

	Citation	Abstract
2022		
A	PUBLISHED JOURNAL ARTICLES	
A.1(2022)	<p>Ascari, G. and Mavroeidis, S. (2022) 'The unbearable lightness of equilibria in a low interest rate environment', <i>Journal of Monetary Economics</i>, 127.</p>	<p>Structural models with no solution are incoherent, and those with multiple solutions are incomplete. We show that models with occasionally binding constraints are not generically coherent. Coherency requires restrictions on the parameters or on the support of the distribution of the shocks. In presence of multiple shocks, the support restrictions cannot be independent from each other, so the assumption of orthogonality of structural shocks is incompatible with coherency. Models whose coherency is based on support restrictions are generically incomplete, admitting a very large number of minimum state variable solutions.</p>
A.2(2022)	<p>Benoit, P., Clarke, A., Schwarz, M. and Dibley, A. (2022) 'Decarbonization in state-owned power companies: Lessons from a comparative analysis', <i>Journal of Cleaner Production</i>, 355.</p>	<p>A rapid decarbonization of the electricity system is urgently required for the Paris Agreement objectives to stand a reasonable chance of being met. While state-owned power companies (SPCs) are the dominant firm type in the global electricity sector, representing nearly two thirds of global electric power generation capacity, most climate policy literature focuses on private sector companies when analyzing decarbonization interventions. SPCs' distinct corporate governance structures, objectives, relationships with government, and sources of finance, however, vary considerably when compared to private companies. Here, we develop a framework for analyzing the extent to which common and divergent features of SPCs, and the markets in which they operate, affect their relationship to government interventions on decarbonization, and consider the implications for the effective implementation of sector-wide decarbonization strategies. We then apply this framework using a comparative case study analysis of six major SPCs, and highlight how differences in their agency, motivation, capacity and market exposure result in different potential responsiveness to government regulatory, policy and market interventions on decarbonization. We generalize these findings by developing four SPC archetypes and illustrate how they might respond differently to government interventions targeting decarbonization. Our analysis points to the finding that, under certain circumstances, an SPC can be a more effective vehicle for decarbonization relative to private sector companies. Similarly, under certain circumstances, market-wide policy interventions, such as carbon pricing, are likely to be less effective interventions with respect to SPCs than their private counterparts, particularly when the SPC is ill-equipped to translate these incentives into decarbonization</p>

		<p>action. Ultimately, governments will need to step up their climate ambition to achieve the ultimate end game of sector-wide carbon neutrality. SPCs can, and where they are major market players, must, be key actors in driving decarbonization when the appropriate interventions are utilized and therefore deserve significantly more attention in the climate policy debate.</p>
A.3(2022)	<p>Bloemendaal, N., De Moel, H., Martinez, A.B., Muis, S., Haigh, I.D., Van der Wiel, K., Haarsma, R.J., Ward, P.J., Roberts, M.J., Dullaart, J.C.M., & Aerts, J.C.J.H. (2022) 'A globally consistent local-scale assessment of future tropical cyclone risk', <i>Science Advances</i>, 8(17).</p>	<p>There is considerable uncertainty surrounding future changes in tropical cyclone (TC) frequency and intensity, particularly at local scales. This uncertainty complicates risk assessments and implementation of risk mitigation strategies. We present a novel approach to overcome this problem, using the statistical model STORM to generate 10,000 years of synthetic TCs under past (1980–2017) and future climate (SSP585; 2015–2050) conditions from an ensemble of four high-resolution climate models. We then derive high-resolution (10-km) wind speed return period maps up to 1000 years to assess local-scale changes in wind speed probabilities. Our results indicate that the probability of intense TCs, on average, more than doubles in all regions except for the Bay of Bengal and the Gulf of Mexico. Our unique and innovative methodology enables globally consistent comparison of TC risk in both time and space and can be easily adapted to accommodate alternative climate scenarios and time periods.</p>
A.4(2022)	<p>Campos-Martins, S. and Amado, C. (2022) 'Financial market linkages and the sovereign debt crisis'. Forthcoming, <i>Journal of International Money and Finance</i>.</p>	<p>We develop a novel approach to investigate the presence of financial contagion during the European sovereign debt crisis. The novelty lies in modelling bond yield market co-movements allowing the individual long-run variances to be time-dependent and the correlations to change smoothly between two extreme states according to time and observable financial variables. The new model has the flexibility to discern between long-run and short-run contagion effects on the basis of the variable used as indicator for the time-variation in correlations. The main results provide evidence of long-run contagion effects across peripheral countries following the more acute phase of the sovereign crisis.</p>
A.5(2022)	<p>Castle, J.L. (2022) 'Forecasting with big data: theory and practice', Forecasting: theory and practice; Special Issue of <i>International Journal of Forecasting</i> (ed.) Fotios Petropoulos</p>	<p>We discuss regularization methods for modelling big data, and how they might perform when dealing with non-stationarity especially what forecasting methods should be used. The practice concerns the viability of different sources of big data, how to combine theory with big data applied to forecasting the monthly UK unemployment rate.</p>
A.6(2022)	<p>Castle, J.L. and Hendry, D.F. (2022) 'Econometrics for Modelling Climate Change', <i>Oxford Research Encyclopaedia of Economics and Finance</i>, Oxford University Press.</p>	<p>Greenhouse gas emissions, such as carbon dioxide, nitrous oxide and methane, are a major cause of climate change as they cumulate in the atmosphere and re-radiate the sun's energy. As such emissions are currently mainly due to economic activity, economic and climate time series share many features such as considerable inertia, stochastic trends and distributional shifts.</p>

		<p>Consequently, tools for empirically modelling non-stationary economic outcomes are also appropriate for studying many aspects of observational climate-change data. Moreover, both disciplines lack complete knowledge of their respective data generating processes (DGPs), so model search retaining viable theory but allowing for shifting distributions is important. Reliable modelling of both climate and economic related time series requires finding an unknown DGP (or close approximation thereto) to represent multivariate evolving processes subject to abrupt shifts. Consequently, to ensure that DGP is nested within a much larger set of candidate determinants, model formulations to search over should comprise all potentially relevant variables, their dynamics, indicators for perturbing outliers, shifts, trend breaks and non-linear functions, while retaining well-established theoretical insights.</p> <p>The model selection approach at Climate Econometrics uses a variant of machine learning with multi-path block searches commencing from very general specifications, usually with more candidate explanatory variables than observations, to discover well-specified and undominated models of the non-stationary processes under analysis. To do so requires applying appropriate indicator saturation estimators (ISEs), a class that includes impulse indicators for outliers, step indicators for location shifts, multiplicative indicators for parameter changes, and trend indicators for trend breaks, all of which are illustrated here in simple settings. All ISEs entail more candidate variables than observations, often by a large margin when implementing combinations, yet can detect the impacts of shifts and policy interventions to avoid non-constant parameters in models, as well as improve forecasts. To characterize non-stationary observational data one must handle all substantively relevant features jointly: a failure to do so leads to non-constant and mis-specified models and hence incorrect theory evaluation and policy analyses. The approach is applied to empirical climate modelling including an application to a model of UK CO2 emissions.</p>
A.7(2022)	<p>Castle, J.L. and Hendry, D.F. (2022) 'Climate econometrics', Royal Economic Society Newsletter.</p>	<p>Economists frequently confront change – witness the economic responses to the Covid-19 pandemic – but if you want an example of really dramatic change, look towards climate data. Eight Ice Ages came and went over the last 800,000 years with atmospheric carbon dioxide variations of ± 25ppm (parts per million). But then humanity arrived and started to influence the climate, with stark consequences: an astounding jump of 100ppm since the Industrial Revolution. <i>Change</i> is the keyword in both disciplines.</p>

A.8(2022)	Castle, J.L., Hendry, D.F. and Martinez, A.B. (2022) ' The role of energy in UK inflation and productivity ', <i>VoxEU</i> .	The recent rise in UK price inflation was unanticipated, leading to a flurry of activity rethinking inflation models. This column models UK price and wage inflation, productivity, and unemployment over a century and a half. The authors find that a reduction in energy availability simultaneously reduces output and exacerbates inflation, and also find empirical evidence for a wage–price spiral once inflation exceeds about 6–8%. Given that inflation in the UK was 8.8% in July 2022, this non-linearity warns how inflation could potentially take off.
A.9(2022)	Doornik, J.A., Castle, J.L. & Hendry, D.F. (2022) ' Short-term forecasting of the coronavirus pandemic ', <i>International Journal of Forecasting</i> , 38(2), pp. 453-466.	<p>We have been publishing real-time forecasts of confirmed cases and deaths from coronavirus disease 2019 (COVID-19) since mid-March 2020 (published at www.doornik.com/COVID-19). These forecasts are short-term statistical extrapolations of past and current data. They assume that the underlying trend is informative regarding short-term developments but without requiring other assumptions about how the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus is spreading, or whether preventative policies are effective. Thus, they are complementary to the forecasts obtained from epidemiological models.</p> <p>The forecasts are based on extracting trends from windows of data using machine learning and then computing the forecasts by applying some constraints to the flexible extracted trend. These methods have been applied previously to various other time series data and they performed well. They have also proved effective in the COVID-19 setting where they provided better forecasts than some epidemiological models in the earlier stages of the pandemic.</p>
A.10(2022)	Guggenberger, P., Kleibergen, F. & Mavroeidis, S. (2022) ' A test for Kronecker Product Structure covariance matrix ', <i>Journal of Econometrics</i> .	We propose a test for a covariance matrix to have Kronecker Product Structure (KPS). KPS implies a reduced rank restriction on a certain transformation of the covariance matrix and the new procedure is an adaptation of the Kleibergen and Paap (2006) reduced rank test. To derive the limiting distribution of the Wald type test statistic proves challenging partly because of the singularity of the covariance matrix estimator that appears in the weighting matrix. We show that the test statistic has a χ^2 limiting null distribution with degrees of freedom equal to the number of restrictions tested. Local asymptotic power results are derived. Monte Carlo simulations reveal good size and power properties of the test. Re-examining fifteen highly cited papers conducting instrumental variable regressions , we find that KPS is not rejected in 56 out of 118 specifications at the 5% nominal size.

A.11(2022)	Hendry, D.F. (2022) ' Does an empirical economic relation have a life? A review essay', <i>History of Political Economy</i> .	This is a review of Jeff Biddle's recent book <i>Progress through Regression: The Life Story of the Empirical Cobb–Douglas Production Function</i> , a clearly told story of a theory and its implementation from its first proposal as a log-linear empirical relation linking outputs to inputs by Charles Cobb and Paul Douglas (1928), resulting in a plethora of highly critical, constructive and supportive reactions, through to its acceptance as a substantive production function relationship in a wide range of research areas. The developments, their continued criticisms and responses are carefully discussed building on extensive archival research. I conclude that the existence of a relation between inputs and outputs was perhaps the most fundamental requirement for the success of any enterprise seeking to discover its form. That granted, the Cobb–Douglas production function lives on.
A.12(2022)	Hendry, D.F. (2022) 'Model selection theory with applications to climate change', Forecasting: theory and practice ; Special Issue of <i>International Journal of Forecasting</i> (ed.) Fotios Petropoulos	We explain selection for forecasting facing multiple breaks at unknown times when there may be more candidate variables than observations, to highlight the costs and benefits of selection for forecasting. We then apply the approach to forecasting UK CO ₂ emissions, forecasting the next 100,000 years of Ice Ages without human interventions, the forecasting Ice Ages under anthropogenic emissions to reveal the likely dangers.
A.13(2022)	Hendry, D.F. & Pretis, F. (2022) ' Analysing differences between scenarios ', <i>International Journal of Forecasting</i> .	Comparisons between alternative scenarios are used in many disciplines, from macroeconomics through epidemiology to climate science, to help with planning future responses. Differences between scenario paths are often interpreted as signifying likely differences between outcomes that would materialise in reality. However, even when using correctly specified statistical models of the in-sample data generation process, additional conditions are needed to sustain inferences about differences between scenario paths. We consider two questions in scenario analyses: First, does testing the difference between scenarios yield additional insight beyond simple tests conducted on the model estimated in-sample? Second, when does the estimated scenario difference yield unbiased estimates of the true difference in outcomes? Answering the first question, we show that the calculation of uncertainties around scenario differences raises difficult issues, since the underlying in-sample distributions are identical for both 'potential' outcomes when the reported paths are deterministic functions. Under these circumstances, a scenario comparison adds little beyond testing for the significance of the perturbed variable in the estimated model. Resolving the second question, when models include multiple covariates, inferences about scenario differences depend on the relationships between the conditioning variables,

		<p>especially their invariance to the interventions being implemented. Tests for invariance based on the automatic detection of structural breaks can help identify the in-sample invariance of models to evaluate likely constancy in projected scenarios. Applications of scenario analyses to impacts on the UK's wage share from unemployment and agricultural growth from climate change illustrate the concepts.</p>
A.14(2022)	<p>Jiao, X and Pretis, F. (2022) 'Testing the Presence of Outliers in Regression Models', <i>Oxford Bulletin of Economics and Statistics</i>.</p>	<p>We propose two sets of tests for the overall presence of outliers in regression models. First, 'simple' tests on whether the proportion and the number of detected outliers deviate from their expected values. Second, 'scaling' tests on whether the proportion of outliers decreases with the cut-off used to detect outliers. We apply our tests to a panel difference-in-differences model of transport CO₂ emissions in response to the introduction of North America's first major carbon tax. Our tests show the presence of significant outliers in the un-taxed control group, which results in an overestimation of the estimated impacts of the tax.</p>
A.15(2022)	<p>Jjemba, E. & Thalheimer, L. (2022) 'Harnessing anticipatory action to avoid or reduce disaster displacement', <i>Anticipation Hub</i></p>	<p>Recent years have seen a surge in people being displaced by disasters – often within their own countries. In 2020 alone, weather- and climate-related events led to more than 30 million people worldwide being displaced within their country, according to the Internal Displacement Monitoring Centre. The Nansen Initiative describes such situations as 'disaster displacement' and, as the world becomes warmer, there is an increased likelihood of extreme weather putting vulnerable communities at risk of disaster displacement, as projected in the recent IPCC report.</p>
A.16(2022)	<p>Koch, N., Naumann, L., Pretis, F., Ritter, N., & Schwarz, M. (2022) 'Attributing agnostically-detected large reductions in road CO2 emissions to policy mixes', <i>Nature Energy</i>.</p>	<p>Policymakers combine many different policy tools to achieve emission reductions. However, there remains substantial uncertainty around which mixes of policies are effective. This uncertainty stems from the predominant focus of ex-post policy evaluation on isolating effects of single, known policies. Here, we introduce an approach to identify effective policy interventions in the EU road transport sector by detecting treatment effects as structural breaks in CO₂ emissions that can potentially occur in any country at any point in time from any number of <i>a-priori</i> unknown policies. This search for "causes of effects" within a statistical framework allows us to draw systematic inference on the effectiveness of policy mixes. We detect 10 successful policy mixes that reduced emissions between 8% and 26%. The most successful policy mixes combine carbon or fuel taxes with green vehicles incentives and highlight that emission reductions on a magnitude that matches the EU's zero-emission targets are possible.</p>

