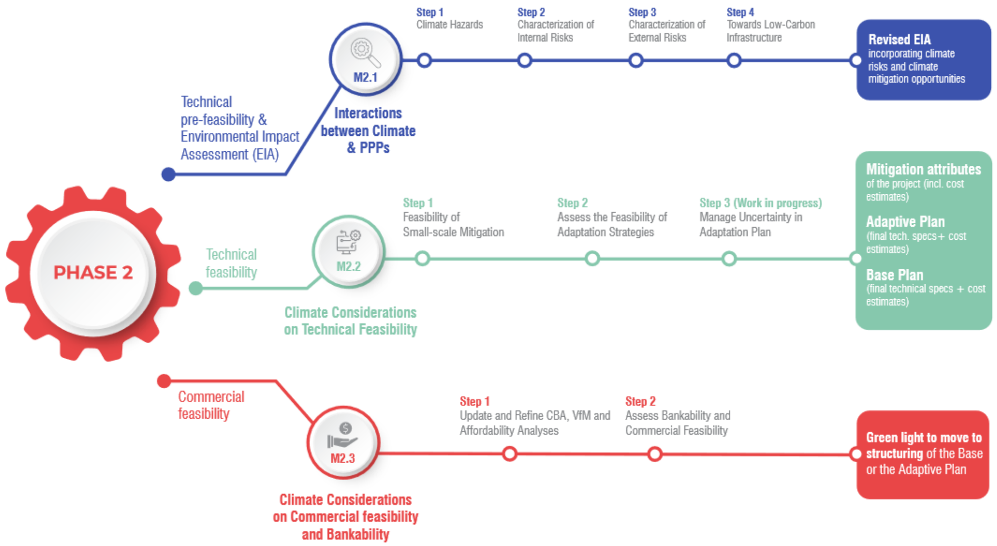


Example of hedging strategy through the use of call options : the butterfly hedge
- Long one call with strike X-a
- Long one call with strike X+a
- Short 2 calls with strike X

1. Hence the mandatory use of clearing houses and margin calls for most of the derivatives

Risk allocation through contractual techniques

- In risk management, the economically most efficient way to handle risk is to allocate it to the party who is the most competent to mitigate it or absorb it, should it materialise
- In contractual arrangements (especially in project finance), **risk matrices** are drawn up for the whole duration of the project from initial permitting to decommissioning
- **Contractual clauses** allocate the risks between different actors (counterparty risk analysis is a prerequisite). This raises the question of the compliance of these actors with the contracts in the future
- **Pass-through clauses** allow the party to fully transfer a risk to another party (for example in a long-term supply contract, inflation can be directly passed to the final customer)
- **Liquidated damages** clauses allow a party to collect pre-defined sums of money should a counterparty not respect its obligations (for example delays / budget overshoot / specification issues). These raise the issue of the liquidity and solvency of the counterparty
- **Letters of credit** issued by banks can guarantee payments on a short-term basis, however guarantees from parent companies may be required (deep pockets). Collateral may be required as a form of guarantee should no actor have sufficient creditworthiness
- Extremely rigid architecture, extremely vulnerable to Force Majeure



Source: World Bank, Climate toolkits for infrastructure PPPs, 2022, 384 pages

The limited understanding of systemic risk

- **Systemic risk** emerged as a concept after the 2008 crisis where the whole financial system was shaken, causing harm to the rest of the economy, independently from actual market or individual risk
- Systemic risk can be thought of as the consequence of the lack of investment of individual actors into the common good that is financial stability (**tragedy of the commons**). It then becomes an **externality** for the rest of the economy. It is extremely complex to price the correct level of investment.
- **Contagion** plays an important part in the emergence of systemic risk. It can arise from (1) domino effects through payments, (2) exposure to the same assets and (3) uncertainty because of lack of precedent
- Because of contagion risks, large institutions are deemed "**too big to fail**" and rescued (moral hazard)
- **Ex ante planning**: Insurance mechanisms, ring-fencing of assets, resolution planning, contingency buffers…
- **Ex post intervention**: Effective resolution, temporary loans, socialisation of costs

Is climate risk a systemic risk ?

