BASIS RISK IN DISASTER RISK FINANCING FOR HUMANITARIAN ACTION

POTENTIAL APPROACHES TO MEASURING, MONITORING, AND MANAGING IT

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About the Centre for Disaster Protection

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EXECUTIVE SUMMARY

In finance, 'basis risk' is the systematic or inherent risk accepted in hedging.[1] In disaster risk financing (DRF), where statistical risk models are used to try and predict the outcome of a likely or current event—and can trigger the release of financing—basis risk lies in the combination of inherent model error, context outcome uncertainties, and miscommunication or misinterpretation of a model's capabilities. Clearly, as this paper sets out, in the context of humanitarian or crisis action, the ability of DRF systems to identify, calculate, reduce, and manage these risks is key to protecting lives, livelihoods, and assets.

High quality, objective data and risk models have the potential to significantly increase the neutrality and impartiality of humanitarian decision-making, to offer a new type of financing, and increased accountability. However, their ability to become a radical game changer hinges on some key requirements around the identification of a new design lens on DRF systems for humanitarian purposes—and specifically, in this paper, the use of data and management of basis risk:

- risk models need to be open, and the logical steps for decision-making clear to specialists and non-specialists alike;
- the certainty of uncertainty and error must be acknowledged, communicated, understood, and actively managed by all decision makers, at all levels;
- the data in the model must be representative of the risks experienced by the poorest people and households—not just the risks to large-scale economic assets;
- those at risk should have the opportunity to inform both model and system design, and to contextualise and query them;
- there needs to be a clear logic 'line of sight' between modelling and operational planning on the one side, and financing triggers, volumes and timing on the other;
- models that trigger financing need to be able to take humanitarian complexity into account; they should be nested within a wider national disaster management and response system and decision-making/data strategy; and they should be transparent and open, allowing financial providers to price competitively, and accountability to people at risk.

This paper offers a number of potential technical solutions to assessing, managing, and reducing basis risk (summarised in Figure 1). It acknowledges that, in order to be effective, these need to be accompanied by political and coordination efforts, and a wider look at DRF operational systems that are fit for crisis settings.

The authors invite further ideas and discussion on this topic, including any opportunities to test and innovate new operational designs.

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[1] For more information on what basis risk means in the financial markets go to: https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/what-is-basis-risk/

Figure 1: Summary of proposed technical risk management steps

Basis risk	Reduce the risk	Manage the risk live
Model error	**Develop an R&D plan** for each model component, including planned improvement to source data, re-analysis of real-time data and calculations.	**Comparative monitor** of similar metrics to triangulate the primary triggering model. **(Basis risk assessment, measurement protocols and review panel.)**
Context outcome uncertainty	**Research and understanding of the various drivers of risk** to understand attribution of outcomes and all risks that need to be monitored. (e.g. conflict, El Niño, or pests on food security impacts, and drought.)	**Comparative monitor** of diverse risk metrics to review impact with regard to the various drivers to contextualise the outcome to the primary triggering model. **(Basis risk assessment, measurement protocols and review panel.)**
Misunderstanding of model error and context outcome uncertainty	**Increased investment in training and learning** on hazard science and modelling. Greater **investment in communicating science tools.** **Simplification of contractual wording** in respect of model performance and basis risk.	**Continual updates and basis risk assessment** over the live risk period. Clear protocols for monitoring and measuring basis risk, and a clear objective way to resolve data divergence and conflicts and disagreements at the end of the risk period as a standard part of data processes. Identification of a global arbitrator.

CHAPTER 1

INTRODUCTION

This paper explores what the term 'basis risk' means in the context of DRF from a humanitarian operational perspective. The paper outlines how DRF might introduce predictability, new financing, and improved systems, into the realities of messy and chaotic humanitarian situations. However, this potential will only be realised if a new design lens on DRF systems is developed for humanitarian action—and, significantly within this, the management of basis risk.

Modelled DRF products have worked somewhat sustainably for over 30 years in the private sector—because basis risk is positive and negative over the years, financially both sides break even, or the market readjusts itself by changing the premium following losses. But the issue now, particularly for DRF systems in crisis settings, is that the checks and balances of the financial world do not apply when lives are at risk. A life lost in one year is not balanced by a life saved the next year. Hence, basis risk needs to be looked at differently. The application of models and systems developed primarily for private sector DRF should not be unquestioningly applied unchanged in the humanitarian space without defining a new design lens or criteria, to ensure they are fit for purpose.[2]

This paper suggests that the key to identifying, calculating, and managing basis risk lies in tackling three areas: model error; outcome uncertainty; and misunderstanding and miscommunication. The paper highlights examples of where these elements have had an adverse effect on DRF systems, and the significant implications this can have. It explores a risk management approach to basis risk, looking at methods to reduce the risks associated with modelling, and offering ideas about operational mechanisms that might help manage basis risk in 'live' humanitarian action. Critically, this includes the introduction of a comparative indicator monitoring system alongside the primary model, and rapid expert and automated adjustment protocols of financing and implementation plans. Essentially, it explores the potential of a system that functions on the basis of pre-planning and prepositioned resources—but one that is also flexible enough to adapt and flex to evolving crisis situations in real time.

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[2] Upcoming discussion series, *Impact before instruments*, C. Harris, Start Network, and C. Jaime, The Red Cross/Red Crescent Climate Centre.

By way of conclusion, the paper summarises the risk management approaches outlined—and highlights that technical proposals such as this cannot operate in a vacuum and will require political and coordination efforts too. To ensure success, the management of basis risk requires humanitarian actors, disaster financiers, and scientists at a country level to come together to co-design and own the solutions, leveraging each other's skills, knowledge and resources.

The authors invite further ideas and discussion on this topic, including any opportunities to test and innovate new operational designs.

CHAPTER 2

WHAT IS BASIS RISK IN DISASTER RISK FINANCING?

In the finance and insurance industry, 'basis risk' means the risk that a trader might accept in terms of the product not performing as it should when hedging positions.[3] In DRF and the use of parametric solutions, the term applies to situations where statistical models are used to predict the outcome of a likely or current event (the payout is not indemnity-based but predicted or modelled loss) to trigger financing. In the case of DRF, the basis risk lies in the combination of:

- model error—the inherent errors found within a model's data and calculations;
- outcome uncertainties—the uncertainty within which the model operates (the difference between the model results and real-world results);
- social miscommunication or misinterpretation of a model and product's capabilities.

These three elements are discussed in further detail in the following subsections.

While this paper addresses a definition encompassing all three areas of basis risk—as they all need consideration and addressing in operational management—many argue that technical basis risk of model error, and uncertainty and the more perceived elements of basis risk around miscommunication and lack of financial layered resources, are very different. Clearly, in the context of humanitarian or crisis action, being able to reduce or manage all these risks is key to protecting lives, livelihoods and assets by ensuring that the right financing is triggered at the right time, for the right actions, however basis risk is defined.