A.17(2022)	Marcondes Pinto, J. and Castle, J.L. (2022) ' Machine learning dynamic switching approach to forecasting in the presence of structural breaks ', <i>Journal of Business Cycle Research</i> .	Forecasting economic indicators is an important task for analysts. However, many indicators suffer from structural breaks leading to forecast failure. Methods that are robust following a structural break have been proposed in the literature but they come at a cost: an increase in forecast error variance. We propose a method to select between a set of robust and non-robust forecasting models. Our method uses time-series clustering to identify possible structural breaks in a time series, and then switches between autoregressive forecasting models depending on the series dynamics. We perform a rigorous empirical evaluation with 400 simulated series with an artificial structural break and with real data economic series: Industrial Production and Consumer Prices for all Western European countries available from the OECD database. Our results show that the proposed method statistically outperforms benchmarks in forecast accuracy for most case scenarios, particularly at short horizons.
A.18(2022)	Martinez, A.B. (2022) 'Robust equilibrium-correction forecasting devices' (Section 2.3.16) and 'Forecasting productivity' (Section 3.3.4) in F. Petropoulos (Ed.) Forecasting: Theory and Practice . <i>International Journal of Forecasting</i> .	The use of equilibrium-correction models is ubiquitous in forecasting. Hendry (2010) notes that this class commonly includes models with explicit equilibrium-correction mechanisms such as vector equilibrium-correction models (VEqCM) as well as models with implicit equilibrium-correction (or long-run mean reversion) mechanisms such as vector auto-regressions (VARs; see Section 2.3.9), dynamic factor models (DFMs), dynamic stochastic general-equilibrium (DSGE) models (see Section 2.3.15), most models of the variance (see Section 2.3.11), and almost all regression equations (see Sections 2.3.2 Time-series regression models , 2.3.4 Autoregressive integrated moving average (ARIMA) models). This class of forecast model is prevalent across most disciplines. For example, Pretis (2020) illustrates that there is an equivalence between physical energy balance models, which are used to explain and predict the evolution of climate systems, and VEqCMs.
A.19(2022)	Martinez, A.B., Castle, J.L. and Hendry, D.F. (2022) ' Smooth robust multi-horizon forecasts ', Chudik, A., Hsiao, C. & Timmermann, A. (Ed.) <i>Essays in Honor of M. Hashem Pesaran: Prediction and Macro Modeling (Advances in Econometrics, Vol. 43A)</i> , Emerald Publishing Limited, Bingley, pp. 143-165.	We investigate whether smooth robust methods for forecasting can help mitigate pronounced and persistent failure across multiple forecast horizons. We demonstrate that naive predictors are interpretable as local estimators of the long-run relationship with the advantage of adapting quickly after a break, but at a cost of additional forecast error variance. Smoothing over naive estimates helps retain these advantages while reducing the costs, especially for longer forecast horizons. We derive the performance of these predictors after a location shift, and confirm the results using simulations. We apply smooth methods to forecasts of UK productivity and US 10-year Treasury yields and show that they can dramatically reduce persistent forecast failure exhibited by forecasts from macroeconomic models and professional forecasters.

A.20(2022)	Mavroeidis, S. (2022) ' Identification at the Zero Lower Bound ', <i>Econometrica</i> .	I show that the zero lower bound (ZLB) on interest rates can be used to identify the causal effects of monetary policy. Identification depends on the extent to which the ZLB limits the efficacy of monetary policy. I propose a simple way to test the efficacy of unconventional policies, modeled via a "shadow rate." I apply this method to U.S. monetary policy using a three-equation structural vector autoregressive model of inflation, unemployment, and the Federal Funds rate. I reject the null hypothesis that unconventional monetary policy has no effect at the ZLB, but find some evidence that it is not as effective as conventional monetary policy.
A.21(2022)	Pretis, F. (2022) ' Does a carbon tax reduce CO2 emissions? Evidence from British Columbia ', <i>Environmental and Resource Economics</i> .	Using difference-in-differences, synthetic control, and introducing a new break-detection approach, I show that the introduction of North America's first major carbon tax has reduced transportation emissions but not 'yet' led to large statistically significant reductions in aggregate CO ₂ emissions. Proposing a new method to assess policy based on breaks in difference-in-differences using machine learning, I demonstrate that neither carbon pricing nor trading schemes in other provinces are detected as large and statistically significant interventions. Instead, closures and efficiency-improvements in emission-intensive industries in untaxed provinces have reduced emissions. Overall, the results show that existing carbon taxes (and prices) are likely too low to be effective in the time frame since their introduction.
A.22(2022)	Rafaty, R. and Heerma, B. (2022) ' Sensitive Interventions in China's Coal Phaseout ', <i>Energy Policy</i> , 163.	China's investment decisions will shape the global market for coal in the coming decades, putting substantial power over global climate change mitigation in the hands of few actors. We apply the Actor-Objective-Context (AOC) framework proposed by Jakob et al. (2020) to investigate the stakeholders and interests at play in China's managed coal phaseout follow the country's announced 2060 carbon neutrality target. We analyse the power dynamics among actors, elaborate a policy toolkit for transitioning away from coal, and evaluate the plausibility of candidate policy sets in light of domestic institutional constraints. This leads to several important conclusions. First, China's central energy policy framework needs little adjustment—it is already suitable to facilitate a rapid curbing of coal market development. Instead, and secondly, the incentive structure for provincial governments and state-owned enterprises needs substantial improvement to comply with central policies. This leads us to conclude that the most efficient and effective way to change the incentive structure is to alter the official promotion criteria for Chinese provincial officials to reflect the central government's decarbonization agenda,

		and to create worker compensation and regional investment schemes in provinces that shift away from coal.
A.23(2022)	Sato, M., Rafaty, R., Calel, R., & Grubb, M. (2022) ' Allocation, allocation, allocation! The political economy of the development of the EU ETS ', Forthcoming in <i>WIREs Climate Change</i> .	The European Union's pioneering emissions trading system, the EU ETS, has inspired countries around the world to launch their own CO2 markets. This paper analyses the evolution of the EU ETS from a political economy perspective, emphasising the interaction of economic principles and political interests at pivotal moments, and showing how each compromise changed the scope for future design choices. We focus on the allowance allocation issue, which provides a window into the complex tug-of-war between economic efficiency and the politics of distribution. Our account highlights the dynamic nature of CO2 market reform, and provides lessons that can help inform the design of more stable and effective CO2 markets in the future.
A.24(2022)	Scheer, A, Schwarz, M., Hopkins, D. and Caldecott, B. (2022) ' Whose jobs face transition risk in Alberta? Identifying sectoral employment sensitivities to oil price to guide Just Transition policy ', <i>Climate Policy</i> .	Labour markets of oil-exporting regions will be impacted by a global transition to low-carbon energy as oil demand must plummet to meet the Paris Agreement goals. Together with direct job losses in the oil and gas industry, increasing job precarity and indirect employment effects on other sectors must be considered to ensure a Just Transition. Here, we attempt to quantify direct and indirect job losses by analysing the effects of oil price fluctuations on the labour market of Alberta, a Canadian province reliant on oil sands extraction. We employ a mixed methods approach, contextualising our quantitative analysis with first-hand experiences using in-depth interviews with oil sands workers. We estimate a vector autoregression for province-wide insights and explore sector-specific dynamics using time series and panel models. We offer three key insights. First, at a provincial scale, oil price affects employment levels, leading to job precarity. Second, local factors that determine the price discount on Canadian oil sands crude seem to matter relatively little when compared with internationally determined factors. This finding challenges the long-term employment benefits of new pipelines and other export opportunities. Third, we show that labour dynamics resulting from oil price are heterogeneous between the province's economic sectors. Our results indicate the sectors which could be heavily impacted by a low-carbon transition and warrant special attention in the development of provincial and national Just Transition policy. Transitional assistance policies can support workers directly, while economic diversification measures should be taken to ensure stable opportunities in existing and new sectors that reduce reliance on international oil markets. Tripartite social dialogue between government, employers, and

		employees could contribute to policy development aimed at protecting workers' livelihoods.
A.25(2022)	Srivastav, S. and Rafaty, R. (2022) ' Political strategies to overcome climate policy obstructionism ', <i>Perspectives on Politics</i> .	Great socio-economic transitions see the demise of certain industries and the rise of others. The losers of the transition tend to deploy a variety of tactics to obstruct change. We develop a political-economy model of interest group competition and garner evidence of tactics deployed in the global climate movement. From this we deduce a set of strategies for how the climate movement competes against entrenched hydrocarbon interests. Five strategies for overcoming obstructionism emerge: (1) Appeasement, which involves compensating the losers; (2) Cooptation, which seeks to instigate change by working with incumbents; (3) Institutionalism, which involves changes to public institutions to support decarbonization; (4) Antagonism, which creates reputational or litigation costs to inaction; and (5) Countervailance, which makes low-carbon alternatives more competitive. We argue that each strategy addresses the problem of obstructionism through a different lens, reflecting a diversity of actors and theories of change within the climate movement. The choice of which strategy to pursue depends on the institutional context.
A.26(2022)	Thalheimer, L., Simperingham, E., & Jjemba, E.W. (2022) ' The role of anticipatory humanitarian action to reduce disaster displacement ', <i>Environmental Research Letters</i> , 17 .	Displacement due to weather and climate-related events (disaster displacement), including the adverse effects of climate change, is one of the greatest humanitarian challenges of the 21st century. Even though the forecasting of extreme events and early warning systems has improved globally, less attention has been given to translating anticipatory humanitarian action into the disaster displacement context with the aim to minimize forced displacement from extreme weather events through pre-allocated funds for the readiness, pre-positioning and activation costs. In this analysis, we assess the opportunities and challenges associated with utilising forecast-based financing (FbF) to expand anticipatory and early humanitarian action, based on the structured judgements of experts. These multi-disciplinary experts agree that FbF can reduce displacement risks and address the humanitarian impacts of disaster displacement early, or before a hazard materializes. We propose four action steps along the stages of disaster displacement to provide practical intervention points for researchers and practitioners. Finally, we discuss the implications of our findings and outline next steps. By integrating cross-disciplinary expert judgement, this paper provides a much-needed pathway to transform humanitarian action to be more anticipatory and adaptable to change, and help minimize disaster displacement in climate change vulnerable regions.

A.27(2022)	Thalheimer, L., Jjemba, E. & Simperingham, E. (2022) ' The role of forecast-based financing ', <i>Forced Migration Review</i> (69), 34-36.	Can forecast-based financing reduce the humanitarian impacts of disaster displacement? This was the focus of a study recently conducted by the Red Cross/ Red Crescent Climate Centre (RCCC), together with the International Federation of Red Cross and Red Crescent Societies (IFRC) and the School of Geography and the Environment at Oxford University. The study found that anticipatory action (supported by forecast-based financing) can indeed be integrated into existing disaster preparedness to minimise the humanitarian impacts of displacement. This article addresses the opportunities, challenges and limitations associated with using forecast-based financing (FbF) to support early humanitarian action in the context of disaster displacement.
C	PUBLISHED REPORTS	
C.1(2022)	Jjemba, E. & Thalheimer, L. (2022) ' Harnessing anticipatory action to avoid or reduce disaster displacement ', <i>Anticipation Hub</i> .	Recent years have seen a surge in people being displaced by disasters – often within their own countries. In 2020 alone, weather- and climate-related events led to more than 30 million people worldwide being displaced within their country, according to the Internal Displacement Monitoring Centre . The Nansen Initiative describes such situations as 'disaster displacement' and, as the world becomes warmer, there is an increased likelihood of extreme weather putting vulnerable communities at risk of disaster displacement, as projected in the recent IPCC report .
C.2(2022)	Otto, F.E.L., [...], Thalheimer, L., [...] et al. (2022) ' Climate change increased rainfall associated with tropical cyclones hitting highly vulnerable communities in Madagascar, Mozambique & Malawi ', (World Weather Attribution).	The Southwest Indian Ocean, including the Mozambique Channel is a recognized hotspot of tropical storms and cyclones, and associated with significant loss and damage in the areas hit. In late January, Tropical Storm Ana brought winds, heavy rains, damage and destruction to parts of Madagascar, Mozambique, Malawi and Zimbabwe. Ana was followed by Tropical Cyclone Batsirai hitting the South coast of Madagascar on February the 5th 2022. Ana and Batsirai were the first storms of the 2021-22 Southwest Indian Ocean cyclone season (November-April) and affected several hundred thousand people across the affected countries. Following those two storms three weaker storms, Dumako, Emnati, and Gombe also made landfall that led to further flooding and casualties.
C.3(2022)	Pinto, I., [...], Thalheimer, L. [...] et al. (2022) ' Climate change exacerbated rainfall causing devastating flooding in Eastern South Africa ', (World Weather Attribution).	On April 11-12, the eastern coast of the provinces KwaZulu-Natal (KZN) and Eastern Cape (EC) in South Africa witnessed exceptionally heavy rainfall of more than 300mm in some areas within less than 24 hours. The event was caused by a cut-off low (COL) that diverged from the mid-latitude westerly wave, and tracked across the east coast and interior of South Africa. COLs are synoptic-scale baroclinic systems that, in this region, as in other regions, can cause severe weather, heavy rainfall events and floods. COLs are a common

		occurrence in the month of April in this region. The impact from the April 11-12 COL was additionally exacerbated by moisture-laden, low-level maritime winds from the southern Indian Ocean (South Africa Weather Services -SAWS 2022).
C.4(2022)	Šedová, B. & Thalheimer, L. (2022) ' How climate change and migration cascade in the EU ', <i>EuropeNow</i> .	The number of forcibly displaced people has been steadily on the rise. In 2015, over one million refugees and migrants reached Europe, the largest fraction of whom were fleeing the civil war in Syria. In public and academic debates, it has been widely discussed to what extent climate change plays a role in these dynamics and how. The ongoing crisis in Afghanistan has also drawn attention to the question of how climatic conditions contribute to political unrest and civil wars, and what this ultimately means for international security.
C.5(2022)	Thalheimer, L., Webersik, C. and Gaupp, F. (2022) ' Systemic Risk Emerging from Compound Vulnerabilities '. United Nations Disaster Risk Reduction (UNDRR) Global Assessment Report on Disaster Risk Reduction (GAR2022).	This paper analyses systemic risk and compound vulnerabilities, by highlighting a case study to help decision-makers formulate effective strategies to address the nature of systemic risks in their societies. We put a spotlight on several risks and propose actions and policy recommendations. These spotlights include i) extreme weather events and internal displacement, ii) conflict and iii) food security. Overall, this report presents a case for climate hazards as the exogenous starting point, as well as crop losses and high food prices as intermediary variables that impact food security. A common theme of each of the spotlight areas is that close attention needs to be paid to compound vulnerabilities such as regional manifestations of armed conflict and (mal)adaptive forms of human mobility to conflict hotspots to understand systematic risk from a changing climate perspective for food security. As the era of hazard-by-hazard risk reduction comes to an end, we need to better understand the systemic nature of risk.
C.6(2022)	Zachariah, M., [...], Thalheimer, L., [...], F.E.L. Otto (2022), ' Climate change made devastating early heat in India and Pakistan 30 times more likely ', (World Weather Attribution).	Since the beginning of the 2022 meteorological summer, large parts of South Asia including India and Pakistan have been experiencing prolonged hot weather. The month of March was the hottest in India since records began 122 years ago according to the Indian Meteorological Department (IMD). Temperatures were consistently 3°C-8°C above average, breaking many decadal and some all-time records in several parts of the country, including the western Himalayas, the plains of Punjab, Haryana, Delhi, Rajasthan and Uttar Pradesh. The states of Odisha, Madhya Pradesh, Gujarat, Chhattisgarh, Telangana and Jharkhand also experienced heatwaves, in some areas severe, with temperatures ranging from 40°C–44°C in the last days of March. In Pakistan many individual weather stations recording monthly all-time highs in March 1. The heatwave conditions continued into April, reaching its preliminary peak towards the end of the month. Around 300 large forest fires

