The University Of Sheffield.

SPERI Paper No. 13

Climate Risk, Big Data and the Weather Market.

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Jo Bates is a Lecturer in Information Politics and Policy in the Information School, University of Sheffield. She researches the political economy of data, particularly data sets that are produced by public bodies and which are often referred to as Public Sector Information. Her research focuses on understanding the socio-cultural and political economic factors shaping developments in this field, including the ideas, practices and policies shaping the production and distribution of public data sets and their re-use by third parties including citizens and businesses. Her research has explored the development of the UK's Open Government Data initiative. Her current project is focused on the distribution and re-use of weather data.

ISSN 2052-000X

Published in May 2014

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Introduction

In a recent SPERI paper, Colin Hay and Tony Payne (2013) develop the concept of "The Great Uncertainty" to describe our current era. They point to "three major processes of structural change" which underlie this uncertainty – financial crisis, shifting economic power and environmental threat – arguing that, despite their differing historical timespans, these deep structural changes are all taking place in the present and "arguably will come to a head at broadly the same time" (Hay & Payne 2013, p. 3). This paper draws together two core elements of "The Great Uncertainty" – financial crisis and environmental threat – with Sandra Braman's (2006) concept of "informational power" to explore the relationship between this uncertain terrain and developments in ('big') data analytics.

Focusing on the development of weather index-based risk products as a response to climate instability, the paper explores the critical role of "informational power" in the development of these risk markets over the last two decades. Through analysis of two different forms of weather market – weather derivatives and weather indexed insurance schemes for farmers in developing countries – the paper makes the key argument that it is important to understand how these emerging responses to climate change risk empowering established economic interests, whilst deepening the threats facing the majority, and particularly the most vulnerable in society.

The Great Uncertainty and the Rise of Informational Power

Financial Crisis

The recent financial crisis has been rooted by many observers in the regulatory framework for the US and UK financial markets that has developed over the last 30 years. How specifically these developments should be interpreted by political economists is debated. For example, some argue that what we have experienced since the 1980s is a period of competitive deregulation between the UK and US governments (Hay 2013; Stiglitz 2012, p. 43); whereas others argue that it is not de-regulation but "a process of reregulation as depoliticization" that has occurred (Major 2012, p. 538). However, despite these disagreements many agree that these regulatory processes have been the result of a neoliberal logic shaping financial market governance, and, furthermore, since the crisis began little has changed:

> At the macro level, and within the core economies of the global financial system, the ethos of political economy at work within global finance and banking remains robustly neoliberal in character (Germain 2012, p. 531).

These regulatory changes in the financial markets led to significant growth in the sector's contribution to the UK's GDP, and despite the recent financial crisis the UK's economic dependency upon the finance sector has not abated (Hay 2013). As Berry (2013, p. 15) demonstrates, drawing on data from the Office of National Statistics' Blue Book, in terms of the composition of the UK economy by sector, there has been little change in the composition of the UK economy since before the crisis, and certainly "no dramatic shift away from financial services". Thus, as Berry points out, whilst there have undoubtedly been changes between the pre- and post-crash economy, "the government has sought to revisit a form of the previous growth model" (Berry 2013, p. 24).

Furthermore, despite the decline in public trust for the financial sector in recent years (Edelman 2013; Curtice & Park 2011), Berry (2013, p. 24) argues, drawing on the work of Jodal *et al.* (2012), we can perceive the "strengthening of the City's political influence" post-crash due to the fact that the government has allowed the banks to recapitalise by reducing the credit availability that fuelled growth pre-crash.

These observations draw attention to the continuing, and potentially increasing, power of the financial markets within the UK – both economically and politically. They highlight the importance of critically exploring innovations and developments in the sector closely, particularly when these innovations intersect with other processes of deep structural change that are leading to uncertainty within the global political economy.

Environmental Threat

One such process of deep structural change that Hay and Payne (2013) build into their framework of The Great Uncertainty is environmental threat. They echo many other commentators including the Intergovernmental Panel on Climate Change (IPCC 2013) by stressing the significant and potentially catastrophic consequences of human action on the stability of planetary ecosystems. Hay and Payne draw specifically on a much cited 2009 *Nature* article by Johan Rockström and colleagues about planetary "carrying capacity" (Rockström *et al.* 2009). In this paper Rockström *et al.* attempt to quantify a range of "planetary boundaries", aiming to "identify the Earth-system processes and associated thresholds which, if crossed, could generate unacceptable environmental change". Their analysis suggests that the boundaries for "climate change, rate of biodiversity loss and interference with the nitrogen cycle" have already been passed, and, in the case of "global freshwater use, change in land use, ocean acidification and interference with the global phosphorous cycle" are quickly approaching.

Hay and Payne's (2013, p. 6) critical argument here is that many of these earth systems are already in the 'red zone' and further degradation is directly related to "aggregate global [economic] growth rates". This leads them to conclude that "we face not just a crisis of growth, but, much more significantly, a crisis *for* growth…we will need to wean ourselves off growth if we are to do anything that takes us out of the 'red zone'". Their argument that economies must move beyond growth in order to shift towards a sustainable form of development is not new, and has been approached from a number of perspectives. The Club of Rome's 1972 report on the Limits to Growth (Meadows *et al.* 1972), for example, was the first analysis of the problematic relationship between economic growth and environmental sustainability, and these ideas have been taken up across a range of fields including, for example, sustainable development and ecological economics.

