DO YOU KNOW WHAT YOUR **CLIMATE MODEL** IS MADE FROM?

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The climate scenario modelling ecosystem has changed considerably over the last 5 years. As the adoption of Task Force on Climate-Related Financial Disclosures TCFD guidance becomes widespread, and in places mandatory, it is arguably a natural point to pause to consider whether models used thus far remain appropriate, or whether there are more suitable alternatives.

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The TCFD Guidance was first published across 2016 and 2017; it sought to set out recommendations for more effective climate related disclosures. In 2017 climate scenario modelling was a nascent field, with very few early movers looking to adopt the then brand-new TCFD guidance and a small field of start-ups and progressive established data providers.

At the time, Russ Bowdrey was deeply involved in a major international insurer's TCFD project and recognised the need to leverage any established modelling or data and to be realistic. The aim for his team was to build a 'good enough' picture of the risks and opportunities, as robustly as possible, but pragmatically, recognising the shortcomings in their approach. Russ's article published in the **May 2020 issue of *The Actuary*** expands on this experience and discusses some of the use cases.

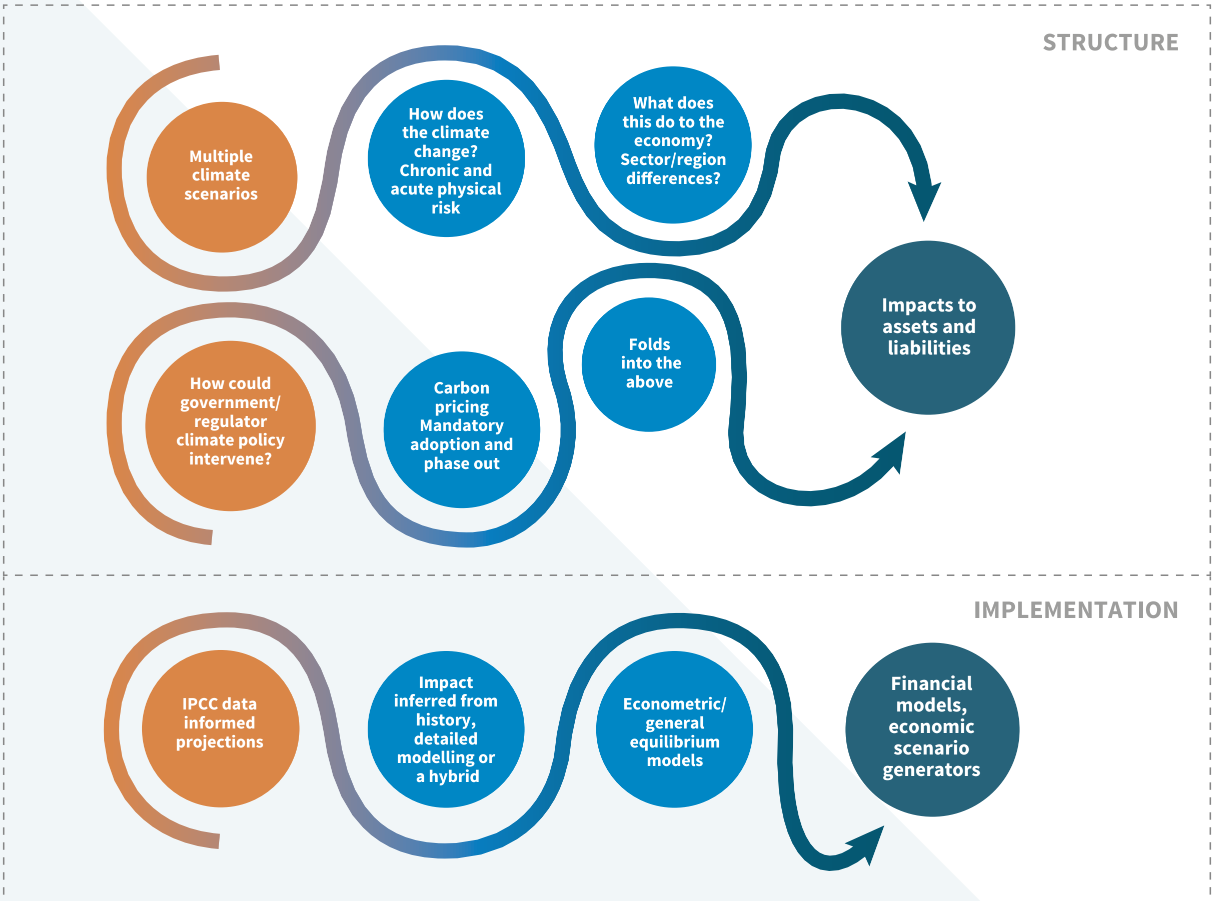
AN OVERVIEW OF CLIMATE SCENARIO MODELS

In a nutshell, asset owners (such as insurers or pension schemes) and asset mangers use climate scenario models to understand how the interplay of climate change, and the attempts to mitigate it, will affect their balance sheets. *Figure 1* summarises the key components and interactions.

