NEW ANALYTICAL TOOLS AND TECHNIQUES FOR ECONOMIC POLICYMAKING

OECD-NAEC and Baillie Gifford

In association with Partners for a New Economy (P4NE); Rebuilding Macroeconomics; Institute for New Economic Thinking (INET) Oxford; European Commission Joint Research Centre; International Institute for Applied Systems Analysis (IIASA); Fields Institute, Complex System Institute of Paris idF; the Santa Fe Institute; and Capital Fund Management (CFM)

Abstracts and Bios

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Further information: William Hynes – william.hynes@oecd.org

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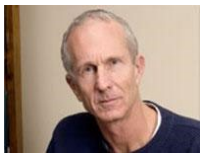
Understanding of economic issues such as growth, financial crises, systemic risk, innovation and sustainability can benefit from the revolution taking place across a range of scientific disciplines and in the social sciences. This revolution is being driven by the interaction between technological progress in computing and communications and the new sources and greater quantities of data this makes available.

This NAEC conference offers a timely opportunity for policy-makers, academics and researchers in economics to discuss the state-of-the-art policy applications emerging from the new analytical tools and techniques. It will look at how methodological innovations and inter disciplinary approaches such as agent-based modelling, nowcasting, machine learning, and network analysis could contribute to better understanding of the complexity and interaction of our economic, financial, social and environmental systems.

Monday 15 April

9:30 - 10:00	**Opening remarks:**
	Angel Gurria, OECD Secretary-General (video) Gabriela Ramos, OECD Chief of Staff and Sherpa Laurence Boone, OECD Chief Economist Martine Durand, OECD Chief Statistician
10:00 – 11:00	**Session 1: Why Do We Need New Analytical Tools and Techniques?**
	Moderator: Gabriela Ramos, OECD Chief of Staff and Sherpa Speakers:

- J. Doyne Farmer, Director of Complexity Economics, Institute for New Economic Thinking, and Santa Fe Institute, and Rebuilding Macroeconomics



J. Doyne Farmer *is Director of the Complexity Economics programme at the Institute for New Economic Thinking at the Oxford Martin School, and the Baillie Gifford Professor at Mathematical Institute at the University of Oxford, as well as an External Professor at the Santa Fe Institute.*

His current research is in economics, including agent-based modeling, financial instability and technological progress. He was a founder of Prediction Company, a quantitative automated trading firm that was sold to the United Bank of Switzerland in 2006. His past research includes complex systems, dynamical systems theory, time series analysis and theoretical biology.

During the eighties he was an Oppenheimer Fellow and the founder of the Complex Systems Group at Los Alamos National Laboratory. While a graduate student in the 70's he build the first wearable digital computer, which was successfully used to predict the game of roulette.

- Robert Axtell, Chair of the Department of Computational Social Science at George Mason University, and Santa Fe Institute

Robert Axtell *is an Associate Professor of the Santa Fe Institute who works at the intersection of economics, behavioral game theory, and multi-agent systems computer science. His most recent research attempts to emerge a macroeconomy from tens of millions of interacting agents. He is Department Chair of the new Department of Computational Social Science at George Mason University (Fairfax, Virginia, USA). He teaches courses on agent-based modeling, mathematical modeling, and game theory. His research has been published in "Science," "Proceedings of the National Academy of Sciences USA," and leading field journals. Popular accounts have appeared in newspapers, magazines, books, online, on the radio and in museums. His is the developer of Sugarscape, an early attempt to do social science with multi-agent systems, andco-author of "Growing Artificial Societies: Social Science from the Bottom Up" (MIT Press 1996). Previously, he was a Senior Fellow at the Brookings Institution (Washington, D.C. USA) and a founding member of the Center on Social and Economic Dynamics there. He holds an interdisciplinary Ph.D. from Carnegie Mellon University (Pittsburgh, USA).*

- Jean-Philippe Bouchaud, Chairman, Capital Fund Management (CFM) and Rebuilding Macroeconomics

Jean-Philippe Bouchaud *is Chairman and Chief Scientist. He supervises the research and maintains strong links between the research team and the academic world. He is also a professor at Ecole Polytechnique where he teaches Statistical Mechanics and a course on 'Complex Systems'. He joined CFM in 1994.*

- William H. Janeway, Faculty of Economics, Cambridge University and Advisor, Warburg Pincus

William H. Janeway has lived a double life of "theorist-practitioner," according to the legendary economist Hyman Minsky, who first applied that term to him twenty-five years ago. In his role as "practitioner," Bill Janeway has been an active growth equity investor for more than 40 years. He is a senior advisor at Warburg Pincus, where he has been responsible for building the information technology investment practice, as well as a director of Magnet Systems and O'Reilly Media. As a "theorist," he is an affiliated member of the Faculty of Economics of Cambridge University, a member of the board of directors of the Social Science Research Council and the Fields Institute for Research in the Mathematical Sciences, and of the Advisory Board of the Princeton Bendheim Center for Finance. He is a co-founder and member of the Governing Board of the Institute for New Economic Thinking (INET), and a member of the Board of Managers of the Cambridge Endowment for Research in Finance (CERF). Following publication in November 2012, his book Doing Capitalism in the Innovation Economy: Markets Speculation and the State (Cambridge University Press) became a classic. The fully revised and updated second edition, Doing Capitalism in the Innovation Economy: Reconfiguring the Three-Player Game between Markets, Speculators and the State was published in May 2018.

