Z-Risk Engine®
Unlocking Credit Cycles

Risks in Models of Climate Change Impacts

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Key Points – Uncertainty Creates Complexity in Climate Modelling for Financial Institutions

- Focus in presentation is on **specifying/building climate change models** – not 'model risk' related to implementation, business processes or governance
- Key question: Developing 'Climate Risk Models' when there is limited data & **Substantial Uncertainty**
- Climate modelling for banks:
  - V**ery early infancy - c**urrent research - Regulators, Asset Managers & Academics
  - Data generally available on physical processes: temperature, CO2, Hurricanes, Wildfires etc
  - Probably only narrow data available for broader, direct climate financial & real economy impacts – major climate impacts & policy changes mostly in the future – available emissions data growing
- Potential Climate Change credit risk impacts – 'bigger or smaller than a breadbox' ?
- Consensus climate modelling approach not formed yet, but ….
  - Need shorter & longer time horizons – physical & transition risks
  - Forward-looking, scenario-based **deterministic** approaches are most likely main candidate
  - **Explicit, forward-looking 'what if' scenarios including unexpected shocks from both** climate policy shocks and market/credit shocks - **explicit narratives required**
  - Historical, 200 years of 'carbon market failure' suggests modelling **structural economic change** is a key
  - **Multi systematic Z factor** framework supports application of systematic climate impacts

200 Years of 'Carbon Addiction' Requires Substantial Carbon Policy Intervention 'Green Swans' Are Extremely Complex – With Substantial Uncertainty/'Fat Tails'

Climate risks stem from classic market-failure 'writ planetary':

'the aim is to correct [a 200-year] externality using deliberate policy intervention rather than let a more or less evolutionary trajectory guide the transition'.

See Semieniuk et al, (2020), p 5, 'Low-carbon transition risks for finance'.

Bolton et. al., (2020) has characterised climate change as a 'Green Swan':

'our framing of the problem is that climate change represents a green swan, it is a new type of systemic risk that involves interacting, nonlinear, fundamentally unpredictable, environmental, social, economic and geopolitical dynamics….climate risks are not just black swans, i.e.., tail risk events,….climate change represents a colossal and potentially irreversible risk of staggering complexity'.

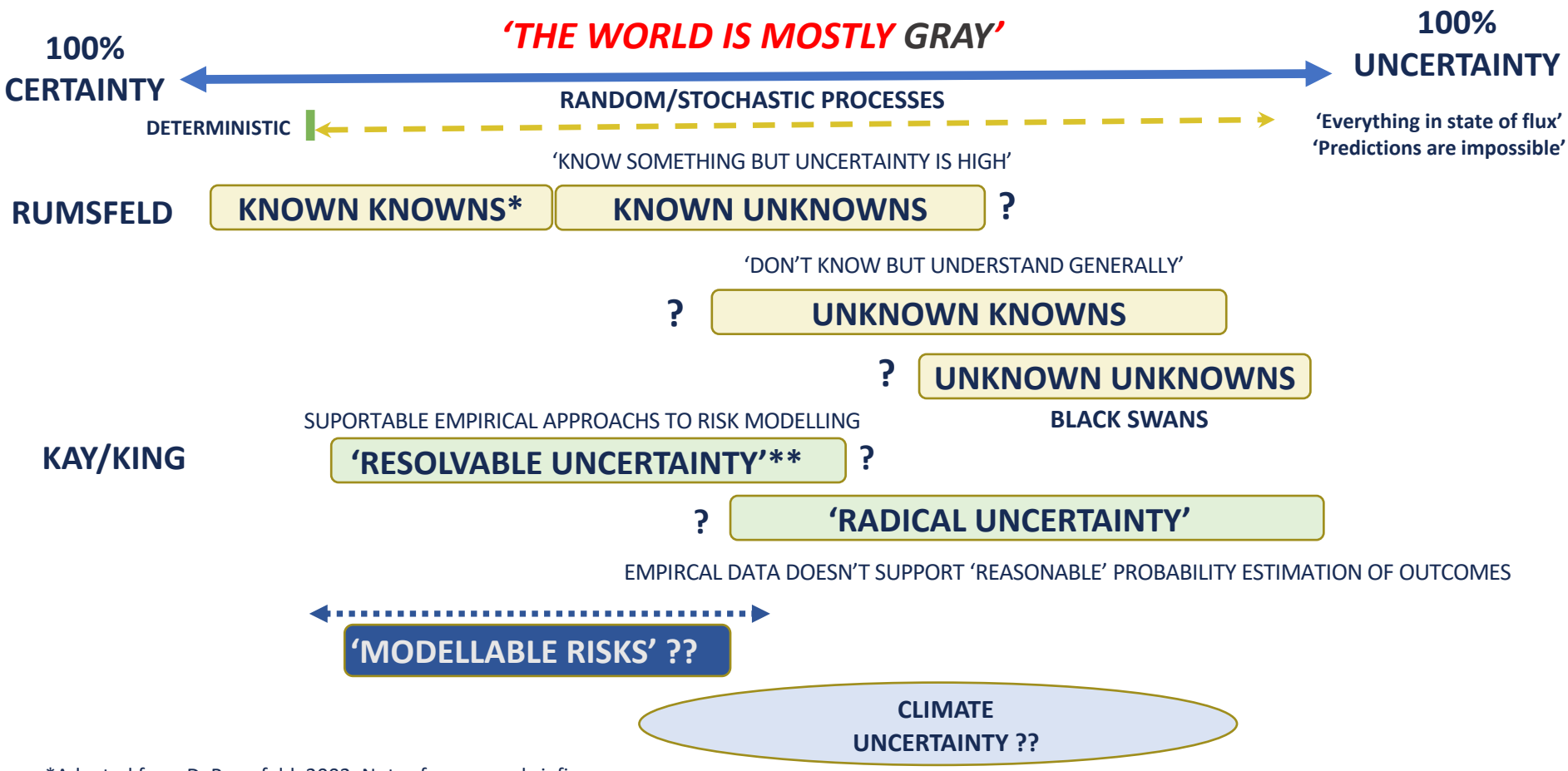
See P. Bolton et. al., (2020), page 6, 'The Green Swan', (BIS/Banque de France)