The results of climate models support strategic and investment decision making, risk management and disclosures. An effective climate model should incorporate realistic and plausible dynamics, such that impacts at an economy and asset level are consistent and explainable. As you may have intuited, this is far from trivial.

This complexity typically lends itself to ensemble models. Trying to tackle all aspects in one model would result in a large and cumbersome model, with all the challenges of developing, checking and maintaining it. So instead, we typically use models that are well suited to each stage. The most pivotal, arguably, being >

FIGURE 1: THE KEY COMPONENTS AND INTERACTIONS OF CLIMATE SCENARIO MODELS



the model layer that translates climate impacts and policies into economic impacts. For brevity, we refer to this as the 'economic translation layer', or ETL.

WHAT IS UNDER THE HOOD OF YOUR CLIMATE MODEL?

Two broad classes of model have been used for ETLs: general equilibrium models (GEM, or sometimes known as Computable General Equilibrium, CGE, models) and non-equilibrium models. This article highlights the differences between the two and assesses their relative merits and drawbacks.

GEMs are currently more widely used in the ELTs underlying climate models. For example, a range of GEMs underly the Network for Greening the Financial System (NGFS) climate model. The popularity of GEMs is arguably partly attributable to familiarity – equilibrium models are associated with neoclassical economics, which is the current mainstream economic thinking. Most economists are trained in this framework, understand its logic.

Non-equilibrium models have an interesting history, arising from the rapidly changing world of the 1960s, where the world seemed anything but in a steady state. This led to the development of macroeconometric models that were better equipped to capture the transitioning world. However, their development outstripped the computing power available at the time, and difficulties with parameterisation and calibration led to outputs which were sometimes counterintuitive or difficult to explain. These challenges undermined confidence in non-equilibrium models and the end result was that more research effort (and funding) went to more traditional equilibrium models, which in turn became established.

Whilst not as widely used as GEMs, non-equilibrium models are increasingly being reconsidered and adopted, especially in fields that require projections for non-equilibrium phenomena such as the low-carbon transition, where it is not clear that the continuation of current trends moves towards a long-term optimum.

WHAT DIFFERENTIATES GEMS AND NON-EQUILIBRIUM MODELS?

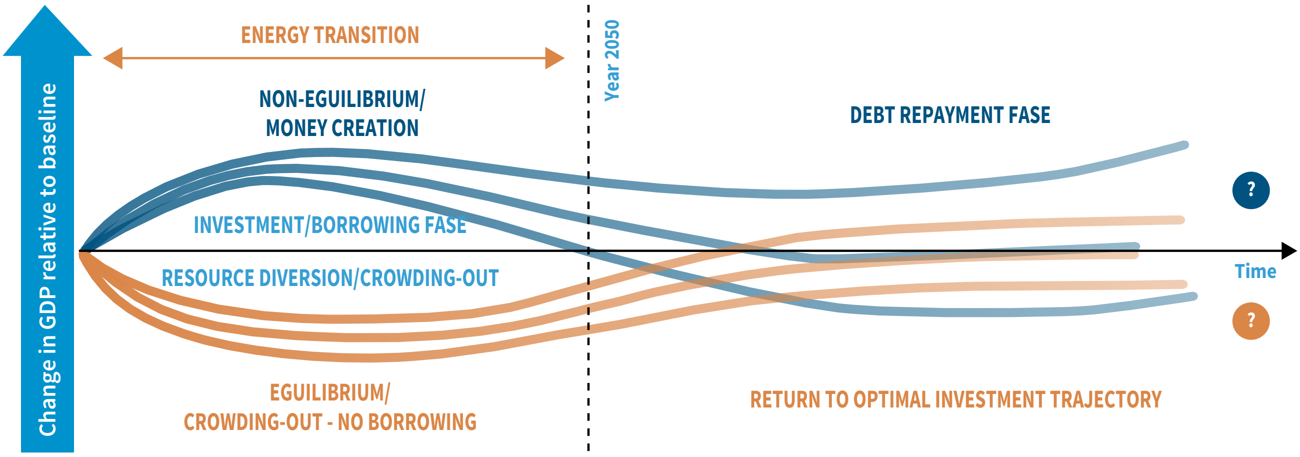
Equilibrium models are based on neoclassical microeconomic assumptions and consider the interaction of multiple rational >