Beyond the environmental limits to growth, David Harvey (2011) has taken the argument further, noting that capitalism's dependency on a minimum global economic growth rate of around 3% per annum to remain 'healthy' is becoming increasingly problematic. It is simply not possible, he argues, to sustain a *compound* rate of economic growth, as to do so would mean finding substantially more new profitable investment opportunities every year: from $0.4 trillion in 1970, to $1.5 trillion today, to $3 trillion in 2030, and so on. Such growth, he argues, is not only environmentally unsustainable, but is also limited to the extent that the rate of profitable investments to be found each year becomes impossible to maintain.

Whilst the argument for moving beyond growth as a measure of economic success might be relatively easy to conclude at the theoretical level, the actual process of transition towards a new economic model is more fraught, and of course deeply political. Furthermore, it is an argument not generally in favour amongst political and economic elites who aim to prioritise continued economic growth in their response to the current environmental threat (see Stern 2006a; HM Government 2013).

These developments draw attention to the difficult and complex needs of our planetary ecosystems as they interact with our human, particularly economic, activity; as well as the political difficulties of collectively ensuring the health of those ecosystems that we depend upon. These issues must also be contextualised in relation to the above analysis of the deepening political and economic power of financial markets as we act collectively in response to these issues and aim to manage the risks that they embody.

Informational Power

A further issue of deep uncertainty as the 21st century unfolds is around developments in the field of digital information and communications technology; one area of growing interest being that of data analytics. It is claimed by IBM (n.d.) that 90% of the world's data has been created in the last two years, and the European Commissioner for Digital Agenda, Neelie Kroes' (2011), has recently claimed that "data is the new gold".

Both environmental science and the financial markets have long been data-dependent domains.

The reason we know that the climate is changing, why it is changing, and how we should respond, is the result of decades of complex processes of data collection, cleaning, analysis and modelling by climate scientists (Edwards, 2013). Data similarly flows through algorithms and models in the financial sector, feeding into human and automated decision-making processes which have significant impact throughout our societies. Developments in ('big') data analytics could therefore have significant impact in these fields. It is clear that data will both contribute to society's response to the great challenges of the 21st century, and that developing practices around data collection and analysis generate deep uncertainties of their own. It is important therefore to integrate these developments into our understanding of the dynamics of The Great Uncertainty.

Much theorising has been undertaken to try to understand better the role and impact of digital information and communications networks on societies (e.g. Castells 2010; Dijk 2012). Some commentators have argued that a new form of society has emerged as a result of informationalisation, drawing on the work of early "Information Society" scholars such as Machlup (1962), Drucker (1969), Bell (1973), and Masuda (1968; 1980). The claims made within this tradition have been adopted by a wide range of policy makers, with explicit "information society" development policies evident in the European Union, Japan, and the United Nations amongst many others. However, other theorists such as Webster (2006), May (2002), and Schiller (2010) have questioned some of the fundamental assumptions of the "information society" position, critiquing the notion that a new form of society has emerged from the old, and emphasising that regardless of the importance of information to contemporary society the "form and function" of information is "subordinate to long-established principles and practices" (Webster 2006, p. 7) evident in earlier forms of capitalist production.

One recent contribution to these discussions emerges in Sandra Braman's (2006) work on the "Informational State", in which she observes the development of a deepening form of "informational power" beginning in the 1970s and 1980s. She argues that, whilst analyses of power have tended to categorise the concept into instrumental, structural and symbolic forms of power, processes of information intensification in recent decades have brought a further type – "informational power" – to the core of contemporary power relations (Braman 2006, pp. 26-27). This "informational" form of power, she argues, interacts with other forms of power by "manipulating" their "informational bases" (p. 26). She illustrates a number of examples of this developing "informational base" for instrumental, structural and symbolic forms of power with reference to Smart Weapons, internet surveillance, personalised web-services, social profiling and manipulation of public opinion. Braman further argues that the processing and distribution of information are also often key factors in "the transformation of power from potential to actual" (p. 27). This argument overlaps with Harvey's (2007) observation that over recent decades it has become increasingly necessary to develop "technologies of information creation and capacities to accumulate, store, transfer, analyse, and use massive databases to guide decisions in the global marketplace" (p. 3) in order to realise neoliberal ideas.

Developments in ('big') data analytics deepen the relevance of Braman's argument. It is critical that this informational form of power is considered as we try and navigate through the complex and uncertain terrain of the contemporary era. The way in which we respond to conditions of Great Uncertainty will, in part, be shaped by the data that is available, and who is able to access and use it and who is not. Further, the different interests that are empowered and disempowered to shape how we use this data will be heavily influenced by the ways in which as a society we imagine possible futures, and how we prioritise different interests in imagining and creating them. This in turn will impact upon a variety of more tangible factors including the regulatory frameworks and funding streams which enable and restrict different types of data activity, as well as whether as a society we have the skills and knowledge to understand and realise what data can empower us to achieve, and where it might mislead or hinder efforts to overcome significant societal challenges.