'Knightian' Uncertainty: '***is a lack of any quantifiable knowledge about possible outcomes and their associated probabilities, as opposed to the presence of quantifiable risk (empirical data)'***

See Knight, F., 'Risk, uncertainty and profit', 1921.

Taxonomy for Modelling Under Substantial Uncertainty - Estimating Possible Outcomes & Relevant Empirical Probabilities Not Straight-Forward

RISK MODELS USUALLY COMBINE KNOWLEDGE ON OBSERVED OUTCOMES TO EMPIRICALLY ESTIMATE PREDICTED OUTCOMES – BUT LARGE UNCERTAINTY MOTIVATES SCENARIO-BASED APPROACH WHEN EMPIRICS DOESN'T WORK WELL

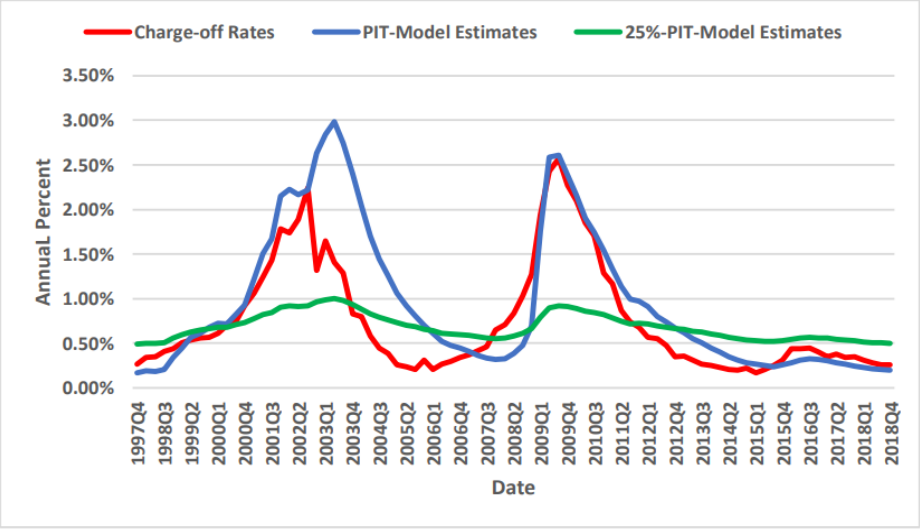


*Adapted from D. Rumsfeld, 2002, Notes from press briefing.
** 'Radical Uncertainty', (2020) J. Kay & M. King