Parametric models in DRF

In DRF, statistical models are used to forecast the likelihood of an event of a specific severity (e.g. drought), and some models look to represent an event's potential impact on people and assets. Payouts are released based on pre-defined data thresholds within the model. These thresholds can be based on hazard severity (for example, rainfall deficits or wind speed), or on the likely impact or loss that could be brought about (for example crop loss forecast, livelihood impact metrics or houses that might be destroyed). This format is usually applied to index-based financing and insurance. Essentially the model can represent an index of all possible hazard severities, and all possible impacts, so can quantify risk and thus price that risk for coverage. However, these outcomes are confined by static and limited risk data.

See Chapter 3 for further details.

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[3] For more information on what basis risk means in the financial markets go to: https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/what-is-basis-risk/

2.1 Model error

Model error includes: mistakes in collecting data; parameter limitations; or simple variations that cannot be explained by the model's mathematics due to the limitation in our understanding of the complex natural and human systems. In statistical terms, 'the error of an observed value is the deviation of the observed value from the true value of a quantity of interest' (for example, forecasted rainfall).[4]

Models used to forecast events are based on hazard science and physical elements within understood earth processes. These are often—but not always—coupled with human vulnerability and exposure components that try to project likely impacts from hazard events. These models can be very tightly interwoven and complex algorithmic models, or they can be more loosely interconnected indicators of the changing risk situation. Models are never able to represent reality completely accurately. For example, errors can result from:

- data limitations – accuracy and quality of the input data and the ability of the algorithms to depict the complexity of the hazard;
- parameter setting errors – selection of driving data and settings of parameters, as well as error from human/ manual customisation.

Models are also often constructed in one of two ways:

- the first is statistical, where cause and effect is simplified to where one data point has a statistical relationship to another within the model;
- the second is dynamical, where the relationship between the two data points is mapped out using mathematical approaches by replicating the system changes, which creates statistical links.

Both techniques are usually used in tandem and can have data limitations and parameter setting errors. All models have a certain amount of error.

The modelled world is always wrong

In Malawi in 2016, the Africa RiskView (ARV) model failed to identify a severe drought and trigger a payout, despite clear evidence that a major drought was taking place, affecting an estimated 6.5 million people. After a basis risk review, ARC made a payment to the government some nine months later. The key technical source of basis risk was the selection of the wrong variety of maize, with a different growing period, which caused the drought risk to be missed. A major parameter setting error (ActionAid, 2017).

Another key example is the use of satellite remote sensing data, where rainfall is a key parameter. Rainfall is estimated by satellites in a number of ways, but not through measuring the actual rain falling from the observed clouds, but through proxies related to this, such as the temperature taken at the top of the clouds, albedo, cloud column height, and lightning flashes. Data limitations and approximation play a clear role in basis risk in satellite rainfall driven models (Sarumathi, Shanthi and Vidhya, 2015).

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[4] See: https://en.wikipedia.org/wiki/Errors_and_residuals.

2.2 Outcome uncertainty

Outcome uncertainty is the uncertainty within which the model operates and is the difference between modelled and real world results. It is complex to try to project the future or to fully understand what is happening in real time. There are multiple external factors that affect reality, and models can never capture them all. The world is too complex, and outcomes have multiple drivers. Thus, models used—for example to predict drought impacts and the number of people who could become food insecure—can miss external factors that would influence results, such as food prices, conflict, and political economic decisions, or additional hazard such as pests and disease. Some hazards and attributed impacts are clearer than others, and the attribution uncertainty lower. For example, if a house is missing a roof following a typhoon, it is fairly certain the missing roof was caused by the typhoon. On the other hand, the attribution of single hazards to outcomes such as food insecurity is much more complex. Attribution uncertainty, and the proxy link between modelled outcome and real outcomes, cannot be eliminated—but it may be understood and managed operationally in DRF systems.

Risks outside the model (unmodelled risks) can result in increased impacts or outcomes, which the model cannot capture. This is what we know as uncertainty. In the financial sector, uncertainty can have a price tag added to it and be accepted as a risk. However, in an operational disaster management sense, the reduction or management of uncertainty is critical to the successful operationalisation of risk-based response actions in an early warning and response period. In practical terms, a model's failure to correctly identify people at risk, or to trigger the early or timely release of finance, can lead to people not being supported or helped.

The problem with modelling a single risk driver

In Senegal, drought models attempt to model the impact of drought on households. However, the number of people at risk of food insecurity reported in the *Cadre Harmonisé* is often different.[5] One of the reasons for this is that the report process not only looks at the drought driver on household food insecurity but also more qualitatively at other drivers such as food prices, antecedents or latent vulnerability due to other hazards and impacts, as well as pests and social issues such as access and commodity prices. While also uncertain and potentially containing error, it demonstrates how one modelled risk driver, which most quantitative models focus on, can rarely be 100% attributable fully to an outcome.

The Solomon Islands withdrew from the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) after the country experienced a failed payout for flash flooding in March 2014, as well as for an earthquake (Newton Cain, 2014). The flooding losses were estimated at 9.2% of gross domestic product but no payout was triggered because the disaster was due to a tropical depression, whereas the policy covered only tropical cyclones (World Bank, 2015). The method of modelling depressions and major cyclones requires a different tailored risk and triggering model, which was not part of the triggering system. However, both a depression and a fully-fledged cyclone may create the same outcome as flash flooding and the resulting loss.

In Jamaica, flooding in May 2017 caused US$400 million in damage (Muir-Wood 2017, cited in Hillier, 2017). However, the Caribbean Catastrophe Risk Insurance Facility (CCRIF) model estimated damages at only US$100 million, which was below the threshold for payout. The difference was due in part to the fact that the CCRIF impact model only covered housing and infrastructure loss, and not agricultural loss (The Gleaner, 2017; Hillier, 2017).

2.3 Misunderstanding and miscommunication

In addition to the above technical components, which are inherently scientific/technical limitations of modelling, basis risk also has a 'social' component. DRF products exist within the realm of human behaviour and understanding, which means that basis risk can extend to a misunderstanding of the scientific and technical limitations in model error and uncertainty, and of what the model can and cannot do. This leads to a mismatch

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[5] The *cadre harmonisé* is the ECOWAS/Sahelian regional framework for consensual analysis of acute food insecurity situations (see: http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/1146522/).

between what we expect statistical models to do, and what they can actually do. This lack of understanding involves several issues. One is the absence of supplementary data, finance, and operational systems to manage error and uncertainty when delivering a response and financing system. Another is the possible decrease in trust in the reliability of DRF systems and services, due to false expectations, which can result in a reduction in risk coverage.