In order to 'make real' some of these issues the rest of the paper will explore one field where each of these spheres of uncertainty intersect: the development of weather index-based risk markets in response to climate instability. The next section will briefly discuss the UK government's position on climate change, economic growth and risk. An analysis of two types of weather index-based risk markets – weather derivatives and weather indexed-based insurance – will then be presented, prior to a discussion about the role of data in driving developments of these markets and the problems emerging in the economic exploitation of environmental uncertainty.

Risk, Growth and UK Climate Change Policy

The Stern Review on the Economics of Climate Change, produced for the UK Government in 2006, positions climate change as "the greatest and widest ranging market failure ever seen" (Stern 2006b, p. i). However, contra Hay and Payne (2013), the review argues that it is possible both to stabilise the climate and maintain economic growth via policy interventions in "carbon pricing, technology policy, and removal of barriers to behavioural change" (p. xviii). Further, the Stern Review argues that some climate change is inevitable given the current situation, and therefore adaptation policy is also required. As part of this adaptation policy, Stern recommends both better information about the climate, and the promotion and enabling of "markets that respond to climate information [which] will stimulate adaptation among individuals and firms" (p. xxi). One form of market referenced by the review is "risk-based insurance schemes", which, it is argued, "provide strong signals about the size of climate risks and therefore encourage good risk management" (p. xxi). The report then stresses the necessity of financial protection for the society's poorest and most vulnerable, who are unable to insure and otherwise protect themselves from the impact of climate change (p. xxii).

Whilst the Stern Review was published in 2006, and a new government has come to power in the United Kingdom since this date, the overarching objectives of the UK's Climate Change policy echo some of Stern's key conclusions. The National Adaptation Plan (HM Government 2013), for example, similarly aims to promote both climate change mitigation and adaptation, within a framework for promoting long-term economic growth and encouraging the exploitation of "business opportunities that arise from the need to manage the risks from climate change and extreme weather events" (p. 83). The question of transitioning to a post-growth economy, as posited by Hay and Payne amongst others, is therefore not one that is engaged within UK Climate Change policy. Instead, a key pillar of adaptation policy is focused on leveraging opportunities for economic growth by encouraging the exploitation of the need to manage climate-associated risk. As part of this monetisation of risk, there have been a range of financial innovations in recent years that have aimed to deepen the financialisation of environmental risk. For example, Jankovi & Bowman (2013) explore the financialisation trend in relation to the growth of the carbon economy, whilst Sullivan (2013) similarly explores the financialisation of environmental conservation. A relatively unexplored trend outside of the technical and applied literature, however, is around the development of index-based weather risk financial products.

The Growth of Index-based Weather Risk Products

Weather Derivatives

> The weather market should probably be called the climate risk market, as climate was and is its principal focus (Dischel 2002, p. 7).

One critical development that ties directly into this policy to exploit the management of climate risk is the emergence of weather derivative markets over the last two decades. These financial products cover businesses for "moderate departures" from expected weather conditions; as opposed to insurance which covers "large departures and catastrophes" (Dischel 2002, p. 8). What is unique about these financial products is that they pay out if certain weather conditions are recorded, regardless of any actual loss. Weather derivative contracts are therefore based on the analysis of large indexes of observed weather data, generally for a few key weather stations within a given geographical region.

Weather derivatives were developed within the US energy industry by Enron, Koch Industries, and Aquila in the late 1990s when Enron found insurance companies unwilling to insure the company against non-extreme weather events such as the company experienced during a period of mild US winters from 1997-99 (Weather Risk Management Association n.d. (a); Dischel 2002, p. 3). The deregulation of the US energy market had resulted in lower, more competitive energy prices in the USA; a situation which aggravated the problem by restricting energy suppliers' ability to extract a surplus from consumers in order to cover periods of unexpected weather conditions (Dischel 2002, p. 3). In order to overcome this barrier, Enron created its own financial product - the weather derivative - taking inspiration from the energy futures markets it was involved in. The development of the product as a derivative (and therefore a financial, rather than insurance, product) allowed Enron to avoid the regulatory constraints placed on energy companies' use of insurance products (Randalls 2010).