Example of 'Risk Modelling' vs 'Modelling Under Uncertainty' - Empirical Risk Model for Credit Cycles vs Potential Future Climate Impacts

Risk Model Example: Predicting Systematic Credit Cycle Impact on Large Corporate Default Rates

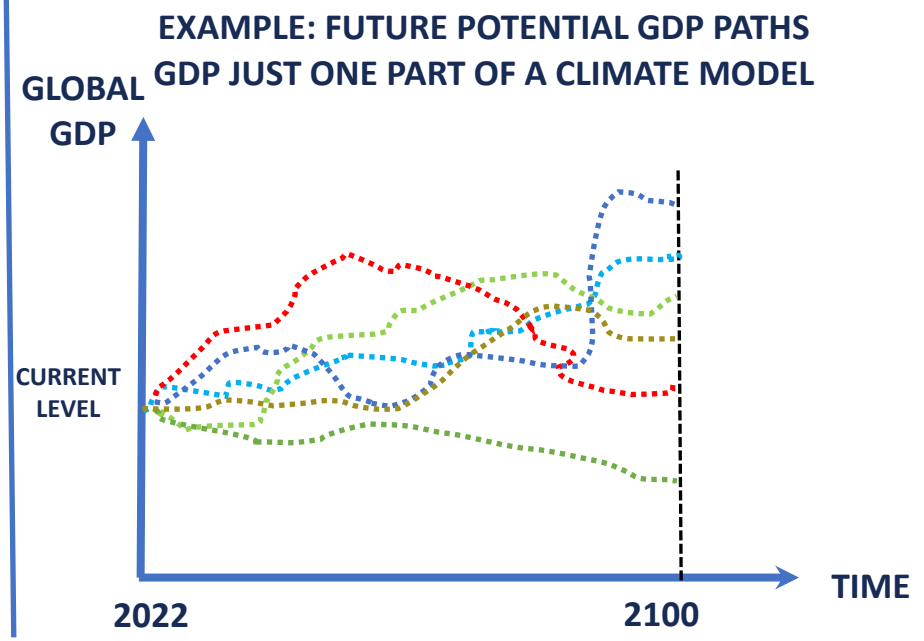
- Detailed Loss & Credit Cycle fluctuations are Observable
- Well specified, statistically significant 'risk models' can be estimated
- Z credit cycle models convert TTC IRB PD models to PIT (**BLUE PIT**) roughly DOUBLING statistical fit of IRB PD Models (GREEN TTC) to improve prediction of observed credit losses (RED)



Back Tests Over 1997Q4-2018Q4 Comparing PIT- and Hybrid-Model Estimates With Actual Values of US-Bank, C&I Charge-Off Rates; *Source: Author's calculations using the ZRE Application, Moody's CreditEdge data, and US Federal Reserve data at* https://www.federalreserve.gov/releases/chargeoff/chgallsa.htm

Climate Uncertainty Example: 'Known Unknowns' Future Possible Global GDP Paths

- Alternatively, Climate Impacts are a 'Known Unknown' which is broadly understood, but is hard to empirically model due to substantial uncertainty
- Narrow physical impacts observed to-date, but broader economic impacts counting explicit climate not fully observed
- Therefore need structured, scenario/narrative approach to derive Hypothetical future GDP paths and climate impacts under different climate scenarios



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Developing a Scenario Framework & Scenarios Isn't So Easy Need '**Outside the Brain**' Approach…

'Neural-Centric Bias': Having individuals chose 2 numbers between 1 and 4 DOES NOT produce a random, uniform distribution – many people choose 2 and 3 due to inherent 'neural bias' - conceptualising 'extremes' is not a usual thought process)

*Considering potential stress testing scenarios requires an '**outside the brain**' thinking process:*

'Patton: There's absolutely no reason for us to assume the Germans are mounting a major offensive. The weather is awful, their supplies are low, and the German Army hasn't mounted a winter offensive since the time of Frederick the Great. Therefore, I believe absolutely, positively, that median US houses prices in 2008 will fall 9.5%.'