Climate change impacts are systemic in nature	Rational individual behaviours lead to worst outcome Risk may only be hedgeable at the collective level
Radical uncertainty and knowledge limitations	RU prevents markets from pricing risk Imperfect and incomplete markets Climate and financial fragility reinforce each other
Climate is an incentive for global financial reform	Promotion of systemic resilience International Monetary reform

Sources: Schwarcz, Systemic Risk, in The Georgetown Law Journal, 2008, 57 pages | Allen, What is systemic risk?, IGIER 20 th Anniversary Conference Bocconi University, June 7, 2011 | Espagne, Climate and finance systemic risks: more than an analogy? The climate fragility hypothesis., in CEPII Working Paper, April 2016, 30 pages

Climate risk is systemic and traditional tools are inefficient

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- Traditional risk management techniques are efficient at managing low-level uncertainty over limited periods of time
- Climate risk is characterised by its complexity, systemic nature and non-linear risk profile. It is a radical unknown
- Green swan events cannot be captured by traditional risk management

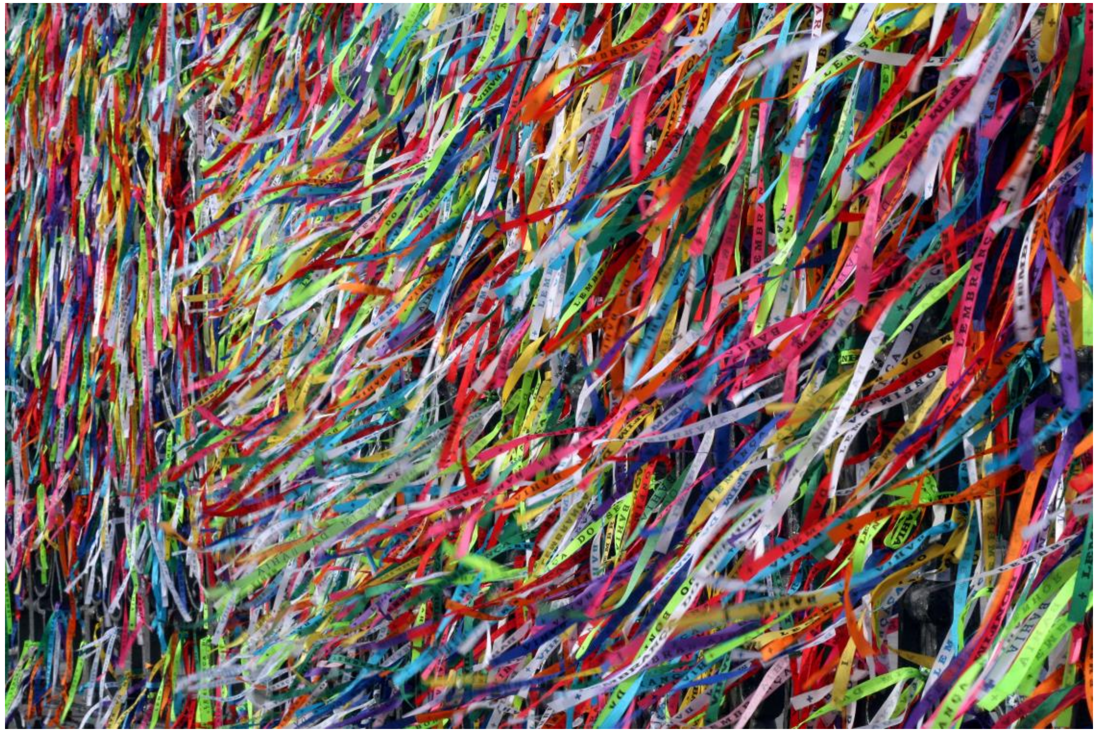
In this context of deep uncertainty, traditional backward-looking risk assessment models that merely extrapolate historical trends prevent full appreciation of the future systemic risk posed by climate change. An "epistemological break" (Bachelard (1938)) is beginning to take place in the financial community, with the development of forward-looking approaches grounded in scenario-based analyses. These new approaches have already begun to be included in the financial industry's risk framework agenda, and reflections on climate-related prudential regulation are also taking place in several jurisdictions.