The issue of miscommunication and misunderstanding of the technical elements of basis risk is further compounded when wider DRF system problems, mistakes, challenges, and learnings are not open—there needs to be a trusted culture of testing and learning among donors, system designers, and implementers. Mistakes, while needing to be managed, should not give rise to blame. Rather, mistakes should be expected, and used as evidence for learning and improvement. Most decisions are made for the right reasons at the time. Many of the highlighted examples in this paper are taken from the African Risk Capacity (ARC)—this is not in any way to overly criticise ARC but in fact is somewhat as a result of this risk pool being very much more open and honest with the issues such systems face as well as having a more humanitarian based food security remit.

Model errors and uncertainty are inherent in statistical modelling and, while they can be reduced, they cannot be entirely eliminated. It is therefore important to raise awareness and understanding of the limitations of models. This is particularly key if statistical models are to be the central method by which we deliver DRF in contexts where existing technical capacity is low. And where the term 'basis risk' is used without a clear understanding of the fact that it refers to the fundamental limitation of *all* models—error and uncertainty.

In terms of disaster risk management, problems arise when the model's limitations are not fully understood, and the need for the nesting of the model within a wider suite of data and financial flows (in order to address any limitations) is not seen or acknowledged. Single models and instruments are considered silver bullets to risk, which in isolation they are not, and can provide a false sense of security due to a misunderstanding of the technical components of basis risk.

The issue when these DRF system are not fully aligned with national disaster management strategies, and other operational plans, is that they are not informed by those who would have the most useful input into their design, such as civil contingency managers and humanitarian actors. This strategic disjoint can lead to DRF systems being seen as gimmicky, which means they are much more likely to be short lived.

Instruments without strategy: misunderstanding the product

Malawi has had two drought insurance policies (now both discontinued), while having no disaster risk reduction (DRR) budget, and no emergency reserves. A good proportion of countries with sovereign DRF policies have no, or inadequate, national DRR funds and emergency contingency funds to complement their coverage, which only covers a small percentage of risk (Hillier, 2017).

In Senegal, the government has consistently taken out policies for drought risk, paying an annual premium of around US$3 million to try to manage this recurrent hazard.

While such efforts by government should be commended, recent evaluations by the International Monetary Fund (IMF) highlight that there is no widespread practice of conducting quantitative analysis of fiscal risks in Senegal relating to drought, potential contingent liability of policy basis risk, or of the uncovered risk. Such analysis would allow for better identification of the key risks and better monitoring and implementation of more effective management measures to complement the insurance policy coverage. The budget in Senegal provides for various kinds of fiscal reserves but they are not linked to crisis or disasters and they are not reserves as they are already earmarked for spending. The quality of fiscal information and the ability of the Senegalese government to mobilise adequate budgetary resources therefore depends on a better assessment of both short- and long-term environmental impacts. The framework governing use of the contingency reserves has also been assessed and found to lack transparency or systematic disbursement. Senegal is far from alone in this—many countries display similar characteristics (IMF, 2019).

CHAPTER 3

WHY USE STATISTICAL MODELS IN DISASTER RISK FINANCING?

Models are used to represent complex systems, processes and ideas, interpreted mathematically. However, as we have seen, the modelled world and the real world are not always completely the same. Data can provide a picture of a situation, but all data has its limitations. In an operational sense, this essentially means that there will be four sets of truth:

- model prediction of what is likely to happen (severity, impact of the hazard);
- additional and alternative data predictions on what is likely to happen;
- what the model or data says has happened and been affected and how;
- what actually happened (perceived or evidenced truth of all of the above).

In traditional, impact-based, humanitarian response, reconciling the final truth has been the main objective in response programme development. Now, with DRF and Forecast-based Financing (FbF), all four have to be reconciled within operational mechanisms. Dealing with uncertainty requires a technical step change within the humanitarian and wider sovereign disaster management sector—and new ideas and decision-making processes.

Using statistical models to try to forecast events has a number of advantages.

- An index risk model allows you to price risk, and therefore to understand what funds you have available, or will not have available, in different scenarios. It brings certainty and accountability into the system, and to the decisions taken.
- Using an indexed risk model means that risks can be modelled both operationally and financially. This allows for risk layering, and the use of instruments such as insurance more widely. Operationally, an index can also allow plans to be based on analogue years within that index. For example, a one-in-seven-year event that occurred in 2014 can be used to help develop plans and protocols, as well as costings, that would be needed in a similarly sized future event.
- Automatic model triggering reduces human error and bias. Human bias is often not to act until uncertainty is almost zero; however, as time goes on, opportunities to avoid and protect against a crisis diminish. Setting an automatic trigger can start the engine running and put the money on the table, which gets the operational system moving.
- Automatic triggers can ensure that financing and subsequent action can be contracted regardless of political and media bias, operational priorities, or complexity.
- Quantifying risk allows for more transparent risk ownership, shared responsibility, and accountability in disaster management—both financially and operationally.

However, models do have limits and will always be ‘wrong’ to some degree. The levels of uncertainty and error that we are willing to tolerate will depend on the decisions we are taking and the potential implications of those decisions. Again, the literature on risk in decision-making, and decision-making in uncertainty, is widely acknowledged but not yet well employed in the DRF design space.

Examples of questions that arise from a humanitarian operational perspective regarding the use of models in DRF include the following.

- Does the model reflect reality? How do we operationally determine this? If the answer is no, then what is the cause of the basis risk error—uncertainty or misunderstanding? How should this be analysed operationally at the time, and what is the right management approach?
- What is the correct representation of risk and how do we determine this? What should we be monitoring to determine this?
- Do we have a gap in funding due to the basis risk? How do we quantify this?
- Is the planned response in the contingency plan correct? How do we identify this? Based on the type of basis risk, how do we adjust the financing and the response? What information and resources are available?

Approaches to reducing the risks associated with statistical models in DRF are required so that uncertainties and errors are rapidly identified, quantified, and understood within operational disaster management frameworks.

CHAPTER 4

WHY IS IT VITAL TO MANAGE BASIS RISK IN DISASTER RISK FINANCING FOR HUMANITARIAN ACTION?

There are two main reasons why the ability to calculate basis risk is so vital to DRF and humanitarian action:

- it means avoiding gaps in financing, therefore avoiding loss of life, assets and livelihoods;
- the use of objective data for decision-making has the potential to significantly increase the neutrality and impartiality of humanitarian decision-making, bring in larger and new financing, and increase the ability to hold systems to account.