- Michael Jacobs, Professorial Research Fellow, Sheffield Political Economy Research Institute (SPERI)

Michael Jacobs *is a Professorial Fellow and Head of Engagement and Impact. He is an economist and political theorist, specialising in post-neoliberal political economy, climate change and environmental policy, and green and social democratic thought. He is responsible for oversight and leadership with respect to SPERI's engagement and impact work.*

Michael leads SPERI's Corporate Power & the Global Economy research theme with Merve Sancak.

Prior to joining SPERI Michael was Director of the IPPR Commission on Economic Justice, based at the UK think tank the Institute for Public Policy Research. He was principal author and editor of the Commission's final report Prosperity and Justice: A Plan for the New Economy (2018).

Originally a community worker and adult educator, Michael later became a director and then managing director of CAG Consultants, where he worked in local economic development and sustainable development. He was subsequently an ESRC research fellow at Lancaster University and the LSE. He was General Secretary of the think tank and political association the Fabian Society from 1997-2003.

From 2004–2007 Michael was a member of the Council of Economic Advisers at the UK Treasury, and from 2007–2010 he was a Special Adviser to Prime Minister Gordon Brown, with responsibility for energy, environment and climate policy.

After leaving government in 2010, Michael advised governments and others on international climate change policy in the run-up to the UN Climate Conference in Paris in December 2015. He was a founder and senior adviser to the Global Commission on the Economy and Climate.

11:15 – 12:30	**Session 2 : Nowcasting**

Moderator: Lucrezia Reichlin, Professor of Economics, London Business School

Speakers:

- Laurent Ferrara, Head of International Macro Division, Banque de France
  When are Google data useful to nowcast GDP? An approach via pre-selection and shrinkage

Nowcasting GDP growth is extremely useful for policy-makers to assess macroeconomic conditions in real-time. In this paper, we aim at nowcasting euro area GDP with a large database of Google search data. Our objective is to check whether this specific type of information can be useful to increase GDP nowcasting accuracy, and when, once we control for official variables. In this respect, we estimate shrunk bridge regressions that integrate Google data optimally screened through a targeting method, and we empirically show that this approach provides some gain in pseudo-real-time nowcasting of euro area GDP quarterly growth. Especially, we get that Google data bring useful information for GDP nowcasting for the four first weeks of the quarter when macroeconomic information is lacking. However, as soon as official data become available, their relative nowcasting power vanishes. In addition, a true real-time analysis confirms that Google data constitute a reliable alternative when official data are lacking.

When are Google data useful to nowcast GDP? An approach via pre-selection and shrinkage

Laurent Ferrara *is Head of the International Macroeconomics Division at the Banque de France in Paris, in charge of the outlook and macroeconomic forecasting for advanced economies, as well as global policy issues such as exchange rates, commodities or global imbalances. Main tasks of this division of around 20 people are policy briefing, preparation of international meetings (ECB, IMF, OECD, G20) and economic research. He is also involved in academics and has been appointed Adjunct Professor of Economics at the University of Paris Nanterre in September 2011.*
Laurent Ferrara is Director of the International Institute of Forecasters, an international association aiming at bridging the gap between theory and applications in forecasting, through the organisation of workshops and conferences and the publication of an academic journal, the International Journal of Forecasting. He is also an associate editor of this journal.
Dr. Ferrara holds a PhD in Applied Mathematics from the University of Paris North (2001) and a Research Habilitation in Economics from the University of Paris 1 – Panthéon – Sorbonne (2007). His academic research mainly focuses on macroeconomic forecasting, international economics, econometric methods, non-linear modelling and business cycle analysis. He published more than 50 papers in international and national academic journals, chapters in books, as well as book on time series analysis and forecasting.

- Elias Albagli, Chief Economist, Central Bank of Chile
  Real-time VAT data in Chile: Applications for Monetary and Financial Policy

The Central Bank of Chile has been developing new administrative data sources for advancing its analytical and forecasting tools. Since 2016, the tax administration authority (SII) mandates transaction between firms to be electronically transmitted in real time for VAT accounting purposes. This wealth of data allows several important advances, both for projection and macroeconomic analysis purposes, as well as for structural economic research. We highlight three applications. First, real-time transactions allow computing value-added proxies for several sectors, enhancing *nowcasting* capacity and eventually diminishing the lag between economic activity data and Monetary Policy decisions by about a month. Second, the complete network structure also allows to better interpret linkages between supply and demand side of national accounts in real time. For instance, an expansion of wholesale machine and equipment intermediation sector can be linked precisely with the end-user sectors which are increasing fixed investment. This knowledge is of particular interest for a commodity exporting country, where mining investment has different lags and spillovers on overall economic activity as other sectors. Third, merging this data with credit information (also available for the universe of Chilean firms) is of potential use in detecting macroeconomic and financial stability risks. Indeed, the network structure in real-time can be used to detect disruptions (i.e., imminent firm closure), assess their spillovers to interconnected firms (customer and supplier), and predict the overall macroeconomic impact across different sectors as well as their implications for debt service capacity of affected firms.