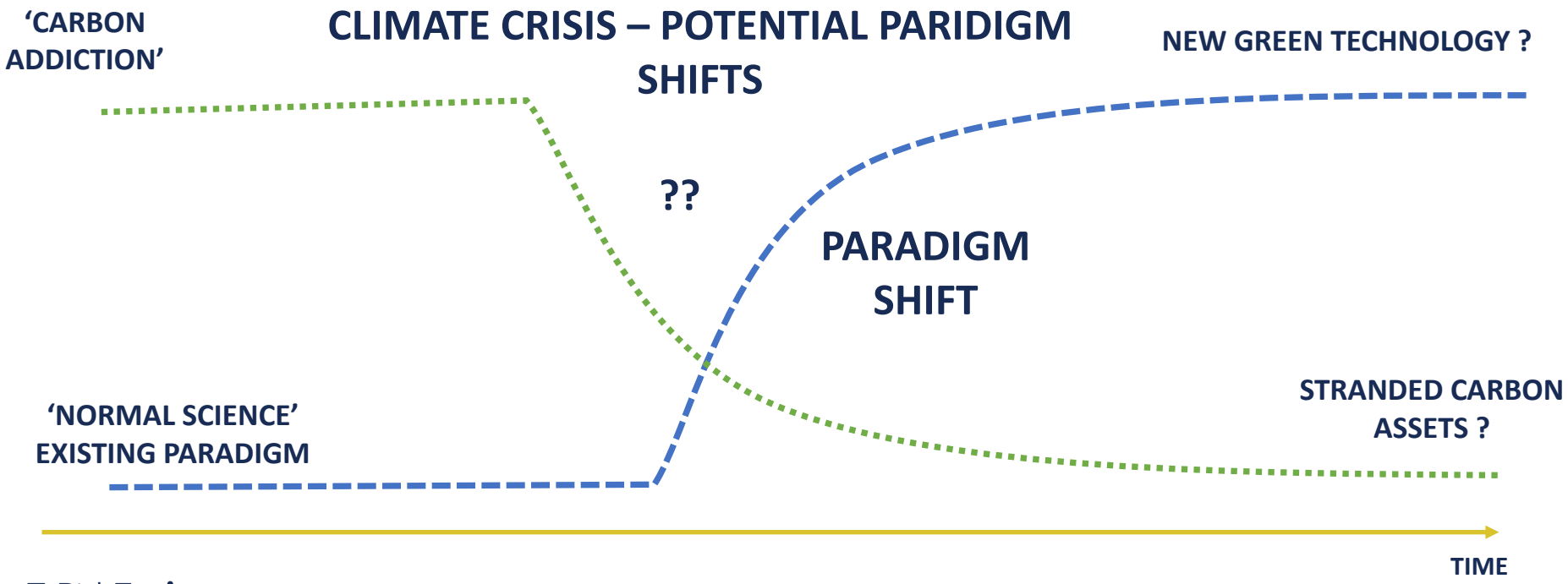
George C. Scott, playing Patton (1970) and his projection of 'Great Recession' house price declines (2008).

See D. Kahneman, 'Thinking Fast and Slow' 2011

Thomas Kuhn, 'The Structure of Scientific Revolutions' (1962)
Science Evolves in 'Jumps' – Not Continuous Cycle of Smaller Improvements

'Epistemological Break Suggested as Key'