However, the ability of risk models to become a radical game changer in humanitarian action hinges on some key requirements:

- the risk model needs to be open and the logical steps for decision-making within the data clear to specialists and non-specialists alike;
- the certainty of uncertainty and error must be acknowledged, communicated, understood, and actively managed by all decision makers, at all levels;
- the data in the model must be representative of the risks experienced by the poorest people and households—not just the risks to large-scale economic assets;
- those at risk should have the opportunity to inform both model and system design, and to contextualise and query them;
- there needs to be a logical 'line of sight' between modelling and operational planning on the one side, and financing triggers, volumes and timing on the other;
- models that trigger financing need to be able to take crisis complexity into account; they should be nested within a wider national disaster management and response system and decision-making/data strategy; and they should be transparent and open, allowing financial providers to price competitively, and for accountability to people affected.

CHAPTER 5

AN APPROACH TO DEALING WITH MODEL LIMITATIONS

Basis risk—or what we now know to be a combination of model error, outcome uncertainty and misunderstanding/miscommunication—needs to be addressed if DRF products are to be delivered effectively for humanitarian action. This could take a traditional risk management approach, focusing on mitigating and reducing model error through improving modelling, its accuracy and precision through learning, research and development. Access to a wider set of data would allow a much clearer understanding of outcome uncertainty. Also needed is an acknowledgment that model errors and uncertainty are inherent in all modelling—and will never be reduced so far as to not require an understanding of the limitations. In addition to this, developing a system to manage these limitations within the operational and financial systems of disaster management is central to delivering DRF.

5.1 Using the best suited data and model

Models are used to make decisions in DRF, with the aim of achieving objective and risk-driven results. These decisions ultimately determine whether an at-risk population receives resourcing to be protected against a likely disaster event. Until recently, there has been little thought put into the utility of models for operational risk management purposes, and little requirement on model developers to evidence their work for the purpose of triggering finance or operational response. However, reliance on models to assist in vital decision-making further ups the need to ensure that processes are in place to select, assess, and test the models and data therein.

Operational evidence and accountability will require a collective effort on the part of research funders and risk financing system developers to demand high quality from their modelling partners, creating modelling tenders and development projects that have sets of requirements in testing and aligning to operational decision-making as well as financing instruments. Therefore, analytics and models need to be co-designed and co-developed by scientists and modelers, operational disaster managers, responders and financiers—and communicated to ensure accountability in those models and decisions to people at risk. The design modellers must be fit for purpose for all for the DRF system to achieve impact and accountability.

Scientific due diligence: The Drought Risk finance Science Laboratory

Developed in 2017, the Drought Risk finance Science Laboratory (DRiSL) project set out to improve the accountable selection of data and models for DRF—a process of scientific due diligence (SDD). Specifically, the team was trying to assist Start Network and Welthungerhilfe obtain the best evidence for use of available data sets for drought risk financing systems for Pakistan, Zimbabwe, and Madagascar. The project will provide an independent report for each country, based on the system decision-making framework.

DRiSL's independent panel of scientists took the models proposed by the insurer and tested them against other possible data sets and models. The work included uncertainty testing—intermodal comparison and skill testing of various models and data products to measure how well they performed when compared to historical data (hindcasting).[6] Historical data in many lower income countries is often scarce and varied in quality, thus limiting the test bed. In the case of food insecurity, there can be many drivers, so attribution of results can be challenging.

The DRISL team collected secondary data on food security, drought, and other drivers such as pests and conflict to look over each past year and evaluate what influence they were having on food security. They also tried to improve the historical data.

Once the secondary data was exhausted, a need was identified to go back to the people on the ground to ask about past drought and food security events. Owing to limited timeframes, a mobile phone crowd sourcing survey was developed, enabling over 1,000 farmers to share their experiences.

The scientists are analysing the results through a number of lenses, including temporal scale and location, as well as severity of event. The project is yet to conclude but the results of the analysis will be compared to the decision-making frameworks of each risk financing system. A 'good enough' SDD guide will also be produced to guide others.

The results aim to enable reflection on the following questions.

- Do we need to change the way the system analyses and makes decisions to be more reflective of the science skill?
- Should the decision-making system remain as it is, and different data and modelling with higher skill and reliability selected within the system's decision-making framework?
- Even with the best data and reflective decision-making, what are the likely sources of basis risk, and under what circumstances are they likely to materialise operationally (i.e. At what level of severity? What are the other risk drivers—El Niño years? Restricted land access due to conflict spikes? Pests?).

DRiSL is a project of the Start Network, Welthungerhilfe, the University of Sussex, the University of Reading and the International Research Institute for Climate and Society at Columbia University, in partnership with Global Parametric. It is funded by Natural Environment Research Council (NERC) and UK Department for International Development (DFID) and the Centre for Disaster Protection.

Data Entry & Exploration Platform

The Data Entry & Exploration Platform (DEEP) is a new interagency platform, built through the joint efforts of the UN, International Red Cross and Red Crescent Movement, private sector and NGOs, designed to help analysts make sense of crisis situations using tools such as severity rankings, information reliability scoring, analytical frameworks and humanitarian profiling. It also aims to help the collation and recording of event information. In time, initiatives such as this should provide much stronger historical time sets that models can be tested against (International Federation of Red Cross and Red Crescent Societies (IFRC), 2019).

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[6] Hindcasting is when a model is run backwards in time to see if it correctly picks up and depicts known historical events. The assumption is that if it does well against historical events, it is likely to serve well going forward. Good 'skill' is when model results show good correlation to historical events.

5.1.1 Knowing the limitations of model data and calculations

With results from SDDs (see box), conclusions can be drawn about the limitations of selected scientific models. Once limitations are known, they can be dealt with operationally and also communicated correctly during the decision-making process. Knowing the limitations also allows the decision maker to anticipate possible model failures. Once areas of weakness are known (for example, when the Indian Ocean dipole is strongly negative, the storm or rainfall model is likely to be over 30% overestimated) they can be dealt with pre-emptively in the system design. Equally, if there is a pest infestation at the same time as a drought, the likelihood of the model being inaccurate on the yield and number of food security outcomes can be anticipated.

5.1.1 Knowing the limitations of model data and calculations

Over-complexity in modelling can be a problem, even if more complex models show slightly better skill than simpler ones. While models might be able to mathematically represent physical earth processes fairly accurately, on the vulnerability and impact side, complexity and overfitting data can become a moral hazard. Vulnerability and impact models look to take the physical event and identify its likely impact on people and assets. When the vulnerability and impact part of a model begins to become very removed from the reality of people, and complex in its treatment of the data with different factors being weighted and interrelated, decision-making processes can become unclear or opaque. While a model might be open, it can be difficult for anyone to question the results or see where it may have been designed incorrectly. This is a problem if we want these decision-making systems to be transparent and accountable. Overly complex, black-box models do not allow for a more humanitarian approach to DRF.

Complexity can also become a problem for basis risk. When models are highly complex, their components can become very tightly coupled. This makes it difficult to identify and fix a single or set of points of failure. The ideal is models that are not overly complex but show good skill—i.e. good correlation to historical events. Inevitably, there will be instances where a compromise will have to be made, based on a trade-off between complexity, skill, and transparency.