Elías Albagli is the Director of Central Bank of Chile´s Monetary Policy Division, since August 2018. Previously, he was Director of Central Bank of Chile´s Research Division since June 2018. Previously he was Manager of Modeling and Economic Analysis of the Bank, (December 2014 through June 2018). He holds a Bachelor's degree in Business and a Master's in Financial Economics from the Catholic University of Chile (2002), where he received the best graduating student award.. He received his Ph.D. in Economics from Harvard University in 2010. Previously he worked in the Central Bank's Economic Research Division, most recently as a senior economist (June 2013 to November 2014) and also as an economic analyst (2002–2005). He was an assistant professor of Economics and Finance at the University of Southern California from 2010 to 2013. Mr. Albagli has taught courses on Financial Markets and Macroeconomics at different institutions, including the Economics Department at the Catholic University of Chile and the Economics and Business Management Department at the University of Chile. He has published numerous journal articles, book chapters and working papers on issues related to macroeconomics and financial markets.

14:00 - 16:00

Session 3 : Agent Based Modelling

Moderator: J. Doyne Farmer, Director of Complexity Economics, Institute for New Economic Thinking, University of Oxford, and Rebuilding Macroeconomics

Speakers:

- Alissa Kleinnijenhuis, Researcher, Mathematical Institute, Oxford, and Institute for New Economic Thinking, University of Oxford, and Thom Wetzer, DPhil candidate in Law and Finance, University of Oxford
  Foundations of System-Wide Stress Testing

Microprudential stress tests have been credited for restoring confidence in the banking sys-tem and allowing for a successful recapitalisation of banks (Bernanke (2013)). They have gained enormous importance in the post-crisis regulatory toolkit. Their core goal is to assess systemic risk. Despite their victories, microprudential stress tests lack interconnections, and thereby their ability to consider endogenously-amplified systemic risk. This fundamental deficiency impairs their ability to assess resilience, which has led various academics and regulators to call for system-wide stress tests (e.g. Brazier (2017)). Yet, no generic method exists yet (Anderson et al. (2018)). Challenges include (Anderson et al. (2018)): to capture systemic risk amplification mechanisms comprehensively and consistently; to encapsulate the behavioural responses to shocks; to encompass interactions between constraints and behaviour; to con- sistently incorporate non-banks; to reect the heterogeneity of objectives, resources and constraints (Danielsson and Shin (2003)); to exibly adjust to a changing financial system; and to deal with a lack of suffciently granular and well-covered data.

In this paper, we propose a novel method for system-wide stress testing { that is, to our knowledge, the first to jointly tackle these challenges. It consists of five building blocks: institutions, contracts, constraints, markets, and behaviour. Together, these allow to track contagious dynamics in a multiplex network and assess fragility under various policy set-ups. We illustrate the power of this method by providing an implementation of the building blocks. We show that systemic risk may be significantly underestimated if microprudential stress tests are not supplemented with a `macroprudential overlay'. Based on the tool's foundations, credible stress system-wide stress tests can be built to crown the macroprudential toolkit.

***Alissa Kleinnijenhuis** is a D.Phil Candidate in Financial and Computational Mathematics at the University of Oxford and the Institute for New Economic Thinking at the Oxford Martin School. She is also affiliated with the Oxford-Man Institute of Quantitative Finance. She works under supervision of Professor J. Doyne Farmer. Her research focuses on system-wide stress testing and systemic risk. Alissa acts as a visiting academic to the Bank of England (London), and has also conducted research on stress-testing at the European Central Bank (Frankfurt). In addition, her professional experience includes work for Morgan Stanley (London) and Rogge Global Partners (London). Alissa holds a B.A. (Hons) in Mathematics and Economics from University College Utrecht (partially completed at UC Santa Barbara) and an M.Sc. in Mathematics and Finance from Imperial College London.*

***Thom Wetzer** is a DPhil Candidate in Law and Finance at the Oxford Faculty of Law, the Oxford-Man Institute for Quantitative Finance and the Institute for New Economic Thinking at the Oxford Martin School. His research examines incentive misalignments and the role of law in mitigating them, with a particular focus on systematic misalignments that generate systemic risk in financial systems. He also works on climate risk in the context of the post-carbon transition.*

Thom has been a visiting scholar at Columbia Law School, the Berkeley School of Law, and Yale University, and is currently a visiting academic at the Bank of England and an academic consultant at the European Central Bank. He has worked at the European Commission, Goldman Sachs, and De Brauw Blackstone Westbroek, and is a 'Global Shaper' at the World Economic Forum.

- Stanislao Gualdi, Research Fellow, Capital Fund Management
  Optimal Inflation Target: Insights from an Agent-Based Model

Which level of ination should Central Banks be targeting? We investigate this issue in the context of a simplified Agent Based Model of the economy. Depending on the value of the parameters that describe the behaviour of agents (in particular ination anticipations), we find a rich variety of behaviour at the macro-level. Without any active monetary policy, our ABM economy can be in a high ination/high output state, or in a low ination/low output state. Hyper-ination, deation and \business cycles" between coexisting states are also found. We then introduce a Central Bank with a Taylor rule-based ination target, and study the resulting aggregate variables. Our main result is that too-low ination targets are in general detrimental to a CB-monitored economy. One symptom is a persistent under-realisation of ination, perhaps similar to the current macroeconomic situation. Higher ination targets are found to improve both unemployment and negative interest rate episodes. Our results are compared with the predictions of the standard DSGE model.