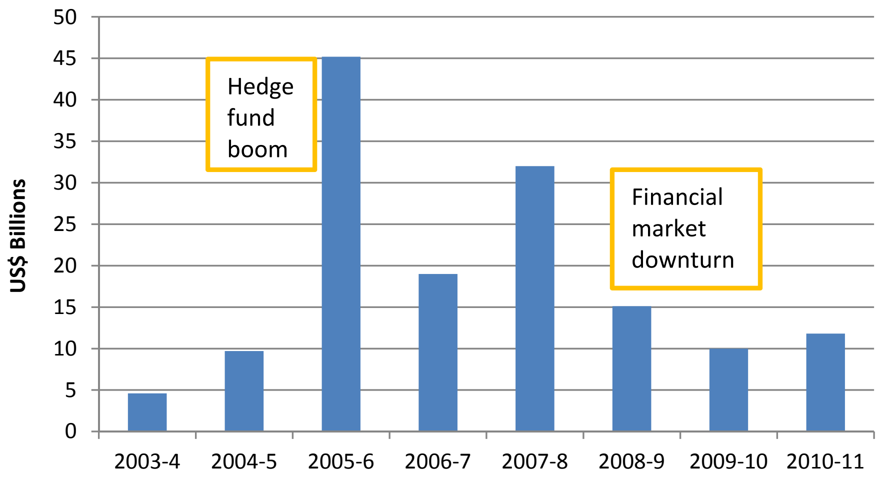
Whilst weather derivative contracts are traded across all forms of weather event, by far the most popular contracts have been based on temperature and the divergence of the average daily temperature from 18 C. These products, which are popular with firms in the energy industry, are known as Heating and Cooling Degree Days (HDD and CDD) contracts (Weather Risk Management Association n.d. (b)). Over recent years, however, the primary market which provides derivative contracts to end-user businesses has diversified, and a wider and more complex range of products are being developed across a range of weather conditions. One such product is the quantity-adjusting option, or quanto, derivative which combines weather and commodity price risk within a single derivative contract. For example, a company could receive a pay-out on a contract if the temperature is lower than expected; however, the pay-out would be calculated in relation to the price of gas (Risk.net 2010). This primary market for weather derivatives has also spread beyond the USA, with Europe now having taken over the USA in terms of number of trades (Risk.net 2010).

There is also a secondary market in weather derivatives which primarily trades via the Chicago Mercantile Exchange (SCOR Global 2012). In this secondary market, sellers of weather contracts in the primary market trade contracts in order to manage their risk. Whilst this secondary market was slow to develop (Dischel 2002) it now provides important liquidity for the weather derivatives market (SCOR Global 2012). It is therefore apparent that the weather derivatives market functions in much the same way as other financial markets: securities are issued in the primary markets, and these contracts are traded on the secondary markets providing liquidity (SCOR Global 2012).

The weather derivatives market saw massive growth in the mid 2000s, experiencing both the hedge fund boom of 2005-6 and the pre-crash boom of 2007-8 (Randalls 2010). As with other forms of financial product, the vulnerability of the weather derivatives market was highlighted when the market crashed during 2008-9 and 2009-10, with only slow signs of growth by 2011 (Weather Risk Management Association 2009; 2011) (See Figure 1). However, the Weather Risk Management Association is hopeful for weather derivatives, pointing to continuing growth outside the US markets throughout the downturn, growing interest in non-temperature related weather derivatives, and increasing interest from outside the energy industry (Weather Risk Management Association 2009; 2011).

Whilst regulatory developments in the wake of the financial crisis, namely, the USA's Dodd–Frank Wall Street Reform and Consumer Protection Act and the EU's European Market Infrastructure Regulation, may impact upon the management and reporting of particular types of trade within the weather derivatives markets on both sides of the Atlantic, there is little indication from industry representatives that regulatory developments could threaten the weather derivative markets in general (Weather Risk Management Association 2011; Osipovich 2012).

Figure 1: Total notional value of weather derivatives market



Source: Weather Risk Management Association annual survey undertaken by PricewaterhouseCoopers.

Weather Indexed Insurance

Whilst the legal differences between weather derivatives and weather indexed insurance are debated in some detail (Rainelli 2012), there are some important similarities including the fact that both are calculated based on indexes of historical and observed weather conditions. This has led many to argue that the two are in fact very similar (Fuchs & Wolff 2011; Clarke *et al.* 2012). There has been a significant increase in the adoption of weather-indexed insurance products in the last decade. Numerous projects encouraging the take up of weather-indexed insurance by farmers in developing countries have been developed by The World Bank (The World Bank n.d.), alongside projects promoting the adoption of a type of weather derivative contract that covers developing country governments for more severe weather events (The World Bank 2008).

These weather-indexed insurance products are increasingly being used to offer protection against climate instabilities to low-income farmers in developing countries, with the insurance premiums often being subsidised, in part or in full, by government agencies (Fuchs & Wolff 2011; Clarke *et al.* 2012). Whilst traditional insurance for farmers has been on the basis of crop loss, the weather-indexed insurance pays out based upon observed weather data collected from weather stations. This is perceived by some to be an advantage since it makes it more efficient to settle claims, there are reduced opportunities for system manipulation, and information asymmetry is less of an issue (Clarke *et al.* 2012, p. 3). Further, it is proposed that the reduced volatility of farmers' income, which should be the outcome of weather-indexed insurance, will increase low-income farmers' ability to obtain credit (Fuchs & Wolff 2011, p. 506).