A recent approach in the Start Network has been to look at impact modelling as close to a 'person at risk' reality as possible, to understand how the model demonstrates impact upon those who are vulnerable. While the data may be complex, it is important to keep the process relatively straightforward and easy for anyone to understand. With this aim, the household economy approach (HEA) was explored as a possible method, and its outcome analysis process used. The HEA profiles households across livelihood zone and identifies the various sources of income and food relied upon during the course of 'a normal standard year'. The households are divided into four wealth groups to create household baselines for each livelihood zone. This process helps identify a set of thresholds, which are based on the amount of money or food required for everyone in the household to maintain a 1,200 kilocalorie food intake a day, known as the survival threshold of income/food. The second threshold is the livelihood threshold, which adds additional costs onto the survival level to support livelihoods, such as seed and fuel for machines and the cost of school. The third threshold in development is the resilience threshold, which also looks more widely at health costs, livelihood diversity and other expenses that are needed to improve the household resilience to various shocks.

The HEA outcome analysis allows the identification of a hazard scenario that can then be used to identify how those household baselines will be affected and where the household is likely to sit relative to the various thresholds in different disaster scenarios and severities. For example, Household A's baseline may be severely affected by a shock due to the nature of that livelihood situation and so fall from just above livelihood threshold to below survival. This provides a quantitative analysis of the likely household deficit from a shock. In risk financing we can use this approach by creating a number of scenarios (mild, moderate and severe) related to the hazard model return period projections, and using the outcome analysis to project the likely household deficits. This can be linearly extrapolated between severity events. The approach can be used in number of ways:

- as part of the modelling itself;
- as the basis for contingency planning;
- to provide a risk-driven base for building up a response budget and required funding from the risk financing system.

While there may be many more scientific and mathematically complex ways of modelling impact, the HEA approach was relatable to householder experience, affording a certain level of accountability, and allowing people at risk to question it (Harris and Swift, 2019). While HEA can potentially provide a useful tool for household impact modelling, it has significant limitations, and further work is needed to find new and adjusted techniques that work for a variety of hazards and risks beyond food security, such as asset loss and health impacts.

5.2 Communicating model error and uncertainty

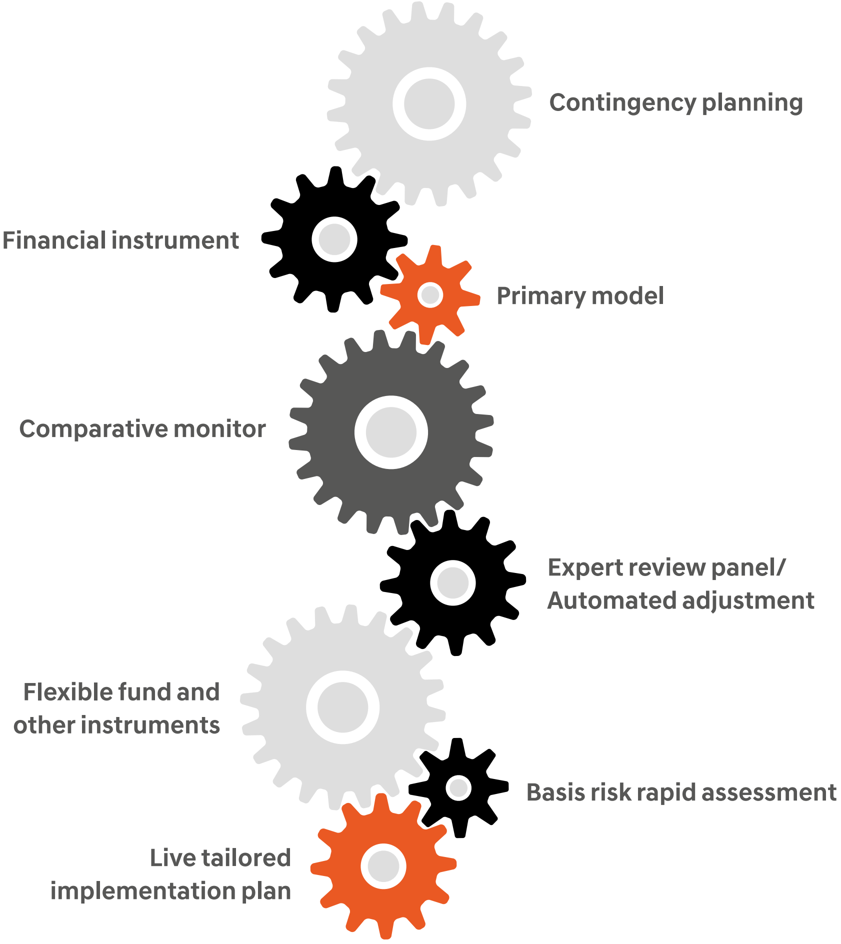
While putting in place the above measures should reduce the likelihood of a basis risk event, it does not entirely eliminate the possibility. It is also often not the technical people who are responsible for signing off a model system—or assigning budget or funds to it. However, it is a process that needs to be very well technically informed.

A key issue is science communication. Despite the use of science now entering a much more operational space, not enough investment has been made in finding ways to communicate and utilise that science in a way that non-scientists can really understand and get to grips with. Or relating that science to financial modelling and decision-making, or operational decision-making. Ways of addressing the shortfall in communication and understanding might include:

- staging operational system scenarios or drills to allow stakeholders to understand what the outcomes might be and why, and subsequently adjusting the systems to account for such eventualities;
- including basis risk centrally in policy documents and contracts, spelling out precisely likely drivers, and how risk will be identified, assessed and managed, so that all parties are comfortable and well aware of this contractually and legally without ambiguity;
- a checklist for assessing understanding and comprehension of the contract and policies to be completed by contract signatories (such as senior ministers), who might not have read all of the small print, but who might be accountable if the systems fail.

5.3 Managing operationally inevitable basis risk events

Figure 2: Operational basis risk management system



5.3.1 Additional data: operational comparative monitor

Outside the primary risk model, additional, more dynamic data sets need to be collected and reviewed. These need to be pre-determined, and sources identified and agreed. A balance between richness and information manageability also needs to be struck, through defined sets of indicators. This balance will vary depending on the time available and depth of decision-making that can be made based on additional indicators. The comparative monitor allows for more diverse information and some level of voice from people at risk to be integrated into the system. The comparative monitor needs to strike a balance between objective and subjective indicators, and to allow for rapid integration and use of both. There also needs to be a balance between what might be termed 'soft' and 'hard' indicators and global and local-level indicators.

While the full set of information will be useful for a disaster manager from a comparative monitor, only the objective and potentially remote sensing or third-party verifiable indicators could be used to quantify any financial adjustments within a DRF contract from the primary model. This is not to say the other indicators could be used to bring in other financial resources to cover unmet or additional risks depicted. There are three sets of data indicators that the comparative monitor could look at.