Stanislao Gualdi *is a Research Fellow at Capital Fund Management. He has a PhD in Theoretical Physics from the University of Fribourg and a Master's degree in Theoretical Physics from Sapienza Università di Roma. He was a Postdoctoral Researcher at Ecole Centrale Paris.*

- Torsten Heinrich, Researcher, Institute for New Economic Thinking, University of Oxford
  An ABM of the insurance-reinsurance sector: Conclusions for systemic risk, market structure, and the insurance cycle

Risk models are employed in the insurance and reinsurance industry to assess the probability and size of risk events. Under the new Solvency II regulations the choice of models that can be used in the insurance sector has become severely limited. This creates a danger in the sense that all insurance companies may rise and fall in tandem, making the sector brittle and creating a public welfare problem. We present here a novel agent-based model of the catastrophe insurance and reinsurance sectors to study this constraint. More than other branches of the insurance industry, catastrophe insurance is subject to heavy-tailed distributions, which occur for damage size, peril frequency, claims, losses, and bankruptcy events. As a consequence, agent heterogeneity, interaction and stochastic influences are of crucial importance. Characterising the system requires studying ensembles of counterfactual cases and considering not only the mean but also the dispersion of realisations. Agent-based modeling is well-suited to fulfill these requirements. We discuss the properties of the model; We substantiate the validation of modeling decisions with economy-level, firm-level, and contract level data; We explain micro- and macro-calibration of the model; And we show some selected results: 1. The reproduction of the insurance cycle. 2. The frequency and distribution of bankruptcies across different settings with different levels of risk model homogeneity. This aspect is directly connected to systemic risk in insurance. 3. Other systematic effects of risk model homogeneity. 3. The sensitivity of the model with respect to parameters such as the rate of market entry, the interest rate, and the capital retention requirements. 4. The resulting market structures in terms of firm sizes and relative shares of insurance and reinsurance business. 5. A market with several operational risk models is a lot more profitable, more competitive and has a higher capacity than a market with only one risk model.

Torsten Heinrich *is a researcher at the Institute for New Economic Thinking (INET) at the Oxford Martin School of the University of Oxford. His work is concentrated methodologically in the fields of agent-based modelling, game theory, complexity economics and evolutionary economics, but also empirical work on industrial organisation and technological change among other areas, with an interest in new technologies, in the potential they create, and in economic, social and political consequences their implementation could entail. He studied economics at the Dresden University of Technology (Dresden, Germany) and the Universidad Autónoma de Madrid (Madrid, Spain) graduating in 2007. He received his PhD from the University of Bremen, Germany, in 2011 with a thesis on technological change and growth patterns in the presence of network effects. Working on complexity systems, agent-based modeling, simulation and strategic games in economics, he has edited special issues in scientific journals and authored both journal articles and monographs. He holds a post-doc position at the Institute for New Economic Thinking (INET) at the University of Oxford, UK, and teaches at the University of Bremen, Germany.*

- Francois Lafond, Senior Research Officer, Institute for New Economic Thinking, University of Oxford
  Automation and bottlenecks in occupational mobility: a data-driven network model

Many existing jobs are prone to automation, raising important concerns about the future of employment. However, history suggests that alongside automation, different jobs are created so that it is crucial to understand job transitions. To do so, we impose an automation shock on a network-based labour market model. We construct an occupational mobility network, where nodes are occupations and edges link occupations that are similar enough for a worker to transition from one to the other. We then model the dynamics of employment, unemployment, and vacancies at the occupation level, based on exogenous (automation-related) reallocation of labour demand, separations and vacancies opening rates, job search, and matching. After discussing the model's calibration and its ability to reproduce the Beveridge curve, we study occupation-specific unemployment and long-term unemployment (27 or more weeks). As expected, in highly automated occupations, workers are more likely to be unemployed or to stay unemployed for a long period. However, the network structure also plays an important role - workers in occupations with a similar degree of automation can have fairly different outcomes, depending on the position of the occupation in the mobility network. Automation may cause 'bottlenecks' in the mobility network, with workers unable to find jobs for long periods. Our work highlights that retraining schemes must not necessarily be directed towards workers in occupations with high risk of automation, but towards workers with limited transition possibilities.

François Lafond *is a senior research officer at the Institute for New Economic Thinking, at the Oxford Martin School Programme on Technological and Economic Change, at the Smith School for Enterprise and the Environment, and an associate member of Nuffield college. He received his PhD from UNU-MERIT / Maastricht University. His main areas of research are in the economics of innovation, environmental economics, networks and complex systems, applied econometrics and forecasting.*

- Christoph Siebenbrunner, DPhil student, Mathematical Institute, University of Oxford
  Money creation and liquid funding needs

Starting from a conceptual discussion about money creation as opposed to loanable funds and money multiplier theories, we categorise different forms of lending; broadly speaking, bank-lending versus non-bank lending, whereby we equate the former with money creation and the latter with loanable funds theories. At this point, we provide a defnition of shadow banking which we link to all lending that is not bank lending and, hence, while increasing leverage for individual borrowers, does not increase system-wide money stocks. The purpose is then to put forward two concluding thoughts: First, the notion of money creation as a result of banks' loan creation for the private sector is compatible with the notion of liquid funding needs in a multi-bank system in which liquid fund transfers across banks happen naturally. Second, conventional interest rate-based monetary policy has a bearing on macroeconomic dynamics precisely due to that multi-bank structure. It would lose its impact in the hypothetical case that only one (\singular") commercial bank would exist. To illustrate the latter two points, we develop a simple agent-based model, with a focus on the bank loan creation (and destruction due to repayment) process, as opposed to pure intermediary lending through capital markets, banks' proprietary trading, and all other non-bank financial and non-financial institution types' channeling of funds within the system. The model comprises bank agents (money creators), non-bank intermediaries (pure \channelers"), a central bank (liquid base money provider),and private sector agents that borrow from banks or non-banks to finance their consumption.