Sources: Bolton et al., The Green Swan, Central Banking and financial stability in the age of climate change, BIS, Banque de France, 2020, 115 pages

New tools for a new era but still no silver bullet

Scenario-based analysis

- Renewed interest for scenarios in order to analyse the risks linked to climate change
- Partial solution though as complexity of both climate change and policy options cannot be accounted for in a model or a scenario from the macro- to microeconomic level
- In this framework, scenarios can explore specific aspects of the issue at hand and provide limited insight under constraining hypothesis. The goal is to identify risk propagation mechanisms and system responses
- The « predict-then-act » logic must be set aside in order to explore various potential futures and to assess the performance of choices in these situations. This does not lead to probability-based quantified decision but to a dynamic understanding of the risks and interactions and to strategic decisions
- Building scenarios is achieved through a combination of consultative processes with stakeholders and iterative forward-looking modelling



Source: Dépoues et al. Pour une autre approche du risque climatique en finance, Tenir compte des incertitudes, I4CE, Nov. 2019, 20 pages. Translation by the author.

Managing uncertainty requires flexibility and adaptability

- Confronted with radical uncertainty, the most economically efficient way to proceed is to invest in the flexibility and adaptability of the organisation
- Cash reserves, higher inventory levels, lower risk profile of the assets, better asset-liability management (ALM), trained and available employees are ways to improve the resilience
- Organisational measures will focus on governance (risk committee, executive compensation…), three-level lines of defence and other risk allocation techniques
- These measures have a cost though and they may prove economically unsustainable in a competitive market
- Rigid / lean organisation are economically more efficient as they reduce decision costs and eliminate under-used resources (which represent a cost for company)
- Public intervention may be required to push companies to implement such measures while preserving a level-playing field for competition

Dynamic Adaptation Pathways

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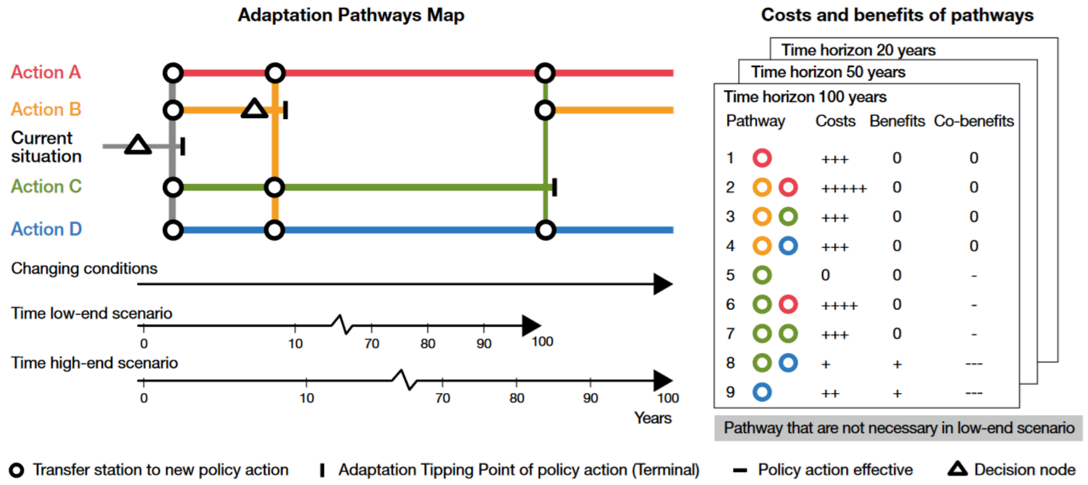
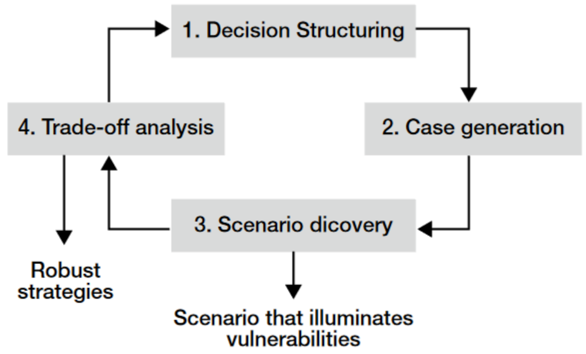
- One of the (many) difficulties of adaptability is to not get locked into choices and to be able to adjust course when new information arise
- Dynamic adaptation pathways are based on the idea of adaptation tipping points, where decisions have to be made:
- Define the final objective and the time horizon by which it has to be met
- Identify risk factors that could compromise the final objective and assess thresholds above which success is no longer assured (+ expected time of crossing)
- Identify mitigation solutions, their costs and requirements, as well as their limits
- Determine pathways to final objective as a string of conditional decisions
- Compare different pathways based on their merits and requirements to identify most favored trajectory