		occurred in the country on April 28, a third of these in Uttarakhand. By April 29, almost 70 percent of India was affected by the heatwave. In Pakistan, temperatures above 49°C were recorded in Jacobabad in Sindh, and 30 percent of the country was affected by the heatwave. Towards the end of April and in May, the heatwave extended into the coastal areas and eastern parts of India.
D	FORTHCOMING/WORKING PAPERS	
D.1(2022)	Ascari, G., Haque, Q., Magnusson, L.M. & Mavroeidis, S. (2022) ' Empirical evidence on the Euler equation for investment in the US '. Working paper.	Is the typical specification of the Euler equation for investment employed in DSGE models consistent with aggregate macro data? Using state-of-the-art econometric methods that are robust to weak instruments and exploit information in possible structural changes, the answer is yes. Unfortunately, however, there is very little information about the values of these parameters in aggregate data because investment is unresponsive to changes in capital utilization and the real interest rate. In DSGE models, the investment adjustment cost and the persistence of the investment-specific technology shock parameters are mainly identified by, respectively, the cross-equation restrictions and the dynamics implied by the structure of the model.
D.2(2022)	Ascari, G., Mavroeidis, S. & McClung, N. (2022) ' Coherence without rationality at the Zero Lower Bound '. Working paper.	Standard rational expectations (RE) models with an occasionally binding zero lower bound (ZLB) constraint either admit no solutions (incoherence) or multiple solutions (incompleteness). This paper shows that deviations from full-information RE mitigate concerns about incoherence and incompleteness. Models with no RE equilibria admit self-confirming equilibria involving the use of simple mis-specified forecasting models. Completeness and coherence is restored if expectations are adaptive or if agents are less forward-looking due to some information or behavioral friction. In the case of incompleteness, the E-stability criterion selects an equilibrium.
D.3(2022)	Dovi, M-S., Kock, A.B. & Mavroeidis, S. (2022) ' A ridge-regularised jackknifed Anderson-Rubin Test '. Working paper.	We consider hypothesis testing in instrumental variable regression models with few included exogenous covariates but many instruments -- possibly more than the number of observations. We show that a ridge-regularised version of the jackknifed Anderson Rubin (1949, henceforth AR) test controls asymptotic size in the presence of heteroskedasticity, and when the instruments may be arbitrarily weak. Asymptotic size control is established under weaker assumptions than those imposed for recently proposed jackknifed AR tests in the literature. Furthermore, ridge-regularisation extends the scope of jackknifed AR tests to situations in which there are more instruments than observations. Monte-Carlo simulations indicate that our method has favourable finite-sample size and power properties compared to recently proposed alternative approaches in the literature. An empirical application on

		the elasticity of substitution between immigrants and natives in the US illustrates the usefulness of the proposed method for practitioners.
D.4(2022)	Guggenberger, P., Kleibergen, F. & Mavroeidis, S. (2022) ' A powerful subvector Anderson Rubin Test in linear instrumental variables regression with conditional heteroskedasticity '. Working paper.	We introduce a new test for a two-sided hypothesis involving a subset of the structural parameter vector in the linear instrumental variables (IVs) model. Guggenberger et al. (2019), GKM19 from now on, introduce a subvector Anderson-Rubin (AR) test with data-dependent critical values that has asymptotic size equal to nominal size for a parameter space that allows for arbitrary strength or weakness of the IVs and has uniformly nonsmaller power than the projected AR test studied in Guggenberger et al. (2012). However, GKM19 imposes the restrictive assumption of conditional homoskedasticity. The main contribution here is to robustify the procedure in GKM19 to arbitrary forms of conditional heteroskedasticity. We first adapt the method in GKM19 to a setup where a certain covariance matrix has an approximate Kronecker product (AKP) structure which nests conditional homoskedasticity. The new test equals this adaption when the data is consistent with AKP structure as decided by a model selection procedure. Otherwise the test equals the AR/AR test in Andrews (2017) that is fully robust to conditional heteroskedasticity but less powerful than the adapted method. We show theoretically that the new test has asymptotic size bounded by the nominal size and document improved power relative to the AR/AR test in a wide array of Monte Carlo simulations when the covariance matrix is not too far from AKP.
D.5(2022)	Pretis, F. & Schwarz, M. (2022) ' Discovering what mattered: Answering reverse causal questions by detecting unknown treatment assignment and timing as breaks in panel models '. Working paper.	Much of empirical research focuses on forward causal questions ("Does X cause Y?") while answering reverse causal questions ("What causes Y?") can provide invaluable insights but is difficult to implement in practice. Here we operationalise the modelling of reverse causal questions through the detection of unknown treatment assignment and timing as structural breaks in fixed effects panel models. We show that conventional treatment evaluation of known interventions in a two-way fixed effects panel (often interpreted as difference-in-differences) is equivalent to allowing for heterogeneous structural breaks in the treated units' fixed effects. Using machine learning, we can thus detect previously unknown heterogeneous treatment effects as structural breaks in individual fixed effects corresponding to unit-specific treatment which can be subsequently attributed to potential causes. We demonstrate the feasibility of our approach by detecting the impact of ETA terrorism on Spanish regional GDP per capita without prior knowledge of its occurrence. Our proposed method to detect breaks in panel models can be

		readily implemented using our open-source R-package 'gets' with the 'getspanel' update or using the (adaptive) LASSO.
D.6(2022)	Roger, C. and Rowan, S. (2022) 'The new terrain of global governance: Mapping membership in informal IOs', Forthcoming in <i>Journal of Conflict Resolution</i> .	We present a new dataset of state membership in informal international organizations—IOs founded with non-binding instruments—which have come to constitute roughly one-third of all operating IOs. We introduce state-IO-year-level membership data for 195 countries and nearly 250 informal IOs from 1925 to 2010. We illustrate key empirical similarities and differences across formal and informal IOs in terms of membership, community, and size. We also analyze the heterogeneous determinants of membership across subtypes of IOs. In each instance, we show how our data either validate or challenge existing conjectures about international cooperation that have been inaccessible for lack of data. We conclude by outlining a research program that considers how informal IOs may reshape our understanding of international cooperation.
D.7(2022)	Rowan, S. (2022) ' Extreme weather and climate policy ', Forthcoming in <i>Environmental Politics</i> .	What effect does extreme weather have on climate policy? Existing studies show that weather shocks have negative economic impacts and increase public awareness of climate change. These findings help identify the impacts of climate change on economic and social systems, and provide reasons for governments to adopt climate policy reforms. However, questions remain about the overall link between local extreme weather shocks and government climate policy. I investigate the effect of temperature shocks and natural disasters on a range of national, international, and subnational climate policies in samples spanning 1990–2018. I find that neither temperature shocks nor natural disasters generate climate mitigation reforms. Given that climate policy is currently insufficient to manage climate change and climate impacts are expected to increase this century, these findings suggest that future climate shocks are unlikely to catalyze meaningful climate action.
2021		
A	PUBLISHED JOURNAL ARTICLES	
A.1(2021)	Castle, J.L., Doornik, J.A. & Hendry, D.F. (2021) ' Forecasting principles from experience with forecasting competitions ', <i>Forecasting (Special Issue)</i> , 3(1), 138-165.	Economic forecasting is difficult, largely because of the many sources of non-stationarity influencing observational time series. Forecasting competitions aim to improve the practice of economic forecasting by providing very large data sets on which the efficacy of forecasting methods can be evaluated. We consider the general principles that seem to be the foundation for successful forecasting and show how these are relevant for methods that did well in the M4 competition. We establish some general properties of the M4 data set, which we use to improve the basic benchmark methods, as well as the Card

		method that we created for our submission to that competition. A data generation process is proposed that captures the salient features of the annual data in M4.
A.2(2021)	Doornik, J.A., Castle, J.L., and Hendry, D.F. (2021) ' Modeling and forecasting the COVID-19 pandemic time-series data ' <i>Social Science Quarterly: Special issue on Public Policy, Opinions, Behavior, and Health Outcomes during the COVID Pandemic</i> .	We analyze the number of recorded cases and deaths of COVID-19 in many parts of the world, with the aim to understand the complexities of the data, and produce regular forecasts. The SARS-CoV-2 virus that causes COVID-19 has affected societies in all corners of the globe but with vastly differing experiences across countries. Healthcare and economic systems vary significantly across countries, as do policy responses, including testing, intermittent lockdowns, quarantine, contact tracing, mask wearing and social distancing. Despite these challenges, the reported data can be used in many ways to help inform policy. We describe how to decompose the reported time series of confirmed cases and deaths into a trend, seasonal and irregular component using machine learning methods. This decomposition enables statistical computation of measures of the mortality ratio and reproduction number for any country, and we conduct a counterfactual exercise assuming the US had a summer outcome in 2020 similar to that of the EU. The decomposition is also used to produce forecasts of cases and deaths, and we undertake a forecast comparison which highlights the importance of seasonality in the data and the difficulties of forecasting too far into the future. Our adaptive data-based methods and purely statistical forecasts provide a useful complement to the output from epidemiological models.
A.3(2021)	Castle, J.L., Doornik, J.A., and Hendry, D.F. (2020), ' Robust Discovery of Regression Models ', <i>Econometrics and Statistics</i> , https://doi.org/10.1016/j.ecosta.2021.05.004	Since complete and correct a priori specifications of models for observational data never exist, model selection is unavoidable in that context. The target of selection needs to be the process generating the data for the variables under analysis, while retaining the objective of the study, often a theory based formulation. Successful selection requires robustness against many potential problems jointly, including outliers and shifts; omitted variables; incorrect distributional shape; non-stationarity; mis-specified dynamics; and non-linearity, as well as inappropriate exogeneity assumptions. The aim is to seek parsimonious final representations that retain the relevant information, are well specified, encompass alternative models, and evaluate the validity of the study. Our approach to doing so inevitably leads to more candidate variables than observations, handled by iteratively switching between contracting and expanding multi-path searches, here programmed in Autometrics. We investigate the ability of indicator saturation to discriminate between measurement errors and outliers, between outliers and large observations arising from non-linear responses (illustrated by artificial data), and apparent outliers due to alternative distributional assumptions. We illustrate the

		<p>approach by exploring empirical models of the Boston housing market and inflation for the UK (both tackling outliers and non-linearities that can distort other estimation methods). We re-analyze the ‘local instability’ in the robust method of least median of squares shown by Hettmansperger and Sheather (1992) using indicator saturation to explain their findings.</p>
A.4(2021)	<p>Castle, J.L., Doornik, J.A. & Hendry, D.F. (2021) ‘Selecting a model for forecasting’, <i>Econometrics</i>, 9(3), 26.</p>	<p>We investigate forecasting in models that condition on variables for which future values are unknown. We consider the role of the significance level because it guides the binary decisions whether to include or exclude variables. The analysis is extended by allowing for a structural break, either in the first forecast period or just before. Theoretical results are derived for a three-variable static model, but generalized to include dynamics and many more variables in the simulation experiment. The results show that the trade-off for selecting variables in forecasting models in a stationary world, namely that variables should be retained if their non-centralities exceed unity, still applies in settings with structural breaks. This provides support for model selection at looser than conventional settings, albeit with many additional features explaining the forecast performance, and with the caveat that retaining irrelevant variables that are subject to location shifts can worsen forecast performance.</p>
A.5(2021)	<p>Castle, J.L., Doornik, J.A. & Hendry, D.F. (2021) ‘The value of robust statistical forecasts in the Covid-19 pandemic’, <i>National Institute Economic Review</i>, 256, 19-43.</p>	<p>The Covid-19 pandemic has put forecasting under the spotlight, pitting epidemiological models against extrapolative time-series devices. We have been producing real-time short-term forecasts of confirmed cases and deaths using robust statistical models since 20 March 2020. The forecasts are adaptive to abrupt structural change, a major feature of the pandemic data due to data measurement errors, definitional and testing changes, policy interventions, technological advances and rapidly changing trends. The pandemic has also led to abrupt structural change in macroeconomic outcomes. Using the same methods, we forecast aggregate UK unemployment over the pandemic. The forecasts rapidly adapt to the employment policies implemented when the UK entered the first lockdown. The difference between our statistical and theory based forecasts provides a measure of the effect of furlough policies on stabilising unemployment, establishing useful scenarios had furlough policies not been implemented.</p>
A.6(2021)	<p>Castle, J.L. & Kurita, T. (2021) ‘A dynamic econometric analysis of the dollar-pound exchange rate in an era of structural breaks and policy regime shifts’, <i>Journal of Economic Dynamics and Control</i>, 128.</p>	<p>We employ a newly-developed partial cointegration system allowing for level shifts to examine whether economic fundamentals form the long-run determinants of the dollar-pound exchange rate over a recent period characterised by structural breaks and policy regime shifts. The paper models</p>

		both long-run and short-run dynamic features of the exchange rate using a set of economic variables that explicitly reflect quantitative monetary policy and the influence of a forward exchange market. Out-of-sample forecasts comparing the model with economic fundamentals to benchmarks including the random walk indicate that fundamentals can help at short horizons but less so at longer horizons.
A.7(2021)	Hendry D.F. and Nielsen, B. (2021) 'Oxford's Contributions to Econometrics', Chapter 1 in Robert A. Cord (Ed.) The Palgrave Companion to Oxford Economics . London: Palgrave Macmillan.	Faculty and graduates of Oxford University have played a significant role in the history of econometrics from an early date. The term econometrics was only formulated by Ragnar Frisch in the 1930s, but in the 17th Century, William Petty created a discipline that he called <i>Political Arithmetick</i> , a forerunner of quantitative economics that led to the more specialized statistical approach of econometrics. During the first half of the 20th Century, Oxford scholars like Colin Clark made major advances in creating aggregate economic measurements. From the late 1970s, the focus was primarily on macro-econometrics for the remainder of that century, buttressed by research on methods for analyzing dynamic panels. In the 21st century, micro-econometrics was added to the portfolio. The most recent addition is Climate Econometrics, developing and applying econometric tools for analyzing climate data, which is driven by human economic behaviour so faces much the same slew of problems as macroeconomic time series.
A.8(2021)	Pretis, F. (2021) ' Exogeneity in climate econometrics ', <i>Energy Economics</i> , 96.	Human activity affects the Earth's climate while itself being affected by climate change. To empirically estimate the impact of humanity onto climate and vice versa, climate econometrics has emerged as a field split into two strands: one side focusing on conditional models of the economic impact of climate change, taking climate as given. The other side empirically models climate, taking economic and human activity as given. However, economic and environmental systems are determined with feedback in both directions. Here I examine one way to reconcile the two strands of climate-econometric research by considering a full (albeit simple) empirical climate-economic system and the conditions under which the system can be studied by only looking at the conditional economic or climate side alone. Weak exogeneity is necessary for valid conditioning, strong exogeneity – required for conditional forecasting – lends itself to the concept of climate-takers and climate-setters (countries measurably affecting local climate), while super-exogeneity can be interpreted as policy invariance for the economic impact side, and as a 'no-tipping point' condition on the physical side. An application to a stylised climate-economic system using temperatures, SO ₂ emissions, and global forcing highlights how

		these concepts can be applied in practice. A system analysis in climate econometrics allows us to move towards fully-coupled empirical climate-economic models accounting for the necessary feedback to obtain empirical estimates of the impact of climate on humanity and vice versa.
A.9(2021)	Pretis, F. and Kaufmann, R.K. (2021) ' Understanding glacial cycles: A multivariate disequilibrium approach ', <i>Quaternary Science Reviews</i> , 251.	We find a consistent relation between orbital geometry and components of the climate system by returning to Milankovitch's original hypotheses and focusing on the well-established physical concepts of an equilibrium state, disequilibrium from that state, and adjustment towards equilibrium. These mechanisms imply that the state of the climate system at any time depends on; (1) the state of the climate system in the previous period, (2) the degree to which this previous state is out-of-equilibrium with orbital geometry, and (3) the rate at which the climate system adjusts towards equilibrium. We evaluate this explanation by running experiments with a statistical model of climate that explicitly represents equilibria among variables and their movements towards equilibrium. Results indicate that; (1) skipped obliquity/precession beats are an artifact of ignoring adjustments towards an equilibrium state, (2) accounting for equilibrium and adjustments to equilibrium can account for all phases of the glacial cycle, and (3) glacial cycles are generated by adjustments to equilibrium relations between orbital geometry and climate and among components of the climate system. Together, these results suggest a new approach to understanding glacial cycles that is based on models which include a rich set of equilibria and adjustments to equilibria for a full suite of climate variables simulated over long periods.
A.10(2021)	Roger, C. and Rowan, S. (2019) ' Analysing International Organisations: How the Concepts we use affect the Answers we get. '	Concepts and measures of international organizations have been gradually diverging. The field maintains a broad conception of IOs that allows for significant internal variation, but has coalesced around a measurement that reflects the characteristics of the major post-World War Two IOs. Since the characteristics of global governance have shifted, prevailing measures of the IOs in operation and of the composition of states' IO memberships differ from the real quantities scholars aim to analyze. Specifically, prevailing measures only count formal IOs, bodies founded with legally binding agreements, and omit informal IOs, which are founded with non-legally binding instruments. Recent research demonstrates formal and informal IOs share many important features, but differ from each other in important ways. These differences imply that formal and informal IOs may have different effects in global politics. We study how the disconnect between concepts and measures matters for empirical research. Using new panel data on state membership in 217 informal