Christoph Siebenbrunner *is a doctoral student in Mathematics and a member of the Complexity Economics research group under the supervision of Prof. Doyne Farmer at Oxford University. His research focusses on modelling systemic risk and financial systems in general, using a wide array of methodologies including statistical modelling, network analysis and agent-based modelling. He has seven years of professional experience working as a stress testing expert and quantitative modeller for central banks including the ECB and the Austrian National Bank.*

Discussant:

Robert Axtell, Chair of the Department of Computational Social Science at George Mason University, and Santa Fe Institute

Robert Axtell *is an Associate Professor of the Santa Fe Institute who works at the intersection of economics, behavioral game theory, and multi-agent systems computer science. His most recent research attempts to emerge a macroeconomy from tens of millions of interacting agents. He is Department Chair of the new Department of Computational Social Science at George Mason University (Fairfax, Virginia, USA). He teaches courses on agent-based modeling, mathematical modeling, and game theory. His research has been published in "Science," "Proceedings of the National Academy of Sciences USA," and leading field journals. Popular accounts have appeared in newspapers, magazines, books, online, on the radio and in museums. His is the developer of Sugarscape, an early attempt to do social science with multi-agent systems, andco-author of "Growing Artificial Societies: Social Science from the Bottom Up" (MIT Press 1996). Previously, he was a Senior Fellow at the Brookings Institution (Washington, D.C. USA) and a founding member of the Center on Social and Economic Dynamics there. He holds an interdisciplinary Ph.D. from Carnegie Mellon University (Pittsburgh, USA).*

16:30 – 18:00 **Session 4 : Network Analysis**

Moderator: David Chavalarias, Director of the Complex System Institute of Paris idF

Speakers:

- Rajan Patel, Technical Specialist, Bank of England
  Textual complexity in bank regulation

Reforms following the financial crisis of 2007-08 have increased the volume of bank regulation and led to concerns about increased complexity. But there are few empirical measures of regulatory complexity, beyond simple page counts. To measure precisely the change in regulatory complexity, we define it as a property of how standards are articulated in regulatory texts, and calculate linguistic and structural indicators that reflect the cognitive costs required to process texts. We extract these measures from a dataset that covers the near-universe of prudential rules for banks in the United Kingdom, including EU directives and supervisory guidance, in 2007 and 2017. To understand the drivers of complexity, we compare different regulatory tools (capital, liquidity, remuneration), and the relative contribution of international versus national rules. We also compare the complexity of rules that apply to small versus large institutions, and benchmark UK with US regulation. Network maps that visualise textual cross-references show that there are many peripheral rules and a few very highly connected ones, and that the latter are not necessarily the rules that were at the centre of the post-crisis debate. Similarly, the distributions of measures of lexical diversity, conditionality, length and readability are skewed. Finally, we combine structural and linguistic complexity to create a map that highlights opportunities for rule simplification.

Rajan Patel *is a Technical Specialist at the Bank of England where his work involves understanding how banks and insurers are responding to prudential regulation. He collaborates with people from across the Bank of England to identify and prioritise examples of regulatory arbitrage and unintended consequences from regulation. He helps policy experts and supervisors mitigate associated risks to the Bank's regulatory objectives. Rajan holds a masters in Economics from the London School of Economics and Political Science (LSE).*

- Gert Buiten, Senior Researcher, and Sjoerd Hooijmaaijers, Researcher, Statistics Netherlands
  A methodology for estimating the Dutch interfirm trade network

Currently, the National Accounts' aggregate Input-Output Tables are the main statistical instrument for analysing the complex circular effects of the economic cycle. A network approach on a micro level would boost the analytic capabilities. This paper describes the methodology developed by Statistics Netherlands for estimating the Dutch interfirm trade network using a combination of input data on trade transactions and auxiliary information from existing official statistics. The estimates result in a directed and weighted network dataset. There are various possible sources for collecting Input data on relationships, such as bank transaction data, overviews of debtors and creditors from company administrations and survey data. Each of these sources has some drawbacks and must be complemented by an imputation method for completing the picture. The past decade, a growing body of methods has been developed for estimating interfirm networks. Most of these methods combine macro or meso economic marginals (such as aggregate turnover by industry group) with one or more assumptions on the distribution of variables by company as well as on interfirm connections by company. The paper describes how this can first be expanded upon by using aggregate public data from Supply-Use Tables and Input-Output Tables as auxiliary data, allowing for a matching procedure between

suppliers and users by commodity group. Secondly, it describes a further improvement based on using non-public micro data on enterprises. The paper concludes with some examples of applications and analyses that can be developed using the estimated dataset.