- Alternative model data/customisation indicators (identifying error): the collection and review of data that is comparable to that in the triggering model. For example, if satellite rainfall data was used in the primary model, reviewing alternative remote rainfall sources would fall into this category. If you were using a specific earthquake or storm window model, you may look at available alternative models.
- Alternative crisis view indicators (identifying error): additionally, the hazard and associated vulnerability that you are trying to ascertain through the model could be viewed from other data perspectives. For example, instead of satellite rainfall and water saturation requirements, a soil moisture indicator from a global circulation model could be looked at. Or in the case of potential impact, other measures of vulnerability and impact.

  The magnitude of divergence and convergence of these data sets could be used to quantify operational and financial adjustment. This could come from one or more instruments or funds. These harder third-party verifiable indicators would have to be used to adjust any instrument payout as they would remain objective.
- Additional driver indicators (uncertainty): the third set of indicators in the comparative model should be linked to risk drivers that are separate from the hazard of the model. In the case of some hazards this will not be so important. For example, if half a town's houses collapse at the point of an earthquake, it is pretty certain that the earthquake was the cause. Additional drivers to food insecurity may include pests, conflict and insecurity, market prices monitoring as well as agricultural and water policies. These could be made up of both hard and soft data, so could include information from communities and ministries. For floods it could be snow melt as well as rainfall-fed floods, dam regimes and decisions. This would provide an understanding if these are also having an influence on outcomes. While these are identified, the result would be to inform the wider response and to identify additional risks from these other drivers that would need alternative financial coverage.

There is also a need for a desterilised monitoring network to ensure that the comparative monitor can get the best live data possible. For this, a networked approach may be needed, with different agencies at national and local levels providing pre-agreed data for the monitor. This would require significant information management and ease to upload information. Technologically innovative ways of data management could support a transition to such 'smart' systems.

There are two uses for the comparative monitor: improving and calibrating the model by creating a data repository of impacts by which to test the models (long-term); and identifying the correct live management approaches needed to respond effectively at the time.

Allowing data from the experience on the ground to filter into the comparative monitor, but used in an appropriate way, provides a conduit for people's observations, voice, concerns and experience to help inform decision-making within large financial systems. This is a key factor for accountability in DRF as well as the technical management of basis risk.

5.3.2 Basis risk rapid assessment

Data used to compare the outputs of models employed for decision-making can be useful to reduce the error and uncertainty around said outputs. However, in order to use that data effectively, framework processes and protocols are required to facilitate decision-making and enable the efficient delivery of results.

Comparative data would be compared against the results of the primary model, to facilitate decision-making about the level and sources of basis risk, and the correct financial and operational adjustments. This is the essential part of basis risk response management. The point where a determination is made as to what is the most likely source of the risk is also important to know where those adjustment liabilities lie, who owns what components of basis risk and should account for them, and what adjustment should be made.

Alongside this, it is crucial that the level and type of basis risk to be tolerated is pre-determined and agreed *before* financing and implementation requirements change. The rapid assessment can also articulate what the span or uncertainty of the results shown by the comparative monitor is, in a centralised, transparent, trusted and legitimate way that can be accessed by operational managers.

In the case of correcting/adjusting for basis risk, a clear set of rules needs to be followed to ensure objectivity in decision-making. Firstly, within the comparative monitor, indicators used to quantify basis risk should be identified at the point of contract signing—not in a live, difficult situation. The indicators need to be objective if using an instrument such as insurance contracting, where people at risk and financiers should not have the ability to change them. The difference between these indicators and the results of the primary model should be quantifiable. However, if more flexible funding sources are used and agreed with the funder, both soft and hard indicators could be used to make this adjustment.

Through consensus or agreed divergence measures, a decision can then be made to recommend changes in financing required, where this should be sourced from (depending on the degree and source of the basis risk), and how the implementation of the response should be taken forward. How this is done, and guidelines that the decision makers need to follow, should also be identified, such as basis risk level tolerance and how the comparative monitor and model data should be compared and assessed. This will vary between the hard and soft indicators, and the adjustments different indicators can inform, based on data quality, objectivity and relevance.

The process requires a defined operational outcome, outlining transparently how and why decisions have been made. This allows operational managers and financiers to see the information, the operational decision made on the basis risk, and the outcome decision. This could be that a new return period of event is identified, or that an additional risk driver is present and requires the activation of additional instruments or funds, as well as how the system should proceed to implementation. Essentially, the aim is to create a predictable and somewhat automated correction system where possible—but one that is smart and adaptive. A hybrid automated and human decision-making system.

An operational timeframe should be agreed in advance, and a timeline put in place for basis risk correction, in order to allow DRF to operate within tight deadlines. This is central to the success of the system and to achieve impact within specified windows of opportunity. Everyone involved needs to know what data they are collecting, and their respective roles in reviewing the data and decision-making. This needs to be contracted, and with clear responsibilities and accountability, as part of national disaster management and humanitarian frameworks. As has been discussed previously, strict time frames for decisions and outcomes must be adhered to. In a slow onset disaster situation, such as a drought, there may be a few weeks available to perform the assessment, without losing the opportunity to support people to manage risks. However, in the case of rapid onset disasters, such as storms or earthquakes, where there is a very short or even no early warning period, time is of the essence. In such cases, the assessment may have to be done within a few hours and may be somewhat automated to allow for the benefits of risk financing and early response.

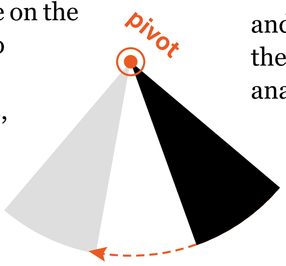
5.3.3 Responsible decision-making panels

The rapid assessment system could be partially automated but also requires a panel of human decision makers. This could be a group of independent experts in-country. Their role would be to ensure the comparative monitors were being provided with agreed data and reviewing this on an ongoing basis. They would also undertake analysis in the divergence assessment from the primary model. This idea is driven from work undertaken at the Start Network on the approach to form forewarning-type groups that would look to fulfil such a role at the national level.[7]

Ideally, the decision-making panel would comprise individuals with diverse skill sets, including scientific and operational. These might be people who are permanent staff members within a nominated organisation, or individuals nominated to the panel on a yearly or two-yearly rota from a group of national and international organisations. In many countries, panels like this may already exist, and in this case, their roles would be formalised to enact risk financing decisions. The organisations would need to include national disaster management agencies, hazard scientists, NGOs and civil society, and the UN. They would need to be guided by a decision-making protocol that defines roles and responsibilities. It is important for people to play a role in these processes in order to deal with more dynamic risks, driven by uncertainty as well as the modelled ones within DRF systems—but they have to do so within an accountable and transparent decision-making framework, with clear guidelines as to which decisions to take and when, and how to determine the decision.