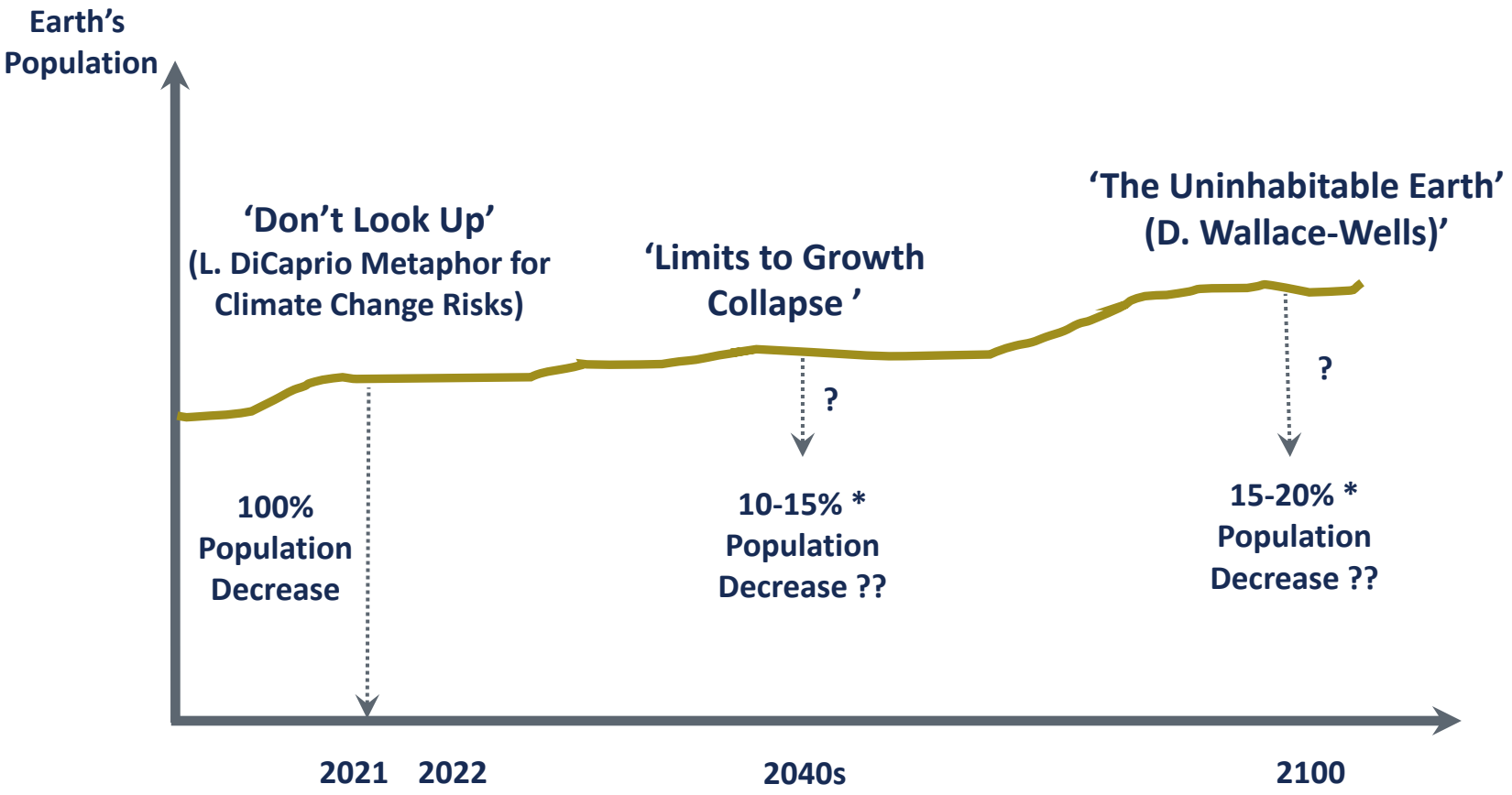
- ***'Scientific progress requires radical breaks from previous ideological conceptions'***
- **Forward not Backward Looking**
- **Minimal Historical Data for model estimation**
- **'Structured mixed model'**
- **Very short & long run horizons to 2100 ?**



Climate Change Uncertainty is Massive – How Bad is the 'Downside Risk' Wagner/Weitzman Estimate 'Tail Risk' of Potentially Exceeding +6 C at Roughly 10%

Climate Change Risk 'Hypothetical Downside Risks'

THIS NOT A 'DOOMSDAY FAIT ACCOMPLI PROJECTION' – THESE EXAMPLES SIMPLY ILLUSTRATE THE NEED FOR INCLUDING 'POTENTIALLY EXTREME NARRATIVES'