However, a number of significant issues have been recognised with these weather-indexed insurance products. One of the critical issues is the granularity of the weather data on which they are based. A farmer may live many miles away from the weather station that generates the observation of weather conditions by which the insurance contract is calculated. This means that many of the products have a high 'basis risk'; the data is not measuring the conditions one hopes to insure. In the case of India this has potentially contributed to a very weak relationship between the average pay-outs to insured farmers and yields. For example, analysis by Clarke *et al.* (2012, p. 9-10) indicates that in the case of a zero yield, the average pay-out under the Indian Weather Based Crop Insurance Scheme was only 12% of the total sum insured, and there was a 1 in 3 chance of a farmer receiving no pay-out at all. Furthermore, when yields were twice those expected, farmers were still receiving on average pay-outs of 6% of the sum insured.

These issues lead to significant questions about the utility of weather-indexed insurance for protecting individual farmers; however, they also highlight broader issues regarding the flow of money from those seeking protection to the providers of the insurance. This becomes more problematic when one takes into consideration the observation that insurance companies have been manipulating the "sales window" to their advantage after taking into consideration up to date weather forecasts, thus disadvantaging farmers and their subsidising governments (Clarke *et al.* 2012, p. 11).

Two further issues with these products also raise significant environmental and social questions. Firstly, some schemes, for example in Mexico, only cover particular crops. Fuchs and Wolff (2011, p. 510) argue that restricting insurance protection to rain fed maize could lead to increased monoculture and aversion to developing irrigation systems, both of which could damage "the environment and long term sustainability" of the region. Secondly, a sudden flow of insurance scheme pay-outs into a region can lead to food price inflation – particularly if crop damage has occurred thus decreasing supply. This, Fuchs and Wolff (2011, p. 510) argue, can impact negatively on uninsured and non-farmers who are not in receipt of a pay-put. They point to this as an issue in Mexico, and argue that the problem could be even more significant in Africa where greater dependence upon agriculture means more insured farmers will be living within a community, and therefore a sudden spate of pay-outs are more likely to impact on food prices.

These issues raise significant questions about whether weather-indexed insurance schemes do in fact help the most vulnerable in society navigate the effects of climate instability as advocated by Stern (2006b). Low demand from farmers for these products suggests that there is doubt within the communities in question as to their benefits. Clarke *et al.* (2012), for example, report a relatively high uptake rate in India (prior to compulsory coverage) suggesting an interest in protection, yet a very low renewal rate suggesting unsatisfactory protection by the products. Studies point to uncertainty about the programme, low willingness to pay for insurance, and the fact that in some countries farmers with loans are already "implicitly insured by the limited liability inherent in the loan contract" therefore insurance premiums are perceived as an unnecessary financial burden (Fuchs & Wolff 2011, p. 506).

This low demand from farmers has been perceived as a problem by a number of governments and international organisations such as the World Bank. Compulsory weather-indexed insurance is therefore becoming more popular, with the Indian government recently making their subsidised National Crop Insurance Programme (NCIP), which incorporates a weather-indexed insurance component, compulsory for all farmers with crop loans (*Economic Times* 2013); after piloting compulsory, subsidised weather based insurance for loanees since 2007 (Clarke *et al.* 2012). The Mexican government, amongst other countries, has also been fully subsidising weather-indexed insurance premiums for entire regions (Fuchs & Wolff 2011).

It is common for providers of these weather-indexed insurance schemes to reinsure their risk in the international financial markets. For example, in Mexico, Agroasemex is a federal agency which designs new agricultural insurance schemes and provides re-insurance for "Mexican insurance institutions, mutual societies and insurance funds" providing insurance for farmers (Forum for Agricultural Risk Management in Development n.d.). Agroasemex in turn manages its risk by reinsuring through the US reinsurance firm Partner RE (Fuchs & Wolff 2011, pp. 507-8).

What is apparent here is a parallel between developing countries investing in weather-index insurance premiums and firms purchasing weather derivatives in the primary markets, in both cases in an effort to protect against climate-related weather instabilities. Furthermore, we observe the development of secondary and reinsurance markets which trade in both types of contracts in the international financial markets in an attempt to spread the risk and increase the liquidity of the market.

Data-driven Developments in Weather Risk Trading

A frequently cited impediment to weather derivatives and weather-indexed insurance trading is the availability and quality of weather data that can be used to calculate contracts. For example, for weather-indexed insurance a minimum of 20 years of independently verified, daily historical weather data that satisfies requirements of reliability, trustworthiness, quality control is recommended by the International Fund for Agricultural Development (2011, p. 31 & p. 43). Furthermore, it is recommended that there should be less than 3% of the total daily dataset missing (International Fund for Agricultural Development 2011, p. 31). In many developing regions such datasets are not available, and therefore it is not possible to calculate contracts and weather risk management products are unlikely to be developed until enough historical data is available.

Whilst reliable historical weather data is far more available in 'developed' regions, a key issue that has emerged in the European markets since the advent of the weather derivative markets has been the cost to traders for accessing and using this data. The data generally used by weather derivative traders is generated by public meteorology organisations, such as the UK's Met Office, on the grounds that these are often the most reliable and comprehensive datasets available (Dischel & Barrieu 2002). However, the ease with which traders can re-use this data varies from country to country. For example, in the USA, weather data has been in the public domain, freely available for anyone to re-use, since before the development of weather derivative markets. In the UK, by contrast, weather data has until very recently been treated as a commodity to be traded by the Met Office.