5.3.4 Operational pivot points

Once a basis risk rapid assessment has been released, adjustments would need to be made to the financing and response plans. These adjustments would be in response to the information from the comparative monitors and assessment report, pivoting and adjusting the financing and the contingency plan to an implementation plan. This is what is termed in this paper as the 'operational pivot points'. The financing and the contingency plans are designed in a static way such that once the model triggers, they respond as a line of dominos falling until the response gets to people on the ground automatically. However, due to operational and basis risk issues, this process is not always that simple. Thus, setting up contingency plans and financing to be flexible and pivot at point of trigger is essential for an effective response.



5.3.5 Identifying and adjusting the financing

Once the panel has made an assessment, it will have made recommendations for the release of adjustment funds or, potentially, the absorption of overpayment. This financial adjustment could be achieved in one of two ways depending on the likely source of the basis risk. If it is found to be based on model error, adjustment funds for basis risk could be built into the original contract within the policy of an insurer or financier as this is essentially an error in reflecting the risk that is covered. If the source of the basis risk is uncertainty, other drivers of risk influencing the likely outcomes, or potentially a misunderstanding of the contract, other funds should be accessed to complement and address the additional risks. This could be other financial instruments or simple flexible disaster response funds, essentially acting as a basis risk pressure value. The contractual arrangement with finances for basis risk and payment adjustments based on a comparative monitor should be quantified within a contract and policy document if insurance. Equally, the source of potential uncertainty adjustment funds should be pre-agreed during design phase.

Adjustment funds should exist to correct for basis risk. However, while they are practical and necessary, they are not always the most attractive investment for donors or financiers. Corrective funds are, in essence, covering unmet needs that arise from uncertainty and potential model errors. The impact of those funds however will be of equal value to those managing risk on the ground—they will not mind which pot the money is coming from. Without having prepositioned basis risk pressure valve funds, responders would still have to come to donors in any case, either at the early stage to try to cover the risks, or at a later stage—potentially at much greater expense if responding to losses. Either way, additional funding would be required, either as part of an overall pre-agreed, well managed, system, or later at a less well managed and potentially late system. More studies are needed on how corrective funds might be financed. One option is cumulative funding, where annual premiums to insurance contracts contribute a specific percentage towards the corrective flexible fund. The adjustment fund, while likely held nationally, could also be pooled globally to allow for efficient financial flows. Whatever the source, the adjustment fund's function is to act as a financial pressure valve to account for the error and uncertainty in the primary model; establishing where the basis risk lies, and the degree of that risk, must be well analysed and explained before systems go live.

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[7] See: FOREWARN (https://startnetwork.org/forewarn).

5.3.6 Adjusting the contingency to an implementation plan

The jumping-off point: quantification of local contingency plans aligned to the model

The development of contingency plans allows for the coordination of a response based on the modelled impacts and needs in different scenarios. When the model triggers, and financing adjustments are required, the modelled contingency plan needs to adjust or pivot to an implementation plan.

It is important that the model impact analytics and the contingency plans are linked. Once the model has shifted, the response plans can shift in the same fashion, as easily and quickly. For example, a model may estimate that 200,000 people are likely to be affected, with income deficits totalling £800,000 in a one-in-seven-year event. The contingency planning scenarios should correspond to this in the actions and budget needed to cover those modelled needs and risks in a response.

Once the main causes of basis risk are identified, the financing and response plan can shift appropriately as planned. This helps ensure a rapid response that is adapted to reality, while not being hindered by the basis risk, which should have been properly and formally managed.

Adjustment and alignment with contingency and implementation plans allow the best of both worlds: an automated, pre-planned and coordinated triggered response to prevent inaction, combined with flexibility and adjustment process to ensure basis risk is well managed, and that appropriate financing and response ensues—essentially creating a ’smart‘ humanitarian DRF system.

Quantifying brings power to advocacy and fundraising

Due to risk drivers outside of the modelled risk, additional unmodelled and unforeseen needs could be identified through basis risk assessment, through additional driver indicators. For example, a basis risk assessment might reveal additional needs in an existing response. The initial funding provided through an insurance instrument or fund might not be sufficient—but the additional/new risk cannot be ignored in humanitarian response and funding would need to come from a wider, flexible fund.

It is important to note that the quantification of additional/new/evolving requirements brings the ability to advocate for additional funds from other providers in a clear and transparent way. It also evidences the need for such risks to be included within a future modelled DRF system if it is possible to do so.

Always the need for a flexible instrument

While structured DRF systems with quantifiable and easily monitored indicators can go a long way to creating a managed, coordinated disaster risk management, and associated financing and implementation, some highly unpredictable and unforeseen risks cannot be easily identified or monitored. Human risks often fall into these categories, such as conflict or terrorist attacks. But there are also others, for which cascade effects might be unknown. As such, these suggested comparative monitoring and flexible fund systems need to be put in place to allow for the monitoring of a context in real time, with ongoing development of indicators and the ability to access funding flexibly. Examples include flexible risk funds such as Start Network’s Start Fund and anticipation window.

Structured and flexible approaches need to work alongside each other in a comprehensive risk financing suite.