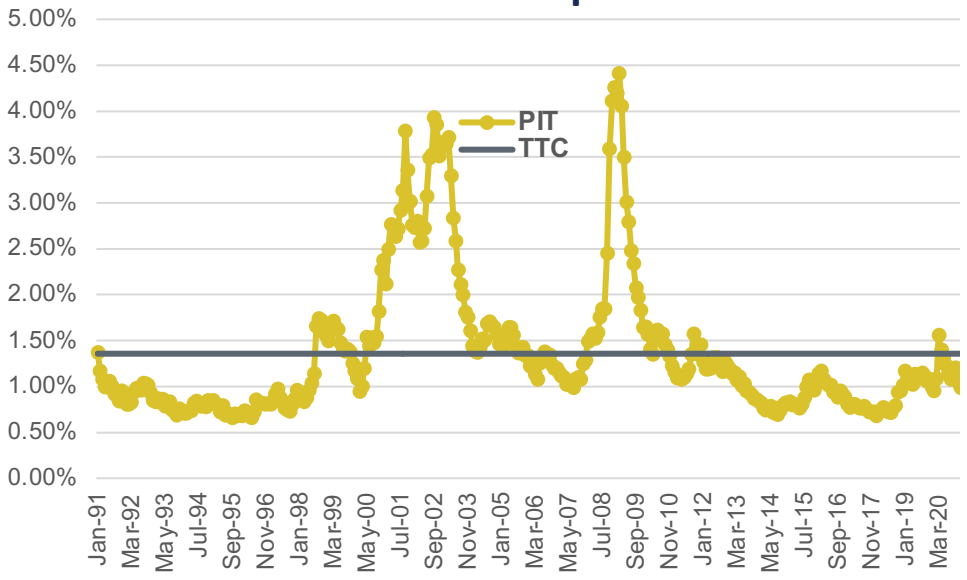
*** '100% Illustrative SWAG Guesstimates'**

In Risk Models & Climate Modelling Under Uncertainty - **Systematic Unexpected** Shocks Drive Potential Future Real/Financial Volatility

Unexpected Credit Risk Shocks Substantially Boosted Observed PIT PDs During the Last 2 Credit Cycles

Unexpected Shocks Drive Systematic Risk

TTC As An Average of PIT Calculated PDs – NA Corporates*



*Derived from Z-Risk Engine and Moody's CreditEdge EDFs

Much of Current Climate Modelling is Driven by Future 'Unexpected' Climate Policy Shocks

Sudden, Unplanned Climate Policy Shocks are Key to Potential Future Negative Impacts
Climate Policy Shocks Coupled With Other Economic/Political/Social/Credit Shocks Create Even Greater Future Risks

- **Examples of Climate 'Shocks' Utilized in Recent Climate Change Modelling:**
  - **2015 Paris Agreement as 'policy shock'**
  - **100% fossil fuel Equity value drop shock**
  - **Bond value shocks – difference between adverse and very adverse climate scenarios**
  - **Various deterministic carbon price shocks (e.g., + $100-300 increases in carbon prices)**

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Current Climate Change Modelling 'Conundrum' Related to Banks 'Is the Impact Smaller or Bigger Than a 'Breadbox' ?

Much of The Early Stress Test & Bank Credit Risk Empirical Climate Analysis Suggests Impacts Aren't Substantial (I.e., less than the 'Great Recession' Mostly

However, Substantial Uncertainty, Suggests 'Tail & Potential Unexpected Shocks' Aren't Fully Represented in Most Current Climate Research

Current 'Traditional' Stress/Risk Modelling for Climate In Its Infancy*

- Mainly NGFS-Centric scenarios
- Scenarios tend to be too 'smooth'
- IAMs imply limited macro impacts
- 'Unexpected shocks' approach still under discussion & application
- Observed historical climate impact in macro & financial data very limited at best
- Designed as preliminary extensions of Reg Capital Stress Tests
- Very limited representation of climate policy, economic structural change or systematic credit cycles

Broader Uncertainty-Based Scenario/Narrative Approaches Most Likely a Requirement *

- Neural-Centric Bias potentially considered
- Kuhn implied 'revolution in approach'
- Major Economic Structural Change key (I/O)
- Non-Linear, endogeneity, tipping points, social/political/credit shocks are important
- Most likely utilize range of deterministic scenarios with detailed narratives
- Apply empirical data where possible (assessing emissions intensity, I/O to facilitate Scope 1/2/3)
- Systematic, multi-factor models for adapting credit models already fairly well specified
- Unexpected policy shocks drive uncertainty in conjunction with other unexpected systematic shocks