When the Met Office became a Trading Fund in 1996, it shifted from being entirely dependent upon public funding, to becoming partially dependent upon commercial activities. One of these commercial ventures, weatherXchange was established in 2001 in partnership with financial broker, Umbrella Brokers, in order to supply data to the weather derivatives market. The venture failed, taking at least £1.5 million of public money with it, and in a parliamentary committee investigating the affair it came to light, that on realising the revenue to be generated from selling data to the weather derivatives markets, the Met Office began "deliberately undercutting business from their joint venture [weatherXchnage] to take a larger share of the market themselves" (Randalls 2010, p. 706).

Whilst the weatherXchange venture was unsuccessful, the practice of the Met Office commercially exploiting its data in the financial markets continued. Those promoting the development of weather derivative markets in the UK, including lobbyists for the UK financial services industry such as Lighthill Risk Network (of which Lloyds of London are a member), have spoken out against this practice for a number of years (Department for Business Enterprise and Regulatory Reform 2008). They have called for Met Office data to be made available at marginal cost, so that traders can freely access and re-use it (Weiss 2002) and, therefore, better compete with the US markets. In the early days of the markets, for example, Weiss (2002) observes that limited access to weather data in the EU had by 2002 resulted in a weather risk management industry 13.5 times smaller than the nascent US industry which by this date had built up $9.7 billion dollars of contract value over 5 years.

These demands have filtered down into UK government policy making. For example, the Stern (2006a) review recommends better climate information to inform markets; and, policy documentation developed by senior policy makers in, what was at the time named, the Department for Business Enterprise and Regulatory Reform (2008) indicates support for the financial industry's demand for free re-use of UK weather data. Whilst policy developments began slowly, the election of the new coalition government in May 2010 led to the demand for access to weather data being quickly incorporated into the government's flagship Transparency and Open Government Data agenda by both Open Data advocates campaigning against the commercialisation of public sector data, and policy makers keen to provide the financial markets with free access to weather data. In the Autumn Statement of 2011, the policy developments came to a head with the announcement by Chancellor of the Exchequer, George Osbourne, that the UK government was 'opening' "the largest volume of high quality weather data and information made available by a national meteorological organisation anywhere in the world" for anyone to re-use without charge (HM Government 2011a). According to one well-placed policy maker (interviewed by the author in 2011), these developments would contribute to the development of a data infrastructure that would make the UK weather derivative market competitive with the US based markets.

Whilst the 'opening' of the UK's weather data for free re-use tackles the key issue of data accessibility, a further "deterrent to growth" (Dischel & Barrieu 2002, p. 27) is the granularity of data and its impact on the 'basis risk' of weather risk products. In most cases, weather derivatives are calculated based upon a small number of weather stations, often airports due to their increased quality control. However, this level of granularity does not suit many buyers as the basis risk is too high. Two interesting developments in this field are by companies working in the field of 'Big Data': Climate Corporation (recently acquired by Monsanto for $930million) and IBM.

As the *Financial Times* (2013) reported, Monsanto's purchase of Climate Corporation signals the "first significant acquisition" of this emerging 'Big Data' industry. Climate Corporation's offering is a form of online self-service weather insurance for US-based farmers. Whilst still offering standard insurance products that pay out if damage to crops occurs, the company also offers an innovative new product called 'Total Weather Insurance' (TWI). Total Weather Insurance is a new form of financial product being sold direct to farmers via online self-service portals; however, it is similar to other weather-indexed insurance products in that it pays out based solely upon observed weather conditions, rather than crop damage.
In order to calculate the price of policies and pay-outs, Climate Corporation data scientists analyse three million new data points a day from twenty-two datasets, using a variety of advanced 'Big Data' analysis techniques (Concurrent n.d.). Their "Climate Monitoring Platform" provides farmers and insurers with, amongst other information,

> Hyper-local weather monitoring…of field and sub field-level environmental conditions by incorporating dozens of public and private environmental observation networks and remote sensing systems, coupled with various proprietary and published models to remotely assess weather, soil, and other environmental conditions (The Climate Corporation n.d.).

This hyper-local monitoring of weather conditions is also observed in some of the recent Smart City initiatives. IBM's Deep Thunder project aims to combine historic and real-time weather observations with sophisticated data analysis techniques, in order to "get extremely accurate weather forecasts and [predict] the impacts of severe events for specific locations (less than a mile) up to three days in advance" (Treinish n.d.). Further, IBM's work with Israeli company Nooli aims to develop "hyper-local sensor-based weather detection" and data collection, providing data scientists with the data they need to generate hyper-local weather forecasts (Israel 2013).

Whilst weather risk products have traditionally relied on public weather data from national meteorological agencies, these developments suggest that private sector hyper-local weather sensoring, which generates ever 'bigger' datasets, together with more sophisticated data analysis and modelling techniques, might come to play an increasingly important role in the calculation of weather derivatives and weather indexed insurance contracts in the future, potentially reducing some of the basis risk of these products for end users by increasing the correlations between the index of observed weather and the events (e.g. yield, demand) to be insured.