		IOs from 1815 to 2010, we find heterogeneous effects for different subtypes of IOs that conflict with existing theories to varying degrees. Existing findings are partly artefacts of the specific way that they operationalize key IO variables, which have not been acknowledged previously. Had alternative measures of key concepts prevailed earlier, IO research may have developed different theoretical arguments.
A.11(2021)	Rowan, S. (2021) ' Does institutional proliferation undermine cooperation? Theory and evidence from climate change ', <i>International Studies Quarterly</i> .	Global politics has undergone a tremendous institutional proliferation, yet many questions remain about why states join these new institutions and whether they support cooperation. I build on existing work to develop a general theory of state participation in dense institutional environments that also helps to explain cooperative outcomes. I argue that states may be dissatisfied when cooperation proceeds either too slowly or too quickly and that these two types of dissatisfaction motivate opposing participation behaviors. Deepeners are states that are dissatisfied with the slow pace of cooperation and join institutions to support cooperation, while fragmenters are states dissatisfied with the quick pace and join institutions to undermine cooperation. I evaluate my argument using new data on sixty-three climate institutions and states greenhouse gas mitigation targets in the Paris Agreement on Climate Change. I find that membership in climate institutions designed to facilitate implementation is associated with more ambitious targets, while membership in general is unrelated to targets.
A.12(2021)	Thalheimer, L., Otto, F., and Abele, S. (2021) ' Deciphering impacts and human responses to a changing climate in East Africa ', <i>Frontiers in Climate</i> .	Climate-related human mobility (climate mobilities) is often portrayed as a key impact of human-induced climate change. Yet, causal, quantitative evidence on this link remains limited and suffers from disciplinary hurdles. One reason for this is that existing case studies do not incorporate insights from climate science methods and pay little attention to contextual factors in climate mobilities. We use a dual-method approach to categorise and classify. By combining a qualitative case study analysis with statistical approaches from topic modelling in an innovative dual-method framework, we show current empirical evidence on weather and climate-related impacts and human mobility in East Africa, an alleged hot-spot of climate change. We find that although climate change is referred to, implicitly and explicitly, as a tipping point for human mobility, studies imply a causal link between human mobility and climate change while under or misrepresenting evidence in climate science. A map of evidence allows studies to be matched with human mobility types and contextual factors influencing such mobilities in a changing climate with a novel and more ambitious form of synthesis, carving out the multi-

		causal nature of human mobility. Our findings show that climatic influences on human mobility are not independent. Rather, climate factors influencing human mobility are closely connected with contextual factors such as social norms, economic opportunities and conflict. The findings suggest that there is currently low confidence in a climate change-human mobility nexus for East Africa. As a way forward, we propose emerging methods to systematically research causal links between climate mobilities and anthropogenic climate change globally.
A.13(2021)	Thalheimer, L., Williams, D., van der Geest, K., Otto, F. (2021) ' Advancing the evidence base of future warming impacts on human mobility in African drylands ', <i>Earth's Future</i> .	A better understanding of climate change impacts and resulting human responses (climate-related human mobility) have been identified as a research priority by the climate science community. Here, we provide the basis for future research efforts by identifying knowledge gaps and consolidating published evidence in the IPCC 1.5 Special Report (SR15) with recent evidence from climate science and the literature on human mobility in African drylands, a region where migrants are particularly vulnerable to climate change. We first synthesise climatic changes and their projected impacts across the region to then contextualize the projected impacts with current knowledge regarding the effect of anthropogenic climate change on human mobility. We discuss these often indirect impact channels and argue that a systems approach is needed to address the interconnectedness of climate impacts and the cascading risks of adverse consequences for human mobility.
C	PUBLISHED REPORTS	
C.1(2021)	A strategy for achieving net zero emissions by 2050— Written Evidence Submitted by Jennifer L. Castle and Professor Sir David F Hendry , to UK House of Commons Public Accounts Committee	To achieve greenhouse gas emissions targets of net zero requires an integrated symbiotic strategy across all fossil fuel uses and all other emitters, less natural absorption and carbon capture and storage, possibly combined with atmospheric CO ₂ extraction. Clean electricity generation is achievable with known technologies, but faces a major storage problem when renewables do not generate power. Small modular nuclear reactors (SMRs) could help with background supply, but storage can be facilitated by decarbonizing the transport sector & using electric vehicles as storage units plugged into an intelligent network connected to the grid to facilitate balancing electricity flow. Batteries alone seem inadequate for this, so we propose supplying electric vehicles via supercapacitors using graphene-based nanotubes (GNTs) which can charge and discharge rapidly and store sufficient power for distance driving. This overcomes an impediment to the uptake of electric vehicles and helps reduce toxic mining. GNTs could supply trains in place of diesel-electric, and are very light

		so advance developments in electric aircraft. By ensuring continuity of electricity supply, renewables capacity can be greatly expanded, so could sustain methane pyrolysis production of hydrogen when other electricity demands are low. Hydrogen gas could replace methane use by households, and liquid hydrogen would supply a high heat source for industry. A by-product of methane pyrolysis is black carbon, which could add to the material available for making graphene, though waste plastic could also be used. New buildings must be constructed to be net zero.
C.2(2021)	Castle, J.L., Doornik, J.A., Hendry, D.F. & Wenham, A. (2021) 'Forecasting in the time of Coronavirus', Nuffield Magazine .	The SARS-CoV-2 virus has had a massive impact worldwide. As we wrote this (mid-August 2020), confirmed COVID-19 cases had passed 85 million and were still rising rapidly. More than 1.8 million people had died, health systems were stressed even in developed countries and there had been large economic losses. To help health authorities plan for hospital admissions and governments decide on their mitigation policies, we have been publishing week-ahead forecasts for confirmed cases and deaths in many parts of the world, updates almost daily. Since 20 March 2020, our forecasts have been largely reliable indicators of what might happen in the following week.
C.3(2021)	Pigato, M.A., Kurle, J.K., & Rafaty, R.M. (2021) ' The COVID-19 crisis and the road to recovery: Green or brown ', World Bank.	With a critical decade ahead for keeping global warming under 1.5-2 degree C degrees, the fiscal stimulus responses to COVID-19 have presented, and continue to present, a critical opportunity for governments to 'build back better'. Combining a theoretical framework for classifying fiscal responses with data from the Oxford-based Global Recovery Observatory (GRO), this paper analyses the policies launched in response to COVID-19 and evaluates their consistency with the world's low-carbon transition. The paper contributes to the analytical framework developed in Hepburn et al. (2020) by (i) applying the analysis to a much larger sample of countries (85 compared with 50 in UNEP (2021)), which now includes more emerging market and developing economies (EMDEs) from March 2020 to May 2021; and (ii) adopting a broader and more granular approach to examining rescue and recovery stimulus packages by introducing a new category of spending policies: 'light brown' (or 'legacy') policies. By the end of May 2021, global announced spending reached the extraordinary amount of US\$19.8 trillion, with the 24 high-income economies in the sample accounting for more than three quarters of this amount. About 85 percent of global spending was aimed at 'rescuing' the global economy, and can be classified, almost entirely, as 'legacy' or 'light brown' spending, aimed at supporting families, businesses and activities that would not have survived otherwise. Recovery spending represented only 15 per cent of total stimulus. It

		included a relatively high share of green spending (19.4 percent) but an even larger share of brown activities (20.4 percent). Even the countries with significant green spending have allocated an equivalent amount or more to brown investment, thus 'neutralizing' the overall positive impact on emissions. It also appears that 'greener' countries have allocated more spending to green measures, possibly widening the gap between them and countries with weaker environmental performance. Finally, COVID-19's impact on the energy transition is mixed, ambiguous, and still to be determined. Overall, the COVID-19 crisis seems to have increased the distance between a group of high-income countries on course to accelerate their low-carbon energy transition, developing countries facing financial challenges to renewable energy deployment, and fossil fuel-dependent countries whose policies have further committed them to high-carbon development.
C.4(2021)	Thalheimer, L. and Šedová, B. (2021) ' Why climate migration is relevant for the EU ', Der Standard, Economics Blog (in German).	The number of forcibly displaced people is increasing. Climate change raises an important question – namely whether climatic conditions contribute to political unrest and civil wars.
D	FORTHCOMING PAPERS/WORKING PAPERS	
D.1(2021)	Campos-Martins, S. and Amado, C. (2021) ' Modelling time-varying volatility interactions '. Working paper.	In this paper, we propose an additive time-varying (or partially time-varying) multivariate model of volatility, where a time-dependent component is added to the extended vector GARCH process for modelling the dynamics of volatility interactions. In our framework, co-dependence in volatility is allowed to change smoothly between two extreme states and second-moment interdependence is identified from these crisis-contingent structural changes. The estimation of the new time-varying vector GARCH process is simplified using an equation-by-equation estimator for the volatility equations in the first step, and estimating the correlation matrix in the second step. A new Lagrange multiplier test is derived for testing the null hypothesis of constancy co-dependence volatility against a smoothly time-varying interdependence between financial markets. The test appears to be a useful statistical tool for evaluating the adequacy of GARCH equations by testing the presence of significant changes in cross-market volatility transmissions. Monte Carlo simulation experiments show that the test statistic has satisfactory empirical properties in finite samples. An application to sovereign bond yield returns illustrates the modelling strategy of the new specification.
D.2(2021)	Campos-Martins, S. and Hendry, D.F. (2021) ' Geoclimate, geopolitics, and the geovolatality of carbon-intensive equity returns '. Revise and resubmit, <i>Journal of Econometrics</i> .	The systemic implications on carbon-intensive equity prices of the disruptive technological progress from decarbonising the global energy system are compounded by the geopolitical nature of both the global oil market and transition

		<p>risk. We show empirically that climate change news affects oil and gas stock return volatilities at the global scale. But not all geoclimatic shocks are alike. Climate change news increases global uncertainty around carbon-intensive equities and it amplifies the effects of oil volatility shocks when the news is bad. Moreover, the impact of climate change news on the global oil and gas carbon intensive equity market differs across topics and themes.</p>
D.3(2021)	<p>Jackson, L.P., Juselius, K., Martinez, A.B., & Pretis, F. (2021) 'Modeling the interconnectivity of non-stationary polar ice sheets'. Working paper.</p>	<p>Understanding changes to the mass of the polar ice sheets is of crucial scientific and socioeconomic importance due to their effect on the wider Earth system and potential to contribute to future sea level rise. On monthly to multi-decadal timescales, there is much uncertainty around the extent to which the non-stationary, non-linear responses of the ice sheets interact through the atmosphere-ocean climate. We test and quantify the nature of non-stationarity and inter-dependence between ice mass balance time series for Greenland, West and East Antarctica using a multi-cointegration vector autoregression model, which has been used to show equivalence between simple climate models and emulations of complex physical processes. We focus on three alternative specifications by comparing I(2) models of cumulative ice mass balance with an I(1) model of the ice mass balance, exploring the model dynamics, and evaluating the out-of-sample forecasts against satellite observations. Our results support the I(2) model with a bipolar relationship between Greenland and West Antarctica and provide some of the first empirical evidence of tipping-points in the recent observed record. Long-term projections indicate that there is considerable risk of Greenland contributing more to sea level rise than under the IPCC's extreme climate change scenario.</p>
D.4(2021)	<p>Jiao, X. (2021) 'A simple robust procedure in instrumental variables regression'. Working paper</p>	<p>A frequent concern in applied economics is that key empirical findings may be driven by a tiny set of outliers. To perform outlier robustness checks in practical applications of instrumental variables regressions, the common practice is first to run ordinary two stage least squares and remove observations classified as outliers with residuals beyond a chosen cut-off value. Subsequently 2SLS is recalculated based on non-outlying observations, and this procedure can also be iterated until robust results are obtained. In this paper, we analyze this simple robust algorithm asymptotically, then provide consistent estimation and valid inferential procedures on structural parameters for practical implementation given the cut-off value. Moreover, this paper provides asymptotic theory for setting the cut-off, which is chosen to control the gauge (proportion of outliers wrongly discovered). Finally, we construct a formal test of outlier robustness</p>

		<p>based on the Hausman type test statistics comparing between the ordinary and robust estimators. Asymptotics are derived under the null hypothesis that there is no contamination in the cross-sectional i.i.d. data. The established weak convergence result involves empirical processes and the fixed point arguments. Thus, this paper also proves the uniform and weak law for a new class of weighted and marked empirical processes of residuals in IVs regressions, allowing for estimation errors of structural parameters. An empirical application to Acemoglu et al. (2019) shows the utility of the proposed theory.</p>
D.5(2021)	<p>Jiao, X., Pretis, F. and Schwarz, M., (2021) `Testing for Coefficient Distortion due to Outliers with an Application to the Economic Impacts of Climate Change`. Working paper.</p>	<p>Outlying observations can bias regression estimates, requiring the use of robust estimators. Comparing robust estimates to those obtained using OLS is a common robustness check, however, such comparisons have been mostly informal due to the lack of available tests. Here we introduce a formal test for coefficient distortion due to outliers in regression models. Our proposed test is based on the difference between OLS and robust estimates obtained using a class of Huber-skip M-type estimators (such as Impulse Indicator Saturation or Robustified Least Squares). Establishing asymptotics of the corresponding Huber-skip M-estimators using an empirical process CLT recently developed by Berenguer-Rico et al. (2019), we show that our distortion test has an asymptotic chi-squared distribution and is valid for cross-sectional as well as panel and time series models. To improve finite sample performance and to alleviate concerns on distributional assumptions, we further introduce and explore three bootstrap testing schemes. We apply our outlier distortion test to estimates of the macro-economic impacts of climate change allowing for adaptation. We find that OLS estimates are significantly different to those obtained using a robust estimator and provide evidence of income-driven adaptation. Projecting the resulting damage curve to the end of the century shows that outlier-robust estimates dampen projected GDP losses and reduce the estimated marginal impacts of additional warming under adaptation.</p>