Sources : Dépoues et al. Pour une autre approche du risque climatique en finance, Tenir compte des incertitudes, I4CE, Nov. 2019, 20 pages. Translation by the author. | Haasnoot et al., Dynamic Adaptive Policy Pathways: A Method for Crafting Robust Decisions for a Deeply Uncertain World, in Global Environmental Change, 2013, 14 pages

Robust Decision Making (RDM)

- Another response to radical uncertainty is to insure that decisions will produce a satisfactory outcome independently of changing conditions (robustness), i.e. which decision will minimise regrets
- Especially useful for long-term investing and infrastructure
- RDM is an iterative discovery process in which (1) extremely high numbers of scenarios are drawn up, testing for different variables and (2) decisions are confronted to these scenarios in order to identify unsatisfactory groups of potential futures and update the initial decision with the information
- RDM combines « brute force » numerical simulations (and is highly dependent on computing power) and expert insight. Its purpose is not to select a decision but to identify the necessary trade-offs
- Extremely expensive and time-consuming methodology, can only be used for the biggest investment decisions



Source : (R. J. Lempert et al. 2013)

Sources : Dépoues et al. Pour une autre approche du risque climatique en finance, Tenir compte des incertitudes, I4CE, Nov. 2019, 20 pages. Translation by the author. | Quentin Perrier. The second French nuclear bet. Energy Economics, Elsevier, 2018, 74, pp.858-877.

Real Options Analysis

- Faced with the limitations of DCF analysis for investment decisions (rigidity in the analysis does not value the potential adaptability of the project), ROA has been introduced
- ROA uses the analytical framework of Options Analysis (i.e. an underlying fundamental value varies randomly) and transposes it to management / investment decisions. The fundamental is no longer a security but the outcome of the project that is revealed over time
- Using the Black and Scholes option valuation model (1973), it becomes possible to decide whether a project should be pursued or not

$$C = SN(d_1) - Ke^{-rt}N(d_2)$$

where:

$$d_1 = \frac{ln\frac{S}{K} + (r + \frac{\sigma_v^2}{2}t)}{\sigma_s\sqrt{t}}$$

and

$$d_2 = d_1 - \sigma_s\sqrt{t}$$

and where:

C = Call option price

S = Current stock (or other underlying) price

K = Strike price

r = Risk-free interest rate

t = Time to maturity

N = A normal distribution

Table 1 Project Gamma Option Valuation Analysis

	Base Case	Sensitivity Cases #1	#2	#3	#4
Common parameters:					
Stock price	$28.5	$22.5	$18.0	$15.8	$15.0
Exercise price	25.4	25.4	25.4	25.4	25.4
Interest rate	4.5%	4.5%	4.5%	4.5%	4.5%
Volatility	50.0%	50.0%	50.0%	50.0%	50.0%
2 Year time horizon cases:					
Option Value	$10.1	$5.9	$3.4	$2.4	$2.1
Decision	Invest	Invest	Invest	Not invest	Not invest
3 Year time horizon cases:					
Option Value	$11.9	$7.6	$4.8	$3.6	$3.2
Decision	Invest	Invest	Invest	Invest	Invest
4 Year time horizon cases:					
Option Value	$13.5	$9.0	$6.0	$4.6	$4.2
Decision	Invest	Invest	Invest	Invest	Invest

Note. Investment decision is based on the value of the option relative to the $2.8 cost of purchasing the option.

Sources : Dépoues et al. Pour une autre approche du risque climatique en finance, Tenir compte des incertitudes, I4CE, Nov. 2019, 20 pages. Translation by the author. | Bowman et al., Real Options Analysis and Strategic decision making, Organization Science, Vol. 12, No. 6, November-December2001, pp. 772-777 | https://www.investopedia.com/terms/b/blackscholes.asp

Questions?