The Exploitation of Uncertainty

The combination of increasing amounts of freely available and re-usable weather data, the development of more advanced 'Big Data' analysis techniques, the growing global demand for a variety of weather risk and derivatives products across a wider range of industries, compulsory coverage being mandated by governments for some types of farmer, and the development of simple online self-service portals for buyers as designed by Climate Corporation all suggest that the exploitation of unstable weather systems is still in its early days.

For advocates of these weather risk products, one of the key benefits is argued to be that they reduce the exposure to financial volatility resulting from climate instabilities experienced by many sectors of the economy. Whilst in the long term a business should expect to pay more in to weather risk products than they receive in pay-outs, the business should also expect gains due to having a less volatile profit margin (Dutton 2002, p. 208). For example, the business will be better able to secure credit and protect its market value. For this reason, many perceive that weather risk products increase the "resilience" of businesses and other end users as they adapt to climate change (Michel-kerjan 2013), allowing them to effectively "eliminate the effects of weather and climate from the income statement" (Dutton 2002, p. 209). As Dischel (2002) states:

> The goal of hedging is to be less concerned, or not concerned at all, about the impact of weather on cashflow or return. Management achieves freedom from the weather when it engages in a hedge (p. 19).

At the same time as increasing the 'resilience' of industries and countries that are vulnerable to climate change, weather risk products, it is claimed, offer a substantial growth opportunity for markets to take advantage of in the coming years. For some, therefore, weather risk products are seen as a double win; helping to stabilise economies as firms navigate the uncertain weather conditions that climate change brings, whilst simultaneously making substantial profits that contribute to overall economic growth, particularly in the financial centres of the global economy.

Many liberal economists would argue with Stiglitz (2012, pp. 42-3) that within a capitalist economy market failure occurs when there is either imperfect competition; externalities (when a group is affected – positively or negatively – by others' economic activity); information asymmetry; or when risk markets are absent. Some might therefore argue that the development of weather risk markets and the increasing availability of free meteorological data might counter some of the market failure problems posed by climate change.

However, in relation to the mitigation of climate change there are deep problems in the development of weather derivative markets, primarily, in enabling end-user firms to be "less concerned, or not concerned at all, about the impact of weather on cashflow or return" (Dischel 2002, p. 19), and allowing sectors of the finance industry to make substantial profits in exchange for generating this sense of security. These weather risk markets are in effect reducing the incentive of powerful economic actors to take and demand significant action to mitigate climate change. Such a scenario could increase the negative impact of the actions of those benefiting from these markets, at the expense of the majority and particularly those most vulnerable to climate change. Even under a liberal economic analysis that does not question the sustainability of continued economic growth, this potential increase in negative externalities should be cause for concern, as it could result in increased market inefficiency despite the reduction in information asymmetry and increase in risk insurance availability.

Despite this issue weather risk markets do have many interested parties advocating on their behalf; however, there are others coming from more critical perspectives that are more sceptical. Melinda Cooper (2010), for example, positions these developments in a similar context to the conditions Hay and Payne (2013) label The Great Uncertainty. She makes a strong argument that weather derivatives are "a claim over the future in all its unknowability – a claim over event worlds that have yet to actualize in space and time" (Cooper 2010, p. 181). Positioning these weather risk products within this broad context of uncertainty is fundamental to developing our understanding of what it might mean to interact with climate uncertainties in this way.

Given that there has been little substantial change post-crash in the general model of economic development in the UK, there is no reason to believe that systemic risk has been removed from the financial system. Further, as is clear from climate science there are no guarantees in the prediction of future climate risk. Whilst climate scientists recognise it is "extremely likely" that human activity is the main cause of observed climate warming since the 1950s, they are less sure about the specific impacts that this will have in particular locales. They therefore work with a variety of models aiming to predict the impact of climate change on weather systems across a range of scenarios (IPCC 2013). Further, as Rockström *et al.* (2009) argue, the impact of environmental threats including climate change could result in "abrupt environmental change, leading to a state less conducive to human development".

It is entirely possible that in certain types of climate scenarios the weather risk markets might be exposed to 'toxic' weather contracts that send shocks around the primary and secondary markets. It is therefore apt to consider what would happen if a climate scenario develops in which the markets are unable to fulfil their obligations to end users – whether businesses hedging against weather conditions or governments dependent on weather-indexed insurance pay-outs to support vulnerable regions that are experiencing crop failure. Similarly, what if a scenario develops in which climate instability deepens and the markets realise that the products are no longer commercially viable and so become reluctant to offer contracts despite entire countries' and industries' climate 'resilience' having grown dependent on them. Recent history would suggest that it will be the financial markets that are likely to benefit, whilst the majority suffer the consequences of any such problems.