D.6(2021)	Sato, M., Rafaty, R., Cael, R., Grubb, M. 'The European Union Emissions Trading System in the Real World.' (follow up article building on Routledge book chapter, currently under review at <i>WIREs Climate Change Policy</i>)	The European Union's pioneering emissions trading system, the EU ETS, has inspired countries around the world, most recently China, to launch their own carbon markets. This paper analyses the evolution of the EU ETS from a political economy perspective, emphasises the interaction of economic principles and political interests at pivotal moments, and shows how each compromise changed the scope for future design choices. We focus on the long- running fight over how carbon allowances are allocated, which provides a window into the complex tug-of-war between principles of aggregate economic efficiency, and the politics of distribution and localised interests. Our account highlights both the pitfalls and the successful reform efforts, to help inform design and evolution of more stable and effective carbon markets internationally. In light of the renewed efforts to reform the EU ETS, we also discuss what lessons can be learned from its history.
D.7(2021)	Thalheimer, L., M. P. Schwarz, F. Pretis (2021) 'Disentangling the effects of climate and conflict on displacement: Evidence from Somalia', Working paper	Weather, climate, and conflict-related events may drive forced displacement. However, their individual contribution to displacement is not fully understood due to challenges around isolating individual channels of causality. Here, we use novel disaggregated data on displacement in all of Somalia's 18 regions from 2016-2018 broken down by reason of displacement and combine it with weather and conflict data to isolate the effects of climate and conflict on forced displacement, as well as the effects of climate and displacement on conflict itself. We find large non-linear lagged effects of weather on displacement and immediate effects of conflict on displacement, which are masked when the data is aggregated. We also show that reduced precipitation increases the probability of armed conflict, however, migration itself has no effect on the probability of conflict events.
D.8(2021)	Thalheimer, L., Gaupp, F. and Webersik, C. (forthcoming) ' Compound vulnerabilities exacerbate systemic risks of food security in Somalia ' <i>Nature Food</i>	The impacts of climate change are increasingly compounding around the world. Simultaneous extreme weather events threaten coping mechanisms such as migration, and food security in breadbasket regions. Systemic risk approaches offer a critical lens to guide risk-informed sustainable action both now, and in the future. This Analysis proposes a generic conceptual framework to address the nature of such risks. We combine data on weather-related displacement, food insecurity, and conflict to characterize compound vulnerabilities underlying systemic risks. Using a Systemic Risk Impact Pathways (SRIP) model, we illustrate intersections between systemic risk elements and compound vulnerabilities in Somalia, a country affected by recurring extreme weather, protracted armed conflict, political instability and displacement. We show how these dynamics have created a complex nexus of strains on the population and

		its ability to guarantee food security. Advancing a risk-informed sustainable development agenda, we recommend taking a systemic risk approach instead of a single hazard approach.
2020		
A	PUBLISHED JOURNAL ARTICLES	
A.1(2020)	Abadie, L.M., Jackson, L.P., Sainz de Murieta, E., Jevrejeva, S. and Galarraga, I. (2020), ' Comparing urban coastal flood risk in 136 cities under two alternative sea-level projections: RCP 8.5 and an expert opinion-based high-end scenario ', <i>Ocean and Coastal Management</i> , 193 .	The high degree of uncertainty associated with the extent of future sea-level rise stems primarily from the potential mass loss of the Greenland and Antarctica ice-sheets. We explore the impact of this uncertainty on economic damage due to sea-level rise for 136 major coastal cities. We compare the probability distribution for damage under the assumption of no adaptation for two relative sea-level projections: the RCP 8.5 scenario from the IPCC Fifth Assessment Report and a High-end scenario that incorporates expert opinion on additional ice-sheet melting. We use the 50th and 95th percentiles to estimate expected damage and one risk measure, the Expected Shortfall ES (95%), which represents the impact of low-probability, high-damage coastal flood risk (above the 95th percentile). Aggregate expected damage by 2050 under RCP 8.5 is US\$1,600 billion, while the aggregate risk measure ES(95%) is almost twice as much as the average damage at US\$3,082 billion. Under the High-end scenario, ES(95%) figures in Guangzhou and New Orleans by 2050 are twice as high as the expected damage. The city of Guangzhou leads the ranking under both scenarios, followed by Mumbai and New Orleans. Our results suggest that it is critical to incorporate the possibility of High-end scenarios into coastal adaptation planning for future sea-level rise, especially for risk-averse decision-making.
A.2(2020)	Castle, J.L. & Hendry, D.F. (2020) ' Can the UK achieve net-zero emissions in a post-Covid-19 economic recovery? ', <i>Economics Observatory</i> , 1 August.	Getting the greenhouse gas emissions that cause climate change to 'net-zero' by 2050 will require significant technological advances. How can that ambitious goal still be achieved while ensuring employment and growth in the aftermath of coronavirus?
A.3(2020)	Castle, J.L. & Hendry, D.F. (2020) ' Climate Econometrics: An Overview ', Invited monograph, <i>Foundations and Trends in Econometrics</i> , 10, 145-322.	Climate econometrics is a new sub-discipline that has grown rapidly over the last few years. As greenhouse gas emissions like carbon dioxide (CO ₂), nitrous oxide (N ₂ O) and methane (CH ₄) are a major cause of climate change, and are generated by human activity, it is not surprising that the tool set designed to empirically investigate economic outcomes should be applicable to studying many empirical aspects of climate change. Economic and climate time series exhibit many commonalities. Both data are subject to non-stationarities in the form of evolving stochastic trends and sudden distributional shifts.

		Consequently, the well-developed machinery for modeling economic time series can be fruitfully applied to climate data. In both disciplines, we have imperfect and incomplete knowledge of the processes actually generating the data. As we don't know that data generating process (DGP), we must search for what we hope is a close approximation to it.
A.4(2020)	Castle, J.L. & Hendry, D.F. (2020) ' Decarbonising the future UK economy ', <i>VoxEU</i> , 4 June.	The UK's 2008 Climate Change Act has led to a 34% fall in CO ₂ emissions by 2019, while real GDP per capita had risen by more than 10% following the crash into the 'Great Recession'. Can the UK achieve its recent net-zero emissions target by 2050 while still growing? This column describes some speculative routes to such a decarbonised future.
A.5(2020)	Castle, J.L., Doornik, J.A. & Hendry, D.F. (2020) ' Can we get accurate short-term forecasts of coronavirus cases and deaths? ', <i>Economics Observatory</i> , 6 July.	In a pandemic, policy-makers need to plan healthcare provision carefully and adjust the intensity of measures to mitigate the spread of the virus. That requires real-time forecasts of cases and deaths that are timely and accurate indicators of what will happen over the next week or so.
A.6(2020)	Castle, J.L., J.A. Doornik, and D.F. Hendry (2020) " Modelling Non-stationary Big Data ", <i>International Journal of Forecasting</i> , 37, 1556--1575.	'Fat big data' characterizes data sets that contain many more variables than observations. We discuss the use of both principal components analysis and equilibrium correction models to identify cointegrating relations that handle stochastic trends in non-stationary fat data. However, most time-series are wide-sense non-stationary—induced by the joint occurrence of stochastic trends and distributional shifts—so we also handle the latter by saturation estimation. Seeking substantive relationships when there are vast numbers of potentially spurious connections cannot be achieved by just choosing the best-fitting equation or trying hundreds of empirical fits and selecting a preferred one, perhaps contradicted by others that go unreported. Conversely, fat big data are useful if they help ensure that the data generation process is nested in the postulated model, and increase the power of specification and mis-specification tests without raising the chances of adventitious significance. We model the monthly UK unemployment rate, using both macroeconomic and Google Trends data, searching across 3000 explanatory variables, yet identify a parsimonious, statistically valid, and theoretically interpretable specification.

A.7(2020)	<p>Castle, J.L., Doornik, J.A. & Hendry, D.F. (2020) 'Short-term forecasting of the coronavirus pandemic' <i>VoxEU</i>, 24 April.</p> <p>Also see https://www.ft.com/content/8684a104-7a52-11ea-9840-1b8019d9a987</p>	<p>While models based on well-established theoretical understanding and available evidence are crucial to viable policymaking in observational-data disciplines, shifts in distributions can lead to systematic mis-forecasting. This column argues that there is an important role for short-term forecasts using adaptive data-based models that are 'robust' after distributional shifts and discusses an approach to doing so for the Covid-19 pandemic.</p>
A.8(2020)	<p>Hendry, D.F. Castle, J.L., & Doornik, J.A. (2020) 'Why short-term forecasts can be better than models for predicting how pandemics evolve', <i>The Conversation</i>, 30 June.</p>	<p>Confirmed COVID-19 cases have now passed <u>10 million</u>: what will they be next week, globally and in your country? Having a good estimate can help health authorities with their responses and will guide governments as they ease lockdowns. To this end, we have been publishing <u>real-time forecasts</u> for confirmed cases and deaths for many parts of the world on an almost daily basis since March 20. These have largely been reliable indicators of what can be expected to happen in the next week.</p>
A.9(2020)	<p>Castle, J.L., Hendry, D.F. and Martinez, A.B. (2020), 'The Paradox of Stagnant Real Wages yet Rising 'Living Standards' in the UK', <i>VoxEU</i>.</p> <p>Also discussed and reported in https://www.ft.com/content/a470b09a-4276-11ea-a43a-c4b328d9061c</p>	<p>Real wages and productivity in the UK, have stagnated since 2007 whereas employment has risen considerably. Many commentators lament the consequent failure of 'living standards' to rise at historical rates (see e.g., https://www.ft.com/content/44401594-2ca0-11ea-bc77-65e4aa615551). But real GDP per capita has grown by more than 20% since 2000 despite the 'Great Recession', so aggregate living standards have in fact risen. This article resolves the apparent paradox.</p>
A.10(2020)	<p>Cohen, F., Schwarz, M., Li, S., Lu, Y. Jani, A. (2020). 'The Challenge of Using Epidemiological Case Count Data: The Example of Confirmed COVID-19 Cases and the Weather', <i>Environmental and Resource Economics: Perspectives on the Economics of the Environment in the Shadow of Coronavirus</i>, 76, 447-517.</p>	<p>The publicly available datasets on confirmed COVID-19 cases and deaths provide a key opportunity to better understand the drivers of the pandemic. Research using these datasets (defining COVID-19 cases as individuals for whom SARSCoV-2 has been detected using RT-PCR) has been growing at a very fast pace. However, little attention has been paid to the reliability of this type of epidemiological data to make statistical inferences. Scientists, policy makers, journalists and the general public need to be very cautious when discussing how the spread of COVID-19 correlates with the weather or any other factor. More attention should be given to how epidemiological data is recorded and used during exceptional epidemics and seasonal outbreaks, since insufficient testing and monitoring can undermine essential statistical analyses. This article calls for the complementary use of different methods for data collection, such as random testing in samples of the population.</p>
A.11(2020)	<p>Doornik, J.A., Castle, J.L., and Hendry, D.F. (2019). 'Card Forecasts for M4', <i>International Journal of Forecasting</i>. Open Access.</p>	<p>The M4 forecast competition required forecasts of 100,000 time series at different frequencies. We provide a detailed description of the calibrated average of Rho and Delta (Card) forecasting method that we developed for this</p>

		purpose. Delta estimates a dampened trend from the growth rates, while Rho estimates an adaptive but simple autoregressive model. Calibration estimates a more elaborate autoregressive model, treating the averaged forecasts from Rho and Delta as if they were observed. The proposed method is easy to understand, combining very fast execution with an excellent forecast performance.
A.12(2020)	Doornik, J.A., Castle, J.L., & Hendry, D.F. (2020) ' Short-term forecasting of the coronavirus pandemic ', <i>International Journal of Forecasting</i> .	We have been publishing real-time forecasts of confirmed cases and deaths for COVID-19 from mid-March 2020 onwards, published at www.doornik.com/COVID-19 . These forecasts are short-term statistical extrapolations of past and current data. They assume that the underlying trend is informative of short term developments, without requiring other assumptions of how the SARS-CoV-2 virus is spreading, or whether preventative policies are effective. As such they are complementary to forecasts from epidemiological models. The forecasts are based on extracting trends from windows of the data, applying machine learning, and then computing forecasts by applying some constraints to this flexible extracted trend. The methods have previously been applied to various other time series data and have performed well. They are also effective in this setting, providing better forecasts in the earlier stages than some epidemiological models.
A.13(2020)	Doornik, J.A., Hendry, D.F., & Castle, J.L. (2020). ' Statistical short-term forecasting of the COVID-19 pandemic ', <i>Journal of Clinical Immunology and Immunotherapy</i> . Open Access.	We have been publishing real-time forecasts of confirmed cases and deaths for COVID-19 from mid-March 2020 onwards, published at www.doornik.com/COVID-19 . These forecasts are short-term statistical extrapolations of past and current data. They assume that the underlying trend is informative of short-term developments, without requiring other assumptions of how the SARS-CoV-2 virus is spreading, or whether preventative policies are effective. We provide an overview of the forecasting approach that we use and assess the quality of the forecasts in comparison to those from an epidemiological model.
A.14(2020)	Hendry, D.F. (2020) ' A Short History of Macro-econometric Modelling ', <i>Journal of Banking, Finance and Sustainable Development</i> , 1 , 1--32	The key stages in the development of empirical macro-econometric model building are briefly described. Essential steps included characterizing the economy as a system, collating aggregate macroeconomic time series on prices and quantities, isolating the many interacting concepts necessary for understanding how to empirically model economies, inventing viable methods of estimation and inference for dynamic systems, developing hardware and software calculating devices to make such approaches operational, then combining all of these to implement empirical macro-econometric modelling, forecasting and policy making. Its history is littered with both successes and

		failures, leading overall to substantive progress in understanding, but highlighting the roles of fashions in economic theory dominating empirical evidence and the pernicious impacts of location shifts causing forecast failures and entailing theory failures.
A.15(2020)	Hillebrand, E., Pretis, F. & Proietti, T. (Editors) (2020) ' Special Issue: Econometric Models of Climate Change ', <i>Journal of Econometrics</i> , 214(1), 1-294.	In this annals issue we have collected articles that focus on the econometric analysis of climate data referred to in the IPCC quote, which is a relatively younger avenue. Many of the papers were presented at the first conference on Econometric Models of Climate Change in Aarhus in 2016, which so far has seen two successor conferences, at Oxford in 2017 and in Frascati in 2018. In 2019, the conference will be held in Milan.
A.16(2020)	Jevrejeva, S., Palanisarny, H. & Jackson, L.P. (2020) ' Global mean thermosteric sea level projections by 2100 in CMIP6 models ', <i>Environmental Research</i> , 16(1).	Most of the excess energy stored in the climate system is taken up by the oceans leading to thermal expansion and sea level rise. Future sea level projections allow decision-makers to assess coastal risk, develop climate resilient communities and plan vital infrastructure in low-elevation coastal zones. Confidence in these projections depends on the ability of climate models to simulate the various components of future sea level rise. In this study we estimate the contribution from thermal expansion to sea level rise using the simulations of global mean thermosteric sea level (GMTSL) from 15 available models in the Coupled Model Intercomparison Project Phase 6 (CMIP6). We calculate a GMTSL rise of 18.8 cm [12.8–23.6 cm, 90% range] and 26.8 cm [18.6–34.6 cm, 90% range] for the period 2081–2100, relative to 1995–2014 for SSP245 and SSP585 scenarios respectively. In a comparison with a 20 model ensemble from Coupled Model Intercomparison Project Phase 5 (CMIP5), the CMIP6 ensemble mean of future GMTSL (2014–2100) is higher for both scenarios and shows a larger variance. By contrast, for the period 1901–1990, GMTSL from CMIP6 has half the variance of that from CMIP5. Over the period 1940–2005, the rate of CMIP6 ensemble mean of GMTSL rise is $0.2 \pm 0.1 \text{ mm yr}^{-1}$, which is less than half of the observed rate ($0.5 \pm 0.02 \text{ mm yr}^{-1}$). At a multi-decadal timescale, there is an offset of $\sim 10 \text{ cm}$ per century between observed/modelled thermosteric sea level over the historical period and modelled thermosteric sea level over this century for the same rate of change of global temperature. We further discuss the difference in GMTSL sensitivity to the changes in global surface temperature over the historical and future periods.
A.17(2020)	Martinez, A.B. (2020) ' Forecast Accuracy Matters for Hurricane Damages ', <i>Econometrics</i> .	I analyze damages from hurricane strikes on the United States since 1955. I use machine learning methods to select the most important drivers for damages and show that large errors in a hurricane's predicted landfall location result in