FIGURE 2:
EQUILIBRIUM VS NON-EQ. MODELS: THE CHOICE OF MODEL TYPE INFLUENCES THE OUTCOMES OF POLICY ASSESSMENTS

Equilibrium models (GEM-E3, GTAP, PRIMES etc.)	Non-equilibrium (E3ME non-eq., post-Keynesian)
Neoclassical microeconomic assumptions	Does not assume optimising behaviour
Rational agents optimise their behaviour to maximize personal gains/profits	Derive behavioural parameters from historical relationships using econometric equations
Efficient Markets Hypothesis broadly consistent with the CGE model assumptions • Prices reflect all available information	More realistic real-world assumptions, e.g. bounded rationality; uncertainty; path dependence; learning effects

Money supply determined by central banks (exogenous)
• If money demand goes up, interest rates adjust, money supply does not
• If nominal money supply increases it generate inflation, not real economic changes
  • Same optimal use of real assets (neutrality of money)
  • Crowding out of investments
	Endogenous money
	• Money is created by banks through new loans
	• No crowding out of investments
	• New investments are financed by new bank loans (if banks have confidence that those investments are profitable)
	• Higher debt will be paid back later from higher receipts from consumers

FIGURE 3: FINAL RESULT REFLECTS THE CHOICE OF MODEL TYPE



KEY TAKEAWAY:

- **Final result reflects the choice of model type**
- **In non-equilibrium models the macroeconomic benefits arise first, and costs are incurred later due to debt financing and no investment full crowding out**

agents that optimise their behaviour, resulting in a general market equilibrium.
By contrast, post-Keynesian non-equilibrium models, like E3ME– a non-equilibrium model built and maintained by Cambridge Econometrics, does not assume optimising of behaviour or full utilisation of resources, and allow for real-world inefficiencies such as involuntary unemployment. *Figure 2* summarises the key differences between the models.

In terms of the practical modelling outcome for climate scenario modelling, the key difference is that for non-equilibrium models, we see typically see economic growth resulting from the energy transition, while equilibrium models usually exhibit an initial hit to growth during the transition, followed by recovery. This follows from investment not being constrained by savings, which is a key tenet of GEMs. *Figure 3* shows various illustrative pathways for each model.

The adverse economic impact of the transition in equilibrium models intuitively makes sense because it is assumed that real assets are utilised in an optimal way, hence any regulatory enforcement will divert the economy from its competitive optimum.

In practice, we often experience that that there are idle resources in the economy, as well as market failures due to institutional constraints, uncertainties or externalities. Under such circumstances, additional green investments triggered by regulatory intervention can push the economy towards fuller utilisation of existing assets in the short term, and to extending the required assets through new investments in the long term. Non-equilibrium models aim to capture these real-world behaviours and relationships. As a result, the outcomes of each type of model can be fundamentally different in direction as well as magnitude.

BOUNDED RATIONALITY, AND THE ADVANTAGES OF ABANDONING OPTIMALITY

A final element of non-equilibrium models worth exploring further is that they explicitly do not assume optimising behaviour. In order to understand how economies adapt to changes we therefore need a mechanism to capture how climate impacts, policies to mitigate them and adoption of the technology to support the green transition. A key advantage of non-equilibrium models is that >

the transition can be implemented in a way that arguably better reflects real-world decision making (e.g. satisficing, bounded rationality, imperfect information).

For example, E3ME a non-equilibrium model built and maintained by Cambridge Econometrics, uses an evolutionary innovation model to capture the diffusion of the technology used to support the green transition. This approach gives more flexibility to reflect the typical uptake and adoption of technology (e.g. early adopters through to laggards) and how that uptake responds to influences from regulation and interactions with other sectors and global economies. This last point becomes particularly important when then translating to impact to assets, such as the equity investments in different sectors and regions around the world as part of a portfolio level climate scenario analysis.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CLOSING THOUGHTS

All models wrong, some are useful, but it is important to consider carefully if the model you are using is appropriate for the purpose you are putting it to. This decision should be considered carefully when choosing a modelling suite for climate scenarios.

On the one hand the NGFS scenarios (which are based on 3 GEMs) provide a much-needed consistent basis for reporting; without it TCFD may go the same way as European Embedded Value (EEV), Market Consistent Embedded Value (MCEV) and other reporting standards that failed to gain traction due to (ironically) a lack of standardisation in their implementation. On the other hand, if the use case is investment decision making based on climate scenario analysis, it is vital that users fully appreciate what the clockwork inside their models is capable of emulating in the real world. <

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