5.4 Dealing with misunderstanding and miscommunication

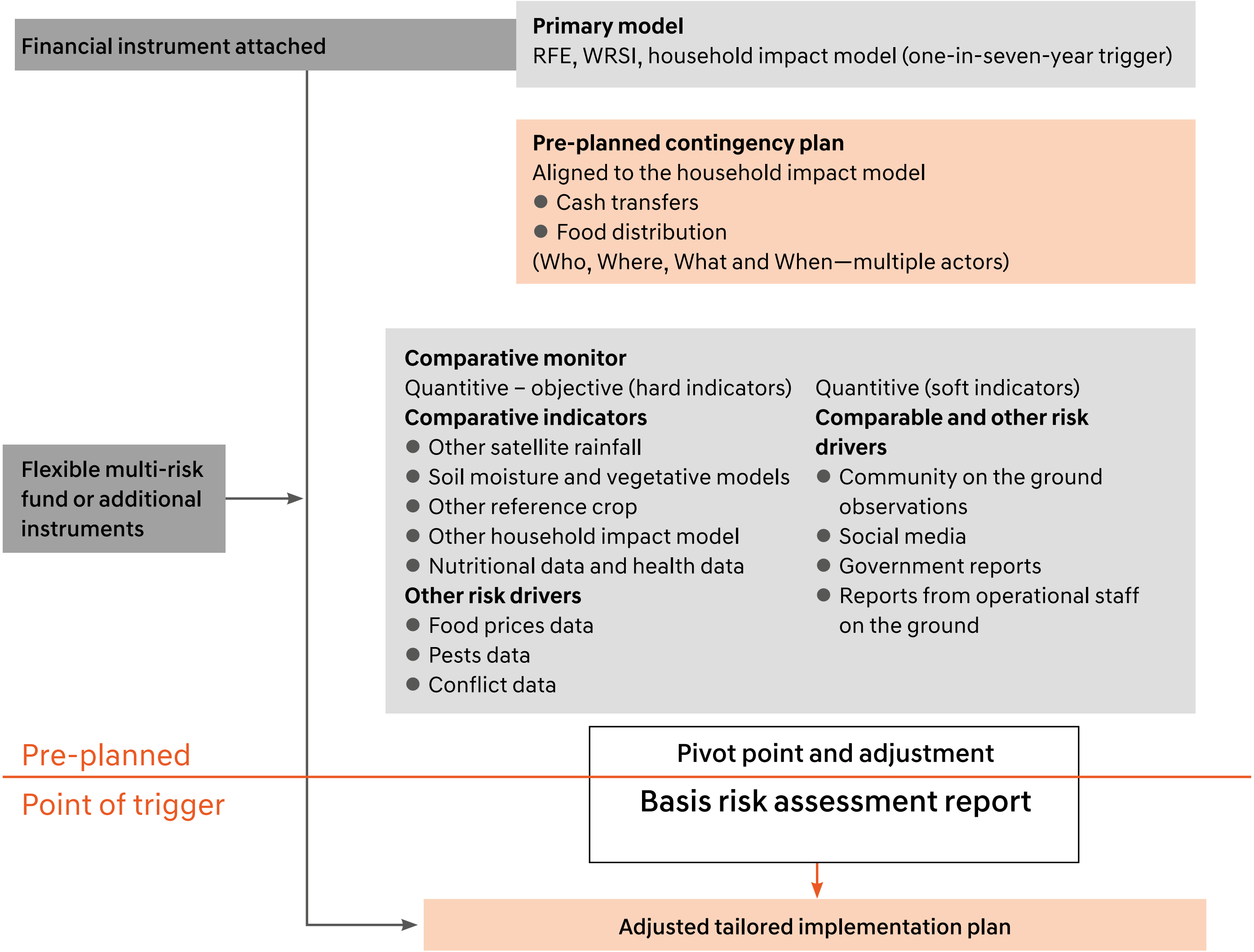
A combination of the technical elements outlined above should significantly help to mitigate basis risk. However, risk cannot be entirely eliminated.

A possible way to manage issues that arise at the point of trigger is to appoint a named neutral party who could arbitrate in the event of disagreement or dispute between clients and financial or model service providers. This body could be global or regional, and again should be guided by a clear, pre-agreed review process. This should set out clear timeframes, including the point at which an arbitrator needs to be called into a situation, as well as deadlines for resolution. This should help avoid situations such as that experienced by Malawi in 2016, where payment was not released for nine months (see Section 2.1).

The ability to manage this risk live is also very dependent on the type of hazard. In the case of cyclones for example, any disputes are likely to have to be managed *after* the response.

Figure 3 shows a theoretical example of where satellite rainfall estimate (RFE) data is coupled with a water requirement satisfaction index (WRSI) data for a given crop and yield drops, and is used to model a likely fall in household income and response cost, which is used to trigger an insurance contract of a one-in-seven-year severity event and above.

Figure 3: Example of a possible DRF basis risk management system



CHAPTER 6

CONCLUSIONS

The ideas outlined in this paper have arisen from the experience of many experts reflecting on the challenges of a single instrument approach, of implementing DRF systems within the humanitarian sphere, and by looking at a pragmatic system design that would achieve the best outcomes for people at risk. With pre-planning, prediction, and prepositioning, DRF systems can be supported by new financing structures, factoring in the complexity and operational reality of humanitarian crises and bringing about new levels of accountability and coordination. (See Figure 4 overleaf for a summary of proposed technical risk management steps.)

As we have seen, some of the technical and communication elements of improved system design are currently being tested by the Start Network, the World Bank, and IFRC. In 2019, Start Network will be trialling a comparative monitor approach (through ARC replica), where the results of ARV will be analysed against a comparative monitor to identify basis risk, and its likely sources, within a live contracted system. There is of course a risk/likelihood that the proposed solutions fail to deliver perfectly. However, the objective of the process outlined in this report is to indicate a possible direction of travel, while looking at a wider dynamic system focused on operationalising the release of DRF and proactively managing uncertainty. It is important to acknowledge that this offers a potential technical solution—and not necessarily a political or coordination-based one.

For new system designs to be fully realised, all actors working on disaster management and crisis response in-country will need to coordinate and pull in one direction, leveraging respective skills, resources and operational mandates. Government, UN agencies, civil society (such as IFRC and Start Network NGO members), donors and financiers, including the World Bank and regional development banks, need to come together to make technical solutions really work for those at risk.

The authors of this paper welcome comments and further ideas on this topic, including options to test and innovate new operational designs.

Figure 4: Summary of proposed technical risk management steps

Basis risk	Reduce the risk	Manage the risk live
Model error	**Develop an R&D plan** for each model component, including planned improvement to source data, re-analysis of real-time data and calculations.	**Comparative monitor** of similar metrics to triangulate the primary triggering model. **(Basis risk assessment, measurement protocols and review panel.)**
Context outcome uncertainty	**Research and understanding of the various drivers of risk** to understand attribution of outcomes and all risks that need to be monitored. (e.g. conflict, El Niño, or pests on food security impacts, and drought.)	**Comparative monitor** of diverse risk metrics to review impact with regard to the various drivers to contextualise the outcome to the primary triggering model. **(Basis risk assessment, measurement protocols and review panel.)**
Misunderstanding of model error and context outcome uncertainty	**Increased investment in training and learning** on hazard science and modelling. Greater **investment in communicating science tools.** **Simplification of contractual wording** in respect of model performance and basis risk.	**Continual updates and basis risk assessment** over the live risk period. Clear protocols for monitoring and measuring basis risk, and a clear objective way to resolve data divergence and conflicts and disagreements at the end of the risk period as a standard part of data processes. Identification of a global arbitrator.

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LIST OF ABBREVIATIONS

ARC	African Risk Capacity
ARV	Africa RiskView
CCRIF	Caribbean Catastrophe Risk Insurance Facility
DEEP	Data Entry & Exploration Platform
DFID	Department for International Development (UK)
DRF	Disaster risk financing
DRiSL	The Drought Risk finance Science Laboratory
DRR	Disaster risk reduction
FAO	Food and Agriculture Organization
FbF	Forecast-based Financing
HEA	Household economy approach
IFRC	International Federation of Red Cross and Red Crescent Societies
IMF	International Monetary Fund
NERC	Natural Environment Research Council
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
RFE	Rainfall estimate
SDD	Scientific due diligence
WRSI	Water requirement satisfaction index

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