Guert Buiten *studied Economic and Social History and works at Statistics Netherlands since 1986. He is one of the inventors of the Business Cylce Clock that is now widely used internationally, also by the OECD. In recent years he has been involved in various innovative research activities, including setting up cooperations with commercial banks for the use of transaction data, applying Complexity and Network Theory in official statistics and the research project for developing a methodology for deriving the interfirm trade network.*

Sjoerd Hooijmaaijers *holds a Masters degree in both Economics and Data Science. He has been working at Statistics Netherlands since 2017 in the research project for developing a methodology for deriving the interfirm trade network.*

- Thomas Hurd, Professor of Mathematics, McMaster University, Toronto
  Systemic Cascades in Financial Networks

Systemic risk (SR), the study of financial crises, has long been understood (see e.g. Kaufman (1994)) to involve cascades of contagious shocks of different types, notably funding liquidity shocks such as bank panics and runs and solvency shocks caused by failed banks. Compared to systems arising in other areas of applied science, the real world financial system is extraordinarily complex in a diversity of aspects. A popular approach to SR (see Nier et al. (2007), Hurd (2016)) has been to construct \deliberately simplifed" random financial networks (RFNs), and explore how different bank behaviour characteristics lead to cascades and amplification of shocks. This paper advances this \network science" approach by introducing a rich new class of \inhomogeneous financial networks (IFN)", each of which consists of a random connectivity \skeleton" graph of N banks, on which is defined a random collection of balance sheets and interbank exposures. Viewed as a multidimensional random variable, such an IFN has an amenable dependence structure known as \locally tree-like independence". The banks are assumed to follow crisis management strategies that boil down to sets of deterministic rules called \cascade mechanisms". Then, in scenarios of a large random shock that weakens the system su_ciently, a cascade sequence of secondary shocks will follow, converging to a \cascade equilibrium" representing the final outcome of the crisis. While detailed simulations are always possible for moderate values of N, instead we will focus on the kind of stylised facts that might be deduced from analytic cascade dynamics in the N = 1 limit. Topics of interest include: spillover effects of international linkages between two countries; comparing partial recovery at default to \hard" zero recovery; firesales in bipartite IFNs.

After an extensive research career in mathematical physics, ***Tom Hurd*** *turned to the mathematical study of financial markets in the late 1990s. Since then he has built an international research reputation, with many publications in areas such as portfolio theory, interest rate modeling, and credit risk. His work is currently focussed on modeling systemic risk, that is, the stability of financial networks, and he has recently published a book on the subject. Over the years, he has supervised numerous M.Sc. and Ph.D. research students in financial mathematics, many of whom have moved on to careers in banking. He is currently Director of the Master in Financial Mathematics program (MPhimac) at McMaster.*

- Igor Linkov, Risk and Decision Science Team Lead, US Army Engineer Research and Development Center
  Resilience and Efficiency in Interconnected Networks

Dr. Igor Linkov *leads the Risk and Decision Science Team and Focus Area at the US Army Engineer Research and Development Center. He is currently leading several projects implementing resilience management for cyber systems, critical infrastructure, energy and environment. He has published widely on environmental policy, environmental modeling, and risk analysis, including thirteen books and over 200 peer-reviewed papers and book chapters. Dr. Linkov has organised more than twenty national and international conferences and continuing education workshops, including 2014 workshop on Risk and Resilience in Berlin. He is recipient of two Army medals for outstanding civilian service and Society for Risk Analysis Chauncey Starr Award for exceptional contribution to Risk Analysis and Fellow Award.*

Tuesday 16 April

9:30 – 11:00	**Session 5: Machine Learning and Big Data**

Moderator: Martine Durand, OECD Chief Statistician

Speakers:

- Claudio Cozza, Assistant Professor of Economics, Department of Economic and Legal studies, University of Naples "Parthenope"
  Can we predict firms' innovativeness? The identification of innovation performers in an Italian region through a supervised learning approach

The study shows the feasibility of predicting firms' expenditures in innovation, as reported in the Community Innovation Survey, applying a supervised machine-learning approach on a sample of Italian firms. Using an integrated dataset of administrative records and balance sheet data, designed to include all informative variables related to innovation but also easily accessible for most of the cohort, random forest algorithm is implemented to obtain a classification model aimed to identify firms that are potential innovation performers. The performance of the classifier, estimated in terms of AUC, is 0.794. Although innovation investments do not always result in patenting, the model is able to identify 71.92% of firms with patents. More encouraging results emerge from the analysis of the inner working of the model: predictors identified as most important – such as firm size, sector belonging and investment in intangible assets – confirm previous findings of literature, but in a completely different framework. The outcomes of this study are considered relevant for both economic analysts, because it demonstrates the potential of data-driven models for understanding the nature of innovation behaviour, and practitioners, such as policymakers or venture capitalists, who can benefit by evidence-based tools in the decision-making process.

***Claudio Cozza** is assistant professor in Economic Policy at the Department of Economic and Legal studies of the University of Naples "Parthenope", Italy. He holds a Degree (University of Rome "Sapienza") and a Ph.D. (University of Ferrara) in industrial economics. His research interests include the Economics of Science, Technology and Innovation (R&D internationalisation, innovation systems and policies), Regional Development and Internationalisation (of both Advanced and Emerging Multinational Corporations). He has been researcher at the European Commission JRC; at ISTAT, the Italian National Statistical Office; and has conducted research and teaching activity in several Italian Universities and research organisations.*

- Janna Axenbeck, Researcher, Digital Economy, ZEW – Leibniz Centre for European Economic Research
  What Do Websites Say About Firm-Level Innovation? - A Machine Learning Approach