In her analysis of some of these deep seated uncertainties, Cooper (2010), drawing on documents produced in 2008 by the US Government's National Intelligence Council and the US non-profit Centre for a New American Security, argues that in the world of US strategic scenario planning, "turbulence" in relation to financial markets, climate change, and energy (p. 169) is no longer perceived as something that there is a possibility of managing and avoiding; rather, "turbulence…is assumed" (p. 184). She argues that, as US strategists have attempted to understand what these deepening uncertainties mean for US geopolitical power in the context of shifting economic power as discussed by Hay and Payne, they have turned to "turbulence" – or The Great Uncertainty – as a form of "productivity" (p. 170) to be leveraged to the end of achieving the key strategic aim of sustaining US geopolitical power. One critical objective of the US strategists aiming to navigate through these uncertain waters, she observes, is "to dominate… the securitized risk markets, in which weather turbulence plays an increasingly significant role [and which]…offer one possible exit strategy from the liabilities of the dollar–oil nexus" (p. 170).

Whilst President Barack Obama's rhetoric, if not action, on climate change policy has admittedly been more supportive of mitigation than his predecessor, and whilst regulatory developments such as the Dodd-Frank Act aim to remove some of the risk from financial markets, there is little to indicate any substantial shift away from the exploitation of "turbulence" that Cooper describes. As Datz (2013) argues, post-crisis notions of the "complexity" of financial market trades have become prominent. This, she argues, has simultaneously "naturalis[ed] turmoil" (p. 460) whilst at the same time called into question the neoliberal belief in the external nature of causes of financial market turmoil, resulting in a broad consensus for some changes to financial market regulation in order to mitigate risk. Yet, she also observes that, by "render[ing] the financial system 'complex' and hence unpredictable" (p. 459), central to the proposed solutions are efforts to 'manage' this complexity with "better computational tools…[that can] better model and effectively simulate complex system dynamics in such a way as to limit the scope of damage when instability unravels yet again" (pp. 473-4). A similar observation is also made by Pike and Pollard (2009), who argue that post-crisis risk continues to be deeply embedded in the financial system as a direct result of market actors' "technocratic belief in their capacity to engineer ever-more sophisticated methodologies and instruments through which to conceive and calculate value and profit from the management of risk" (Pike & Pollard 2009, p. 33). It is precisely this type of attempt to manage risk that we also observe in the development of weather derivative markets, and similarly it is an approach strongly dependent upon the analysis and modelling of ('big') data.

Further empirical research is required to understand more fully the UK government's response to this situation; however, it is plausible to suggest that the general logic of the need to remain competitive with US financial markets which has driven some policy makers' support for opening up access to weather data extends more broadly to a desire for UK markets to remain competitive with the US's efforts to dominate the exploitation of uncertainty more generally. In support of this claim, it is worth noting that the UK government's Open Data White Paper emphasises the benefits of open data for growth across a range of risk-based industries including "homeland security… disaster management, energy and food security" as well as the climate and weather risk industries enabled by the opening of weather data (HM Government 2011b, p. 53).

Conclusion

It is evident that various forms of structural, instrumental and symbolic power are being deployed in the development and promotion of weather risk management products as a response to the uncertainty of climate change. It is also apparent that these products benefit established interests, whilst, perhaps unintentionally, deepening the threats facing the majority, and particularly the most vulnerable in society. For example, it has been observed that such products may impact negatively on the development of sustainable agricultural practices and food price inflation in developing countries (Fuchs & Wolff 2011); that they contain a significant risk of market failure which could have disastrous social consequences if firms and countries' climate 'resilience' becomes dependent upon them; that they potentially feed into geopolitical moves to dominate the global political economy into the 21st century; and, finally, through reducing the risk posed by climate change for powerful economic interests, and thus creating a disincentive for them to engage in action to mitigate climate change, the products could result in deeper environmental threat and climate instability in the long term. There is, therefore, little to suggest that the deployment of such products as a tool to develop 'resilience' to climate change will be successful in mitigating complex risk scenarios, particularly for the most vulnerable in society.

It is also evident that informational power is playing a significant role in the development of index-based weather risk products as a response to climate instabilities. Issues of weather data quality, reliability, granularity, and access all have enabling and restrictive properties with regard to the development of index-based weather risk markets. As Braman (2006, p. 27) argues, information is needed in order to enable the "transformation of power from potential to actual". In the case of the UK government's decision to 'open' Met Office weather data, in part to enable the development of the UK's weather risk market, we can perceive a specific case of information policy being used by a government in order to enable a deeply neoliberal, market-driven response to the conditions of uncertainty that we are facing in the 21st century.

These informational developments in technologies and policy are being shaped to enable particular forms of response to conditions of uncertainty; yet it would be problematic to argue that the increased access to and rights to re-use weather data and information are something to be resisted. Information is after all not only necessary to actualise power for political and economic elites, but also for the broad based forms of collective action that aim to challenge dominant ideas and practices, and establish some form of sustainable, democratic and ecologically sound political economy. However, by training our analytical lens on developments in the "informational base" of power, our attention is quickly draw to the nature of some of the little understood practices that those aiming to engage in such collective action must contend with in order to realise their vision. As Braman (2006, p. 7) argues, it can be illuminating to "look where the light don't shine" in order to get a better appreciation for the influence of information policy on broader policy and societal developments.

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