		<p>higher damages. This relationship holds across a wide range of model specifications and when controlling for ex-ante uncertainty and potential endogeneity. Using a counterfactual exercise I find that the cumulative reduction in damages from forecast improvements since 1970 is about \$82 billion, which exceeds the U.S. government's spending on the forecasts and private willingness to pay for them.</p>
A.18(2020)	<p>Martinez, A.B. (2020) 'Improving normalized hurricane damages', <i>Nature Sustainability</i>.</p>	<p>Normalized hurricane damage can be used to assess the risk of damaging hurricane seasons. Weinkle and colleagues use an economy-wide price deflator to produce normalized damage estimates that suggest that losses from the 2017 hurricane season are likely to be seen again in the future. I argue that a building cost deflator is more relevant for hurricane damage. I find that normalized damage estimates that account for changes in building costs are consistent with historical trends in hurricane landfalls and indicate that there is an even higher probability of extremely damaging hurricane seasons in the future.</p>
A.19(2020)	<p>Mason, D., Lisa, A., Watanabe, S., Jackson, L.P. & Yokohari, M. (2020), 'How Urbanization Enhanced Exposure to Climate Risk in the Pacific: A Case Study in the Republic', <i>Environmental Research Letters</i>.</p>	<p>The increasing risk of coastal flooding and water shortage in Pacific Island Countries is usually attributed to climate change hazards. This ignores other risk components, exposure and vulnerability, of which a major contributor is urbanization. We develop simplified analyses that can be applied to other PICs. By dividing climate risks into hazard and exposure components we determine how urbanization contributed to present-day risks and then predict how growing climate change hazards may increase future risk, using the Republic of Palau as a case study. Results show that urbanization was responsible for 94% of the buildings exposed to coastal flooding today. Projected sea level rise, 30.2 cm by 2050, only increased exposure of today's buildings by 0.5%. In both present and future scenarios exposure resultant from urbanization was more significant than sea level rise. Our water scarcity index showed urbanization caused 3 of the 7 recorded water shortages from 1980-2018. From 2041-2079, analysis of projected rainfall showed mean reductions between 1.6-16.6% and increased variance between 0.3-3.4%. This led to three times as many water shortages under present population levels. In historical and future scenarios exposure from increased population was just as significant in causing water shortages as rainfall variation. These findings suggest that urban management is an important tool to lower exposure to coastal flooding and water shortage and we recommend that decision makers prioritize urbanization within climate risk policy in Pacific Island Countries.</p>

A.20(2020)	<p>Pretis, F. (2020) 'Econometric modelling of climate systems: The equivalence of energy balance models and cointegrated vector autoregressions', <i>Journal of Econometrics</i>, 214(1), 256-273.</p>	<p>Estimates of both the human impact on climate as well as the economic impacts of climate change are crucial to inform policy decisions. Econometric modelling allows us to quantify these impacts and their uncertainties, but models have to be consistent with the underlying physics and the time series properties of the data. Here I show that energy-balance models of climate are equivalent to an econometric cointegrated system and can be estimated in discrete time. This equivalence provides a basis for the use of cointegration methods to estimate climate responses and test their feedback. Further, it is possible to use the estimated parameters to quantify uncertainties in integrated assessment models of the economic impacts of climate change. In an application I estimate a system of temperatures, ocean heat content, and radiative forcing including greenhouse gases, and find statistical support for the cointegrated energy balance model. Accounting for structural breaks from volcanic eruptions highlights large parameter uncertainties and shows that previous empirical estimates of the temperature response to increased CO2 concentrations may be misleadingly low due to model-misspecification.</p>
A.21(2020)	<p>Rafaty, R., S. Srivastav, and B. Hoops (2020), 'Revoking coal mining permits: an economic and legal analysis'. <i>Climate Policy</i>.</p>	<p>Achieving mitigation targets under the Paris Agreement will depend on the early retirement of coal mines and plants over the next decade. In the absence of sufficiently stringent demand-side policies, supply-side injunctions provide a potential avenue to expedite the decline of coal. In many coal-producing jurisdictions, the law provides grounds to revoke coal mining permits. Recent plans to phase out coal use in Germany provide an interesting testing ground for this concept. We study the case of permits granted to RWE Power AG to continue operating Europe's largest opencast lignite mine, situated at the 12,000-year-old Hambach Forest in the state of North Rhine-Westphalia (NRW). We conduct two complementary assessments: (i) a legal analysis finding that German law provides several grounds for the revocation of coal mining permits, particularly when linked to quantifiable damages to local ecosystems and communities; and (ii) an economic analysis using natural capital accounting to quantify the environmental and societal costs associated with alternative scenarios of continued and halted mining activity. We find the net present value of gains from immediately halting operations at the Hambach lignite mine to be €98–208 billion over 34-years, equivalent to 13–30% of NRW's annual GDP. Health-related savings from avoided air pollution are 6.5 times greater than costs of replacing lost capacity with new renewable energy and battery storage infrastructure and two orders of magnitude greater than costs of compensating laid-off mining workers.</p>

A.22(2020)	<p>Sterner, T., Carson, R.T., Hafstead, M., Howard, P., Jagers, S.C., Köhlin, G., Parry, I., Rafaty, R., Somanatan, E., Jan Christoph Steckel, J.C., Whittington, D., Alpizar, F., Amber, S., Aravena, C., Bonilla, Jorge, Daniels, R.C., Garcia, J., Harrington, N., Kacker, K., Kerr, S., Medhin, M., Nam, P.K., Romero, G., Johansson-Stenman, O., Toman, M., Xu, J., Wang, M. (2020) ‘Funding Inclusive Green Transition through Greenhouse Gas Pricing’, <i>ifo DICE Report</i>, 1/2020 Spring, Volume 18, pp. 3-8.</p>	<p>2015 was a special year. During a few months the political stars aligned and made it possible for the international community to agree on the Agenda 2030 for Sustainable Development and the Paris Agreement to limit global warming. Now the signatories need to find ways to implement these agreements, which not only imply a deep decarbonization of the economy but must also meet the Sustainable Development Goals. In this article we discuss the importance of pricing greenhouse gas (GHG) emissions² to make this happen. Climate abatement is a truly global public good and so we actually have to have a functioning policy in all countries. Our interest is thus on pricing in all countries but in particular the developing countries that are bigger and most crucial to the struggle for a green transition.</p>
A.23(2020)	<p>Thalheimer, L. & Heslin, A. (2020). ‘The picture from above: Using satellite imagery to overcome methodological challenges in studying environmental displacement’, <i>The Oxford Monitor for Forced Migration</i>.</p>	<p>Extreme and uncertain climate conditions adversely affect people around the world, including, in extreme circumstances, by displacing them from their homes. In today’s global climate crisis, it is critical to have a range of tools available to measure and address the scale and drivers of such forced migration. Inclusive development and the provision of time-effective humanitarian aid to those displaced requires real-time information on displacement, information that can be difficult to fully obtain through data collection on the ground. Satellite data offers an opportunity to supplement ground-level data collection for targeted intervention in areas most at-risk of displacement. The starting point of this paper is the discourse on environmental displacement, the challenges of studying this type of displacement and the opportunities information from remote sensing provide. We then showcase the applicability of such data in an embedded case study on Somalia, a country with a longstanding history of forced migration, drought and conflict.</p>
A.24(2020)	<p>Thalheimer, L. and Webersik, C. (2020) ‘Climate change, conflicts and migration’, in <i>Environmental Conflicts, Migration and Governance</i>, Tim Krieger, Diana Panke and Michael Pregernig (eds). Bristol University Press. Book Chapter.</p>	<p>Developing countries are among the most vulnerable to climate change and seasonal inter-annual climate variability. Societies living in violence and conflict-affected areas are particularly vulnerable to the physical impacts of climate change – although the magnitude and intensity of these impacts vary across geographical and climatological region. According to the Food and Agriculture Organization (FAO), droughts have affected about 363 million people in Sub-Saharan Africa over the past 20 years – 203 million of these in East Africa alone. In spite of manifold discussions in academic literature, there has yet not been full consent on the role of climate change on security issues, political fragility and armed conflict. This chapter hypothesizes that climate change effects on dry extremes at the local level help sustain prolonged armed</p>

		<p>conflicts and disrupt traditional migration patterns. Climate and conflict-related population movements in the presence of renewable resource scarcity are highly interconnected and undifferentiated. The chapter addresses the multifaceted legitimacy of the climate conflict discourse with respect to political fragility, climatic variability, and the social dimension. By doing so, it investigates different drivers of conflict and fragility over time. It then analyzes the relation of changing actors in conflict, environmental disruptions and mixed migration. The chapter adopt a political economy perspective in an embedded case study to investigate, first, conflicts and second, migration in the context of climate change. It discusses how main actors' interests and power relations are linked to the ongoing conflict in Somalia. The conclusion asks for streamlined, flexible governance measures to address climate conflicts.</p>
B	PUBLISHED BOOKS	
B.1(2020)	<p>Pigato, M.A., Black, S.J., Dussaux, D., Mao, Z., McKenna, M., Rafaty, R. & Touboul, S. (2020) 'Technology Transfer and Innovation for Low-Carbon Development, <i>World Bank</i>.</p>	<p>Technological revolutions have increased the world's wealth to a level that was once unimaginable. They have done so unevenly, however, and in ways that have accelerated climate change. Technology Transfer and Innovation for Low-Carbon Development argues that most of the emissions reductions required to achieve the Paris Agreement goals can be reached through the global deployment of existing and commercially proven low-carbon technologies (LCTs). Deploying LCTs from high-income countries—which account for 80 percent of all LCT innovations and 70 percent of all LCT exports—to developing countries, where they are needed most, will not be easy; but the evidence is clear that it can be done. Transferring LCTs is not only necessary to meet the climate targets, but it is also an opportunity to achieve development goals. The policies needed to deploy LCTs to developing countries could raise output and employment while yielding welfare benefits, such as reduced air and water pollution. Moreover, adopting LCT offers an opportunity for countries to benefit from participation in global value chains and to become LCT producers and exporters.</p>
C	PUBLISHED REPORTS	
C.1(2020)	<p>Cohen, F., Ives, M., Srivastav, S., Schwarz, M., Lu, Y., Mealy, P., Bento Maffei De Souza, P., Jackson, P., & Hepburn, C. (2020) 'Emerging markets and self-interested climate action', A report prepared for Pictet AM by the Oxford Smith School of Enterprise and the Environment.</p>	<p>This report focuses on the role emerging market countries will likely play in the lead up to the climate conference (COP26) in 2021. Our analysis is relevant to two key questions they face:</p> <ul style="list-style-type: none"> - Should emerging market economies more actively push for climate actions? - If so, how should they seek to accelerate the low-carbon transition?

		<ul style="list-style-type: none"> - The report provides an up-to-date analysis of the significant threats to and opportunities for emerging market economies from climate action and from climate impacts, along with an analysis of the growing opportunities for investors to participate effectively in the low-carbon transition in emerging markets. We find that there are ever more ways in which climate action in emerging markets can enhance prosperity in almost all key sectors in these economies.
C.2(2020)	De Fontaubert, C., Hart, T., Thalheimer, L., Dubow, A.Z., Million, J.M.F. & Collier, J.B. (2020) ' Somalia country environmental analysis: Diagnostic study on trends and threats for environmental and natural resources challenges ', <i>World Bank</i> .	Somalia's natural capital is under substantial pressure from inappropriate land uses, conflict, and climate change. In its Ninth National Development Plan (Somalia NDP-9), the government of Somalia has identified vulnerability to environmental shocks as one of the six major causes of poverty. The Plan also observes that among the top four drivers of poverty is natural disasters. Subsequently, the Plan notes that the achievement of the four-national development priority pillars is contingent upon 'better management of Somalia's environment and its natural resources.' The Somalia CEA is an analytical document that systematically evaluates Somalia's environment and natural resources (ENR) sector, using both authors' own data and published secondary information. The end-term goal of the report is to facilitate both a long-term dialogue within Somalia on the interlinkages between environment and development and herald better coordination among development partners on matters touching on the management of Somalia's natural assets. By identifying environmental concerns at an early stage in Somalia's renewed engagement with international financing institutions, the CEA identifies opportunities for managing natural resources to deliver improvements for livelihoods, reducing poverty, and building climate change resilience across all the environmental sectors.
C.3(2020)	Hepburn, C. and Schwarz, M. (2020) ' Climate change: Answers to common questions ' A report prepared for Pictet AM group by the Oxford Smith School of Enterprise and the Environment.	Uncertainty about climate science and economics poses challenges for business and finance. Reasonable and intelligent people frequently ask us for a reference document to set out what is known and not known about climate change, including research that is sometimes contrary to prevailing societal beliefs, if only to avoid debates about areas that are settled and instead to direct attention to the areas where further research is valuable. We have structured this document into nine areas of doubt commonly expressed about climate science and economics, each of which is broken down into points of contention. We also highlight key facts and estimates in which scholars have high levels of confidence. Each section begins with a common challenge about climate science and economics, expressed as a quotation.

C.4(2020)	Thalheimer, L., Jjemba, E.W., Simperingham, E. (2020). " Forecast-Based Financing and Disaster Displacement: Acting Early to Reduce Humanitarian Impacts of Displacement ", <i>IFRC and Red Cross Crescent Climate Centre ISSUE BRIEF</i> .	This issue brief addresses opportunities and challenges associated with utilizing forecast-based financing (FbF) to support anticipatory humanitarian action in the context of disaster displacement. It includes recommendations to governments, UN agencies, NGOs, the IFRC and National Red Cross and Red Crescent Societies, civil society and donors, as well as community-based stakeholders, on how FbF can reduce risks and address the humanitarian impacts of disaster displacement.
D	PAPERS IN PROGRESS/WORKING PAPERS	
D.1(2020)	Castle, J.L. & Hendry, D.F. (2020) ' Identifying the casual role of CO2 during the ice ages ', Discussion paper.	We investigate past climate variability over the Ice Ages, where a simultaneous-equations system is developed to characterize land ice volume, temperature and atmospheric CO2 levels as non-linear functions of measures of the Earth's orbital path round the Sun. Although the orbital variables were first theorised as the fundamental causes of glacial variation by Croll in 1875 following Agassiz's conception of a 'Great Ice Age' in 1840, their minor variations were thought insufficient to drive such major changes, especially the relative rapidity of shifts between glacial and warmer periods. The changes over the ice ages in atmospheric CO2 closely matched changes in land ice volumes, and since temperature changes are in turn affected by CO2 and also closely tracked ice volumes, a key identification issue is the causal role of CO2 in the process. As any links between CO2 and temperature above the forces from the orbital drivers (which of course are still operating) must have been natural ones hundreds of thousands of years ago, understanding their interactions at that time is important now that additional CO2 emissions are anthropogenic. We develop a simultaneous equation system over the last 800,000 years that allows a test of the role of CO2 as endogenously driven by the orbital variations, or an 'exogenous' influence as it now is.
D.2(2020)	Engle, R. F. & Campos-Martins, S. (2020) ' What are the events that shake our world? Measuring and hedging global COVOL '. Forthcoming <i>Journal of Financial Economics</i> .	Geopolitical events can impact volatilities of all assets, asset classes, sectors and countries. It is shown that innovations to volatilities are correlated across assets and therefore can be used to measure and hedge geopolitical risk. We introduce a definition of geopolitical risk which is based on volatility shocks to a wide range of financial market prices. To measure geopolitical risk, we propose a statistical model for the magnitude of the common volatility shocks. Accordingly, a test and estimation methods are developed and studied using both empirical and simulated data. We provide a novel explanation for why idiosyncratic volatilities comove based on a new way to formulate multiplicative factors. Finally, we propose a new criterion for portfolio optimality which is intended to reduce the exposure to geopolitical risk.