This paper explores which website characteristics can identify whether a firm is innovative or not. Firm websites entail information about new products, key personnel decisions, strategies and relationships with other firms. These aspects are all related to a firm's innovative activity. Extracting this information by means of website characteristics would allow to construct efficient innovation indicators that enable an automatised, timely and comprehensive analysis of firm-level innovation activities. I use German firms from the Mannheim Innovation Panel (MIP), classified as either innovative or not, and extract their websites' content by applying the ARGUS web-scraper, which allows me to collect texts as well as hyperlinks. I apply several methods like keyword search, topic modelling and other natural language processing tools to gather website characteristics. Then, I analyse which characteristics correlate most with a firm's innovation status reported in the MIP. Additionally, by using polynomial and interaction features as well as logistic regression and lasso regularisation, I identify which combination of website characteristics best predicts a firm's innovation status. My preliminary results show that innovation-related keywords like 'innovat' or 'change', the sum of hyperlinks and the amount of English language on a website significantly correlate with whether a firm is innovative or not. Moreover, website information significantly improves predictions about a firm innovation status and website characteristics correlate stronger with product than with process innovators.

***Janna Axenbeck** is a Researcher in Digital Economy ZEW – Leibniz Centre for European Economic Research since October 2017. She completed her bachelor's degree in socioeconomics at Hamburg University and her master's degree in public economics at the Free University of Berlin, including exchange semesters at Sciences Po Lille and National Taiwan University. During her master's programme, she focused on innovation economics and policy. Her major research interest is in the impact of digitisation on sustainability.*

- Michael Obersteiner, Programme Director, Ecosystems Services and Management, International Institute for Applied Systems Analysis (IIASA)
  Algorithmic policy making (through Hypernudging)

Michael Obersteiner *is Programme Director of the Ecosystems Services and Management Programme (ESM) at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. His current research team counts 100 staff members constituting the largest global land use and rural development model cluster in the world. They generate high quality data products on the biophysical and socio-economic dimensions of land resources management using novel methods of citizen science approaches. The ESM modelling teams use massive databases for impact assessments of integrated policies in various geographies. For example the ESM model cluster is used for background calculations by Parties to the UNFCCC such as EU, USA, Brazil, Indonesia and Congo basin countries feeding into the INtended National Contributions (INDC) for COP21 in Paris. Other ongoing research integrates high frequency household data logs from specialized mobile apps from remote farm households subject to climate risks to design innovative solutions for international donor and national planning agencies.*

Michael has been the principle investigator and manager of more than 30 international projects covering diverse policy and science fields mostly focus on developing sustainable development pathways subject to climate risks. These projects have built research communities to produce key data sets derived from Earth observation assets mainly focusing on land use attributes. These project have also contributed to numerous model intercomparision exercises such as AGMIP (Agriculture model intercomparision project), ISIMIP (The Inter-Sectoral Impact Model Intercomparison Project), and EMF (Energy Modelling Forum). Dr. Obersteiner also served as a seconded Staff Expert for the Group on Earth Observations (GEO) at the World Meteorological Organization (WMO) in Geneva leading a cross-cut task on socio-economic benefit assessments of Earth observing systems. In addition, he has been a consultant to a number of national and international organizations, including inter alia the European Commission, WWF, OECD, Worldbank and other national and international institutions. He is author of over 250 scientific papers covering many disciplinary science fields.

- Álvaro Gómez Losada, Scientific officer, Directorate General, Joint Research Centre, European Commission, Seville, Spain
  From Big Data to Smart Data

Machine Learning applications require in principle massive amounts of data in order to enhance the knowledge discovery process. In addition to availability and volume, real world datasets suffer from several imperfections. As a consequence, noise in data could lead to poor performance in statistical models. However, useful and valuable knowledge extracted from data is directly related to the quality of the data used and not necessarily to its quantity. Datasets from companies and governments can be considered as smart data (focusing on veracity and value but not on volume) in the sense that they can be effectively used for planning, monitoring and intelligent decision (policy) making.

In this study, three use cases using data science methodologies and medium-sized smart datasets are described. The first is an e-commerce application consisting of a price recommender system using an item-item collaborative filtering approach. Using as the only input time-series (TS) price data, the user-item-rating triple was emulated using a bivariate frequency distribution of values in the TS. The second is an environment application where the background concentration of several air pollutants from 2001 to 2017 in Madrid (Spain) is studied using Hidden Markov models. Finally, a demographic application consists of different machine learning algorithms to forecast Spanish population one year in advance using Eurostat data. The experimental evaluation of these data science techniques and datasets shows that the framework proposed can successfully deal with medium-sized smart datasets in terms of performance, resulting in low computing time and good accuracy. From these results, some economic policymaking issues are discussed.