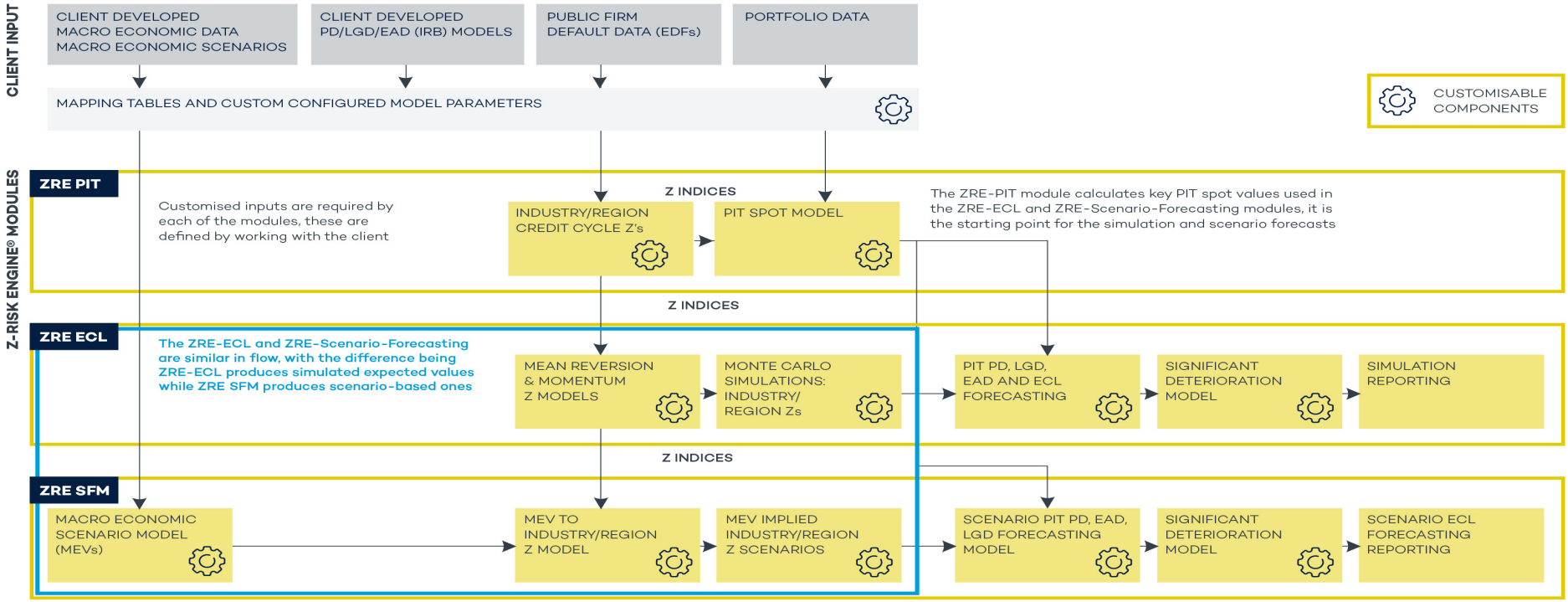
*See, M. Cliffe, 'Stressful Tests', Environmental Affairs, WWW.POLICYEXCHANGE.ORG.UK.

Current ZRE Solution in Python for IFRS9/Stress Testing – Supports Potential to Add Climate to Multi-Factor Systematic Risk Framework That is Already Used to Assesses Future ECLs Under PIT & TTC Credit Conditions

- **Multi-factor approach already projects IFRS9 ECLs using either of two approaches:**

  1. **Deterministic MEV Scenarios: Assess ECLs using MEV scenarios with systematic Z factors**
  2. **Or, simulation-based Z credit factor approach: industry/region second-order Z credit cycle factors**

- **Plan: add detailed Climate Z using scenario approach**



Key Points – Uncertainty Impacts on Climate Modelling for Financial Institutions is Substantial

- **Modelling complexity**: Developing Climate Models when **Substantial Uncertainty** exists with limited observed historical data
- Climate modelling for banks – **in its infancy**
- Climate data from history is available in more detail for physical & narrower climate impact modelling but **probably not** for broader macro assessments as **major climate policies & structural change haven't occurred**
- Preliminary Climate Change modelling impacts on bank credit risk (Physical/Transition) **– 'bigger or smaller than a breadbox' ?** The consensus to-date: **climate impacts show limited bank risk impacts**
- **Consensus** climate modelling approach **not formed yet**, but is under discussion focused most likely on a **forward-looking, scenario-based** framework with explicit narratives due to substantial uncertainty
- **Unexpected shocks**, most likely driven by future **climate policies implemented** on top of other **market/credit systematic shocks** observable in the past & modelled in Z credit factors provides one possible solution

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