D.3(2020)	Hendry, D.F. (2020) "Back to the Future of Economic Forecasting", Forthcoming <i>Econometrics</i> .	<p>Originally written in 1991 to advance the formal analysis of forecasting models and methods, the report considers alternative forecasting devices including guessing, extrapolating, leading indicators, surveys, time-series models and econometric systems. Conditional and unconditional forecasts are reviewed and the issue of data accuracy is discussed. The main focus is on macro-econometric model forecasts and their forecast errors, so forecast variances are described.</p> <p>Forecast comparisons using mean square errors across models are criticized, as are methods of pooling disparate forecasts, which violate forecast encompassing. The non-stationarity of economic data is discussed in terms of unit roots and stochastic trends, technical progress and regime shifts. The various sources of forecast error are delineated including: uncertainty about parameters and non-modelled variables; cumulative innovation errors in forecasting endogenous variables; lagged feedbacks onto exogenous variables, parameter non-constancy; incorrect initial values; and model mis-specifications. The report concludes with some recommendations</p>
D.4(2020)	Rafaty, R. (2020) "A Paradigm Shift in Road Transport Decarbonisation".	<p>This paper utilizes daily road transport CO2 emissions data from Carbon Monitor, mobility data from Google, and policy data from the Oxford COVID-19 Government Response Tracker to estimate the effects of workplace closures and 'telework' restrictions on emissions, in order to evaluate whether workplace flexibilities might be reasonably leveraged to generate lasting emission reductions in the future. The paper estimates individual models of year-on-year changes in daily automobile emissions for 12 national jurisdictions using indicator and step indicator saturation to account for unobserved determinants of outliers and breaks. It is shown that extending telework flexibilities beyond the COVID period, specifically and solely in occupations wherein working from home is technically feasible, could generate lasting reductions in road transport emissions ranging between 8 to 40%, depending on the occupational structure and existing transport infrastructure stock in the jurisdiction.</p>
D.5(2020)	Rafaty, R., Dolphin, G., & Pretis, F. (2020) ' Carbon pricing and the elasticity of CO2 emissions '. Working paper.	<p>We study the impact of carbon pricing on CO2 emissions across five sectors for a panel of 39 countries over 1990-2016. Using newly constructed sector-level carbon price data, we implement a novel approach to estimate the changes in CO2 emissions associated with (i) the introduction of carbon pricing regardless of the price level; (ii) the implementation effect as a function of the price level; and (iii) post-implementation marginal changes in the CO2 price. We find that the introduction of carbon pricing has reduced growth in CO2 emissions by 1%</p>

		<p>to 2.5% on average relative to counterfactual emissions, with most abatement occurring in the electricity and heat sector. Exploiting variation in carbon pricing to explain heterogeneity in treatment effects, we find an imprecisely estimated semi-elasticity of a 0.05% reduction in emissions growth per average \$1/metric ton (hereafter abbreviated as: ton) of CO₂. After the carbon price has been implemented, each marginal price increase of \$1/tCO₂ has temporarily lowered the growth rate of CO₂ emissions by around 0.01%. These are disappointingly small effects. Simulating potential future emissions reductions in response to carbon price paths, we conclude that –in the absence of complementary non-pricing policy interventions – carbon pricing alone, even if implemented globally, is unlikely to be sufficient to achieve emission reductions consistent with the Paris climate agreement.</p>
D.6(2020)	<p>Rafaty, R., Kazhdan, D., Shumailov, I., Zhao, Y., Anderson, R. (2020). “The Energetics and Environmental Impact of Machine Learning”.</p>	<p>Recent years have seen enormous growth in the research, development, and deployment of Machine Learning (ML) in every major sector of the economy. Among other technical catalysts, this growth is commonly attributed to improvements in hardware technology. Yet despite those improvements, ML computations and inferences invariably generate non-zero fixed and marginal costs that are non-trivial in the context of international climate targets to reach ‘net zero’ greenhouse gas emissions by mid-century. Energy-and emissions-related costs of ML can be substantial – a typical inference run performs billions of computations, and the training of modern models requires hundreds of thousands of them – but have only recently garnered attention among ML researchers. In this paper, we quantify the costs of electricity and heat emissions generated by common applications of ML longitudinally. We highlight the challenge of exponential growth in electricity and heat generation requirements and propose a framework for taxing the growing contribution of ML to emissions at large data centers.</p>
D.7(2020)	<p>Roger, C. and Rowan, S. (2020) “The new Terrain of Global Governance: Mapping Membership and Fragmentation across International Organisations”.</p>	<p>The world of international organizations is vast and diverse. However, much of our knowledge about international institutions draws from studies of a particular subset of institutions, namely formal international organizations, as measured with the Correlates of War dataset. This article presents an analysis that uses a new dataset of state membership in informal international organizations–IOs founded with non-binding legal instruments–which have come to constitute roughly one- third of all operating IOs. In this paper, we explain how we conceptualize informal IOs as a distinct sub-type of IOs (both formal and informal). We then use this new dataset to revisit longstanding several questions in the field of international organization: First, who</p>

		<p>participates in IOs and how has participation changed over time? Second, what are the determinants of state membership in IOs? Third, and more generally: is the IO network becoming more fragmented or fragmenting over time? Using our new dataset recasts existing findings on these topics in a new light, showing that taking informal bodies into account can shift key theoretical conclusions. The paper concludes by outlining a research program that takes seriously how considering informal IOs more generally reshapes our understanding of international affairs.</p>
D.8(2020)	<p>Rowan, S. (2020) "Climate Shocks and the Supply and Demand for Climate Governance".</p>	<p>Existing studies have demonstrated substantial and robust effects of temperature shocks on economic growth, agricultural output, labor productivity, conflict, and health. These studies help clarify the impacts of climate change on social and economic systems, yet the relationship between climate shocks and political outcomes are less well identified. What effect do climate shocks have on states' climate policies? In this paper, I estimate the relationship between national-level temperature and rainfall shocks and the supply and demand for international climate governance. Temperature shocks may increase the salience of climate change in national politics and lead political leaders to adjust policies to match. Similarly, temperature shocks may have material consequences that induce adaptation---one avenue being to use international institutions to coordinate a global response to climate impacts. I argue that the responsiveness of national governments to climate shocks is conditioned by the political and natural context in which governments operate. Specifically, I expect that democratic governments will be more responsive to climate shocks, as will countries that are more vulnerable to the impacts of climate change. I assess whether countries that experience more frequent and more severe climate shocks participate more in international climate politics and adjust their climate policies. I examine four sets of outcomes at the national level: (1) membership in international institutions that govern climate change, (2) the provision and receipt of climate finance, (3) representation at the UN climate conferences, and (4) national climate policies. As the climate changes, we are developing stronger evidence about the underlying natural relationships, but the heterogenous effects across socio-political contexts are less well understood. This paper contributes to our understanding of how climate change shapes national policy and with it the ability of countries to manage and adapt to climate change.</p>
D.9(2020)	<p>Schwarz, M. & Pretis, F. (2020) 'An empirical climate damage function accounting for climate extremes and adaptation'. Working paper.</p>	<p>Quantifying the economic impacts of climate change is crucial to inform mitigation and adaptation policy. Allowing for the potential impact of climate</p>

		<p>extremes and plausible adaptation pathways, we estimate a climate damage function using machine learning and econometric model selection. Combined with a novel baseline of country-level long-run forecasts of future economic development, we project a decline in median GDP per capita of around 23% for 1.5°C warming, with median reductions of up to 66% for warming beyond 4.5°C relative to no climate change. Projected marginal impacts suggest an approximate 12% decline in median GDP per capita for each additional degree of warming. We provide empirical evidence of climate adaptation at a macro-economic level, showing that the damage curve has not remained constant over time or incomes. Instability over time has lowered projected median GDP per capita impacts by approximately 20 percentage points. Income-driven adaptation could reduce the marginal impacts of an additional degree of warming by a half. Nevertheless, projected damages remain high and unequal even in the presence of adaptation, suggesting median GDP per capita reductions of around 30-40% for warming beyond 4.5°C, reiterating the urgent case for stringent mitigation policy.</p>
D.10(2020)	<p>Thalheimer, L., Otto, F.E.L. and Abele, S (2020) "Attributing climate change and human mobility in East Africa: A meta-analysis using Topic Modelling" (Under review with <i>Climatic Change</i>).</p>	<p>Increased migration is often portrayed as a key impact of anthropogenic climate change. Yet, causal, quantitative evidence on this link remains sparse and suffers from disciplinary hurdles. Here, we use a simple topic model to classify existing published empirical evidence on climate impacts and population movements in East Africa, an alleged hotspot of climate-related mobility. We find that studies imply a correlation between human mobility and climate change while under or misrepresenting evidence in climate science. In particular, the grey literature depicts climate change as a tipping point for forced migration and conflict, but uses inadequate data to support such claims. Providing examples from other regions and the emerging science of event attribution, we show how recent scientific developments now allow for quantitative evidence on climate change and migration to be provided more comprehensively and that this should be a research priority.</p>
D.11(2020)	<p>Thalheimer, L., Schwarz, M. P., & Pretis, F. (2020) 'Disentangling the effects of climate and conflict on displacement: Evidence from Somalia'. Working paper.</p>	<p>Weather, climate, and conflict-related events may drive forced displacement. However, their individual contribution to displacement is not fully understood due to challenges around isolating individual channels of causality. Here, we use novel disaggregated data on displacement in all of Somalia's 18 regions from 2016-2018 broken down by reason of displacement and combine it with weather and conflict data to isolate the effects of climate and conflict on forced displacement, as well as the effects of climate and displacement on conflict itself. We find large non-linear lagged effects of weather on displacement and</p>

		immediate effects of conflict on displacement, which are masked when the data is aggregated. We also show that reduced precipitation increases the probability of armed conflict, however, migration itself has no effect on the probability of conflict events.
2019		
A	PUBLISHED JOURNAL ARTICLES	
A.1(2019)	Sir David Hendry recommends 'An analysis of the indicator saturation estimator as a robust regression estimator' by Søren Johansen and Bent Nielsen , 1—36 in Castle, J.L. and Shephard, N. (Eds.) <i>The Methodology and Practice of Econometrics</i> , Oxford University Press, 2009, in <i>21st Century Economics: Economic Ideas You Should Read and Remember</i> , Bruno Frey and Christoph Schaltegger(eds), Springer, 2019	It may be thought that testing for outliers and shifts everywhere in a sample might adversely affect statistical inference. Fortunately, the rigorous and innovative analysis by Søren Johansen and Bent Nielsen for impulse-indicator saturation (IIS) allays such concerns. Under the null of no outliers, the limiting distribution of the IIS estimator of economic parameters of interest converges to their population parameters at the usual rate and is normal for stationary data. Yet IIS checks for an unknown number of outliers, of unknown magnitudes and signs, not knowing in advance where they occur in the data.
A.2(2019)	Ericsson, N.R. and Martinez, A.B. (2019) 'Evaluating Government Budget Forecasts' , 37—69 in D Williams and TD Calabrese (Eds) <i>The Palgrave Handbook of Government Budget Forecasting</i> . Springer	This chapter reviews the literature on the evaluation of government budget forecasts, outlines a generic framework for forecast evaluation, and illustrates forecast evaluation with empirical analyses of different U.S. government agencies' forecasts of U.S. federal debt. Techniques for forecast evaluation include comparison of mean squared forecast errors, forecast encompassing, tests of predictive failure, and tests of bias and efficiency. Recent extensions of these techniques utilize machine-learning algorithms to handle more potential regressors than observations, a characteristic common to big data. These techniques are generally applicable, including to forecasts of components of the government budget; to forecasts of budgets from municipal, state, provincial, and national governments; and to other economic and non-economic forecasts. Evaluation of forecasts is fundamental to assessing the forecasts' usefulness, and evaluation can indicate ways in which the forecasts may be improved.
A.3(2019)	Farmer, J.D., Hepburn, C, Ives, M.C., Hale, T., Wetzer, T., Mealy, P., Rafaty, R. Srivastav, S. Way, R. (2019) 'Sensitive Intervention Points in the Post-Carbon Transition' , <i>Science</i> , 364 (6436), 132-134.	Conventional approaches to mitigating climate change are not working. Despite the actions pledged under the 2015 Paris Agreement, actual progress is falling well short. Given limited time and resources, traditional efforts such as the climate stabilization wedge approach are unlikely to be effective on their own. Physical science has shown how complex adaptive systems can cross critical thresholds ("tipping points"), such that a relatively small change can trigger a larger change that becomes irreversible, where nonlinear feedback effects act as amplifiers. We propose to examine how to exploit similar sensitive

		intervention points (SIPs) and amplification mechanisms in socioeconomic, technological, and political systems to advance climate change mitigation. We focus on research and policies in which an intervention kicks or shifts the system so that the initial change is amplified by feedback effects that deliver outsized impact.
A.4(2019)	Jevrejeva, S., Carson, M., Le Cozannet, G., Frederikse, T., Kopp, R.E., Jackson L.P., and van de Wal, R.S.W. (2019) ' Probabilistic sea level projections at the coast by 2100 ', <i>Surveys in Geophysics</i> . Open Access.	As sea level is rising along many low-lying and densely populated coastal areas, affected communities are investing resources to assess and manage future socio-economic and ecological risks created by current and future sea level rise. Despite significant progress in the scientific understanding of the physical mechanisms contributing to sea level change, projections beyond 2050 remain highly uncertain. Here, we present recent developments in the probabilistic projections of coastal mean sea level rise by 2100, which provides a summary assessment of the relevant uncertainties. Probabilistic projections can be used directly in some of the decision frameworks adopted by coastal engineers for infrastructure design and land use planning. However, relying on a single probability distribution or a set of distributions based upon a common set of assumptions can understate true uncertainty and potentially misinform users. Here, we put the probabilistic projections published over the last 5 years into context.
A.5(2019)	Qu, Y., Jevrejeva, S., Jackson, L.P., and Moore, J. (2018) ' Coastal sea level rise and contributors around the China Seas ', <i>Global and Planetary Change</i> , 172 , 454-463.	We analyze the sea level rise along the Bohai Sea, the Yellow Sea, the East China Sea, and the South China Sea (the "China Seas") coastline using 25 tide gauge records beginning with Macau in 1925, but with most starting during the 1950s and 60s. The main problem in estimating sea level rise for the period is the lack of vertical land movement (VLM) data for the tide gauge stations. We estimated VLM using satellite altimetry covering the 18 stations with records spanning 1993–2016. The results show that many tide gauge stations, typically in cities, have undergone significant subsidence due to groundwater extraction. After removing the VLM from tide gauge records, the 1993–2016 sea level rise rate is 3.2 ± 1.1 mm/yr, and 2.9 ± 0.8 mm/yr over the longer 1980–2016 period. We estimate the steric sea level contribution to be up to 0.9 ± 0.3 mm/yr, and contributions from ice mass loss from glaciers and ice sheets of up to 1.1 ± 0.1 mm/yr over the last 60 years. Contributions from VLM range between -4.5 ± 1.0 mm/yr and 1.4 ± 1.3 mm/yr across the stations. Projections of coastal sea level probability distributions under future climate scenarios show that the steric factor is the main contributor under both the RCP 4.5 and High-end RCP 8.5 scenarios except in the upper tails under High-end RCP 8.5 when the Antarctic ice sheet makes the greatest contribution. By 2100 we expect

		median coastal sea level rises at the stations of 48–61 cm under RCP 4.5, and 84–99 cm under High-end RCP 8.5 scenario.
A.6(2019)	Rowan, S. (2019) ' Pitfalls in Comparing Paris Pledges ', <i>Climatic Change</i> , Open Access.	The Paris pledges are unique documents in climate governance that outline what each country intends to do to combat climate change. Often, these documents contain headline greenhouse gas percentage reduction targets that appear to summarize countries' contributions to mitigation. This is a boon for comparative climate policy research. However, I show in this paper that the Paris pledges require detailed interpretation to be comparable. I demonstrate the risks in comparing these targets by re-visiting a recent study linking national public opinion to the stringency of countries' mitigation goals. I develop new indicators that better account for the structure of the targets and show in replications that the original finding is inconsistent with the underlying data. I conclude by drawing lessons for studying the Paris pledges.
A.7(2019)	Walker, A.J., Pretis, F., Powell-Smith, A., & Goldacre, B. (2019). " Variation in responsiveness to warranted behaviour change among NHS clinicians: Novel implementation of change detection methods in longitudinal prescribing data ", <i>British Medical Journal</i> , 367 with a linked editorial https://www.bmj.com/content/367/bmj.l5652 .	To determine how clinicians vary in their response to new guidance on existing or new interventions, by measuring the timing and magnitude of change at healthcare institutions. Substantial variation was observed in the speed with which individual NHS general practices responded to warranted changes in clinical practice. Changes in prescribing behaviour were detected automatically and robustly. Detection of structural breaks using indicator saturation methods opens up new opportunities to improve patient care through audit and feedback by moving away from cross sectional analyses, and automatically identifying institutions that respond rapidly, or slowly, to warranted changes in clinical practice.
B	PUBLISHED BOOKS	
B.1(2019)	Castle, J.L., Clements, M.P., and Hendry, D.F. (2019) ' Forecasting: An Essential Introduction ', Yale University Press.	The book poses and seeks to answer most questions about forecasting based around a dramatically bad car journey where almost everything that might ever go wrong, does. What are forecasts, why do we need them, and how do we make them? Where are we before we forecast and how can we judge forecast accuracy? How uncertain are our forecasts and why do some 'real world' events seem unpredictable? Why do systematic forecast failures occur and how can we avoid them? Is there a way to automatically detect breaks, can we forecast breaks before they hit, and if not, can we improve forecasting during breaks? Would more information be useful, and if so, what kind? Can econometric models improve forecasting and despite their problems, should you trust economic forecasts?

B.2(2019)	Castle, J.L. and Hendry, D.F. (2019). ' Modelling our Changing World ', Palgrave, Open Access.	The evolution of life on Earth – a tale of both slow and abrupt changes over time – emphasizes that change is pervasive and ever present. Change affects all disciplines using observational data, especially time series of observations. When the dates of events matter, so data are not ahistorical, they are called non-stationarity denoting that some key properties like their means and variances change over time. There are several sources of non-stationarity and they have different implications for modelling and forecasting.
C	PUBLISHED REPORTS	
C.1(2019)	Devadason, C.A., Jackson, L.P., and Cole, J. (2019). ' Pacific Island Countries: An Early Warning of Climate Change Impacts ', <i>Report from the Secretariat of the Rockefeller Foundation Economic Council on Planetary Health</i> .	This paper explores the impacts from climate change and associated sea level rise on human health and livelihoods. Small islands states, particularly in the Pacific, are on the front line of these impacts, and this paper identifies fisheries as key sources of government revenue and economic livelihoods in Pacific Island Countries that are at risk. The governance of the response to the challenges that Pacific Island Countries face are a key topic of this paper, including the issue of climate-related migration and refugees.
C.2(2019)	Jackson, L.P. and Devadason, C.A. (2019). ' Climate Change, Flooding and Mental Health ', <i>Report from the Secretariat of the Rockefeller Foundation Economic Council on Planetary Health</i> .	This paper explores the linkages between climate change, flooding and mental health. It shows that the rapid mitigation of carbon emissions will slow the current rate of sea-level rise, thus allowing for a greater range of adaptation options to be implemented. Adaptation options include coastal protection to reduce vulnerability, which limits the potential for mental health impacts, while capital investment to increase mental healthcare quality and capacity will allow states to protect themselves against catastrophic floods. Education is critical to raise awareness of this planetary health issue, so as to improve preparedness and resilience in the wake of future change.
C.3(2019)	Mattauch, L., Creutzig, F., Moore, N., Franks, M., Funke, F., Jakob, M., Sager, L., Schwarz, M. et al. (2019). ' Antworten auf zentrale Fragen zur Einführung von CO2 Preisen (Answers to Key Questions about the Introduction of Carbon Prices. Design Options and their Implications for the Rapid Transition to the Climate-Friendly Society) ', <i>Diskussionsbeiträge der Scientists for Future</i> .	Climate protection is a very high priority for the citizens. This is reflected not only in surveys on a regular basis, but also in the political movement "Fridays for Future" and "Klimastreik". Nevertheless, efforts to reduce greenhouse gas emissions remain inadequate. One key reason for the mismatch between belief and collective action is that greenhouse gases, especially in Germany and Austria, do not have a reasonable price. Climate damaging behavior is often too cheap, climate-friendly alternatives are usually financially less attractive. This applies to everyone: businesses, citizens, citizens and the public sector. As agreed in the Paris Climate Agreement 2015, to keep the temperature rise well below 2 ° C and to make efforts to increase the temperature rise to 1. 5 ° C, the space remaining for other greenhouse gases in the atmosphere is very scarce. Scarce goods should be expensive in a market economy - otherwise

		there is a market failure. However, greenhouse gases have not yet been adequately priced.
C.4(2019)	Thalheimer, L., Ficko, A., Rocque dr Pinho, J., Hashimshony-Yaffe, N., Paschalidou, A., Savic, D., Stojanov, R., Suska-Malawska, M., van der Geest, K., Webersik, C., and Williams, D.S. (2019). Food Security in Drylands under a Changing Climate , <i>Policy Brief</i> .	Food insecurity and climate change pose defining challenges of our time. Improved food security for sustainable development is a key issue articulated at EU and international levels. Today, challenges around food security are numerous, diverse, and interrelated (fig. 1). Due to climate change, extreme climatic events such as floods, droughts and heatwaves are projected to increase in intensity and frequency, adversely affecting poor people already vulnerable to climate change impacts (Hallegatte et al. 2016) and exacerbating global food insecurity. In this policy brief, we outline six priority areas of urgent action for policy makers and private sector leaders in dryland areas to make the next harvests work for a sustainable future in the era of climate change.
D	PAPERS IN PROGRESS/WORKING PAPERS	
D.1(2019)	Sato, M., Rafaty, R., Cael, R., and Grubb, M. (2019). Cap-and-trade in the European Union, Forthcoming in Holt, W.G. (ed.), <i>Contesting Carbon Policies</i> , Routledge. Publication confirmed but delayed to 2021 due to COVID-19.	The European Union's Emissions Trading Scheme (EU ETS) was established in 2005. It was the world's first major international carbon market and by far the largest, covering 12,000 power plants and industrial installations across Europe and more than 40 percent of EU emissions. The history of Europe's flagship climate policy deserves our attention, for it is replete with lessons. As the first policy experiment of its kind, the EU ETS has experienced successive periods marked by disruption, trial and error, and learning-by-doing. Later cap-and-trade systems have also had the opportunity to learn from the EU's experience as a pioneer, both the dos and don'ts—and they need to. To avoid repeating past mistakes and facilitate adoption of more robust carbon pricing models across the world, it is essential that we understand the European experience with carbon trading. The EU ETS has seen its share of ups and downs. After an initial collapse of the price of emissions allowances, allowances traded for single-digit prices for many years. These low prices have often been seen as inadequate to induce significant behavioural adjustment, capital investment, and technological change. Even so, the program helped catapult carbon emissions and energy efficiency onto the agendas of CEOs and shareholders of some of Europe's largest companies. More recently, persistent efforts to reform the EU ETS have borne fruit and we have seen a resurgence of allowance prices to above €20/tCO ₂ in 2018. The question is not whether the EU ETS has been a success or a failure, but rather what its many successes and failures can teach us. Experience teaches us that pricing carbon is very difficult in practice, and the devil is often hiding in the details. This chapter looks at what was done, what we have learned, and most importantly, where we might

		go from here. We draw key lessons from a decade's experience – with respect to implementation, cost impacts, efficiency, and effectiveness – and highlight the key challenges ahead.
D.2(2019)	Thalheimer, L., Pretis, F., Schwartz, M., and Otto, F.E.L. (2019) 'The Multifaceted relationship between extreme weather events, displacement and conflict: New insights from Somalia'.	Extreme weather and migratory events have been topics of great interest for decades. More recently, a debate has emerged whether the human impact of climate change can lead to armed conflict, and how conflict and extreme climate events interact in inducing large-scale displacement. This paper explores the relationship between conflict and displacement in the context of droughts and floods across Somalia, a country in the East Africa region, in which the population has historically been using migration as coping strategy for the effects of recurring climatic extremes and socio-economic uncertainties. Since 2015, Somalia has been affected by a humanitarian crisis, paired with on-going conflict, which subsequently reduced resilience of its population. Empirical evidence suggests significant interaction effects between conflict and extreme weather events on migration, where pre-existing conflict conditions act as accelerators of climate-induced displacement.
D	PAPERS IN PROGRESS WORKING PAPERS 2018 AND EARLIER	
D.1(2018)	Hendry, D.F. and Pretis, F. (2018). 'Quantifying the Uncertainty around Break Dates in Models using Indicator Saturation'.	We investigate the uncertainty around the timing of breaks detected in models selected using step-indicator saturation (SIS). Uncertainties around the magnitudes of breaks found by SIS can be calculated using the variance of the coefficient path. Quantifying the uncertainty around the timing of a break in SIS would help in attribution to known events. Relying on congruence of designed models in general-to-specific model selection, we use the approximate normal distribution of the error terms to compute the probability of the underlying break falling in any specified interval around a detected break. This allows us to compute approximate probabilities of the date of the true break indicator coinciding with the date of the estimated break indicator, as a function of the estimated break magnitude and error variance. This allows hypothesis tests on break dates an invaluable feature when attributing detected shifts to known events, from shocks in economics, to policy interventions in climate change. Analytical results show that a 2 standard-deviation shift precisely coincides with the correct date approximately 64% of the time, with an approximate 95% confidence interval of ± 3 periods. Monte Carlo simulations confirm the approximate confidence intervals for the break date in SIS.

D.2(2018)	Jackson, L.P. and Hendry, D.F. (2018) 'Risk and Exposure of Coastal Cities to Future Sea-Level Rise', <i>Revise and Resubmit, Oxford Martin School Policy Paper</i> .	The Earth's climate is changing. It always has, and it always will. The difference between changes occurring now and the many changes that have occurred in the past is that today's primary cause is rising greenhouse gas emissions produced by us. The climate response to rising emissions will have potentially adverse effects on humanity. The sea level across the globe is rising. Indeed, it is now rising faster than it has done at any time in the last 2000 years. Over the 20th century that rise was around 20 centimetres (cm). Though a rise like this sounds small, future projections by 2100 range from twice to ten times this amount (40–200 cm) and sea-level rise does not occur in isolation. Sea-level rise combined with enhanced waves, tides and storm-surges will increase the height and occurrence of coastal floods, causing an increase in coastal vulnerability where globally 1-in-10 of us live within 10 metres above sea level and most especially in large coastal cities. We explain the connection between sea-level rise, its key components and global emissions. We discuss how much sea level could rise in future given our choice of emissions pathway. We consider the base-line economic cost of sea-level rise for major coastal cities based upon those same pathways and discuss who will be most affected and how parallel problem of mitigation and adaptation can be tackled. We challenge the policy-making community to review their present mitigation strategies to achieve their Paris Accord pledges and develop an appropriate framework for coastal adaptation, as well as promote systems for observing the oceans to improve knowledge of how the Earth functions.
D.3(2018)	Pretis, F., Hepburn, C., Teytelboym, A., and Pfeiffer, A. (2018). Are we Running out of Resources? Working Paper.	Mineral commodities are essential inputs to economic production. For decades, and still today, concerns have been advanced and rebutted about resource scarcity and its impact on global economic output. However, there has been no systematic study that has determined whether mineral commodities have become scarcer over the long run. Here we provide systematic evidence that near-term exhaustion of economically valuable mineral reserves is unlikely. We construct a comprehensive new database of 48 economically-relevant commodities from 1957–2015, including estimates of worldwide production and reserves, US prices and consumption, using publicly-available data and further data requested from the United States Geological Survey. We explore trends in reserve-to-production ratios on a mineral-by-mineral basis, using advanced econometric techniques to allow for structural breaks, and estimate overall trends robust to outliers. For almost all minerals, we cannot reject the null hypothesis of no trend. A panel analysis, to assess whether patterns are common across commodities, also shows no statically

		<p>significant negative trends in reserve-to-production ratios, despite increasing production. Rather, reserves are growing in line with consumption and production despite short-run price spikes and supply constraints for specific minerals, resulting for instance from political instability. Price signals in such markets have guided consumption and provided incentives for innovation and substitution. Concerns about externalities, such as pollution and conflict, and about the collapse of renewable resources where price signals are absent, appear more urgent than concerns about exhaustible resource depletion.</p>
D.4(2017)	<p>Pretis, F., Kaufmann, R.K., and Gopal, S. (2017). Local Emissions Affect Local Climate: Attribution, Impacts, and Policy. Working Paper.</p>	<p>To date, most scientific inquiries regarding the causes for and impacts of anthropogenic climate change assume that the climate effects of most radiatively-active gases are well mixed. Here we test the hypothesis whether local emissions measurably affect local temperatures beyond global average concentrations by estimating a spatially explicit energy balance model from a dataset which includes observations for global radiative forcing, surface temperature, and proxies for local forcing from 1970 to 2008 for 50 grid cells. Results indicate that the measures for local forcing have explanatory power about local temperatures that extends beyond global radiative forcing. SO₂ emissions lower local temperatures contemporaneously and in the long-run, whereas local CO₂ emissions lead to a contemporaneous transitory local warming. These results imply that omitting the local effects of radiative forcing may overlook spatial fingerprints that can be used to attribute climate change to human activities. Omitting this spatial component also may cause empirical models to systematically bias the estimated impacts of climate change on human populations and socio-economic outcomes. Finally, these results suggest that policy to slow climate change can generate local effects, which changes the attractiveness of climate change policy by moving costs and benefits from the 'global commons' to those who reduce emissions.</p>