Álvaro Gómez Losada *is currently providing direct support to the big data lead scientist of the Joint Research Centre of the European Commission. He is specialised in the design, implementation and evaluation of machine learning algorithms and recommendation systems. He obtained its PhD and BSc in Statistics at University of Seville (Spain) in 2016 and 2012, respectively. He also holds a MSc in Applied Statistics at University of Granada (Spain). Previous experience as Data scientist in the Innovation Department of Banco Santander (Madrid). Since 2017, he teaches Artificial intelligence, Statistics and Mathematics at Spanish National University of Distance Education (UNED). He also holds a BSc in Biology from the University of Córdoba (Spain).*

11:15 – 12:45 Session 6: Complexity and Social Science

Moderator: Angus Armstrong, Director of Rebuilding Macroeconomics Network

Speakers:

- Chris Kempes, Professor, Santa Fe Institute
  Scaling theory and the structure of diverse systems

Scaling theory, which describes the changes of a system's features according to its size, has recently had many successes in characterising the structure of diverse systems ranging from single organisms to entire cities. In the biological sciences, where the theory is better developed, simple mechanisms and physical constraints have been connected with a wide variety of physiological and ecological features. This approach provides a quantitative theory for predicting key ecological tradeoffs with implications for environmental policy. Recently, scaling relationships have been observed for a variety of features in human systems, such as the patent production rate and violent crime rate as a function of city size. While these relationships are promising for developing simple explanations of human organisations, there are still many questions about the fundamental mechanisms underlying these systems and what they imply for policy and planning decisions. In this talk I will review the biological scaling literature as an example of the type of theory that may be applicable to human systems. I will then discuss the current theory of urban and institutional scaling along with implications for understanding inequality within cities and the effectiveness of the US higher education system.

Chris Kempes *is a Resident Faculty at the Santa Fe Institute (SFI). He did a Ph.D. programme in physical biology at MIT and was an Omidyar Fellow at SFI following a postdoctoral fellowship with the NASA Ames Research Center and Caltech.*

Using mathematical and computational techniques he studies how simple theoretical principles inform a variety of phenomena ranging from major evolutionary life-history transitions, to the biogeography of plant traits, to the organisation of bacterial communities. He is particularly interested in biological architecture as a mediator between physiology and the local environment.

- Penny Mealy, Postdoctoral Research Officer, Institute for New Economic Thinking, University of Oxford
  Interpreting economic complexity

Economic complexity approaches, which apply network analysis to detailed export and employment data, have shed new light on industrial specialisation patterns and economic development. Two network measures in particular – the country-based Economic Complexity Index (ECI) and product-based Product Complexity Index (PCI) – have been particularly successful at explaining cross-country variation in per capita GDP and economic growth. In this paper, we show that the measures are not what they were thought to be. While previous studies had conceptually framed the ECI with reference to notions of the diversity (or number) of products a country can export, we show that the ECI instead reflects of *the type* of products countries are able to export. Specifically, we demonstrate that the ECI is mathematically equivalent to a widely used spectral clustering algorithm, which optimally separates a similarity graph into two balanced components. We also demonstrate that the measure can be seen as a dimensionality reduction algorithm, which collapses the high-dimensional space of country-export data onto a single one-dimensional ordering that places countries with similar exports close together in the ordering and those with dissimilar exports far apart. Our results casts a number of existing results in the economic complexity literature in a new light and also highlight some important ramifications for applications of the economic complexity measures to policy making.

Penny Mealy *is a post-doctoral researcher at the Institute of New Economic Thinking and the School of Geography and the Environment and is currently working on the Oxford Martin School Programme on the Post-Carbon Transition. She is also leading a project on 'Practical Wisdom in a Complex World' at the Bennett Institute of Public Policy at the University of Cambridge.*

Penny's PhD at Oxford was on quantitative approaches for analysing productive capabilities. She applied these methods to provide insights into long-run development, the division of labour and the transition to the green economy. Her broader research interests include economic complexity, technological evolution, transformational change, network science and agent-based modelling. Previously, Penny worked as an economist in Australia, where she predominantly focused on issues relating to energy, resources and climate change.

- Ross A Hammond, Director of the Centre on Social Dynamics and Policy, Brookings Institute and Santa Fe Institute
  Using ABM and new data streams to study public health

Overview of multiple published and soon-to-be published studies.

Ross A. Hammond *is the Betty Bofinger Brown Distinguished Associate Professor of Public Health and Social Policy at Washington University in St Louis, an External Professor at the Santa Fe Institute, and Director of the Center on Social Dynamics & Policy and Senior Fellow in Economics at the Brookings Institution. His research applies complex systems science modeling methodologies (such as agent-based modeling) to problems in social science and health. Current research topics include obesity etiology and prevention, food systems, tobacco control, health disparities, and early childhood development. Hammond has published extensively in general science and disciplinary journals across social science, biology, medicine, and public health including Lancet, JAMA Pediatrics, PNAS, American Journal of Public Health, Evolution, and Journal of Conflict Resolution, and his work has been featured in The Atlantic Monthly, Scientific American, New Scientist, Salon, and major news media.*

Professor Hammond currently serves in policy advisory roles on the Food and Nutrition Board of the U.S. National Academies of Science, as a Special Government Employee at the FDA Center for Tobacco Products, as a federally appointed member of the Advisory Council on Minority Health and Health Disparities at the National Institutes of Health (NIH), and as a member of the Lancet Commission on Obesity. He has participated in five large NIH-funded modeling networks using complex systems tools: MIDAS (focused on communicable disease), NICH (focused on health disparities), ENVISION (within the National Collaborative on Childhood Obesity Research), ECHO (the NIH early-childhood longitudinal cohort programme), and SCTC (the State and Community Tobacco Control network). Hammond has taught at Harvard School of Public Health, University of Michigan School of Public Health, and the NIH, and is on the editorial board of the journals Behavioral Science and Policy and Childhood Obesity. He is currently a visiting fellow at the Center for Research and Interdisciplinarity (CRI) at Paris Descartes University through June 2019.

- Elena Rovenskaya, Programme Director, Advanced Systems Analysis, IIASA
  Towards a systems perspective on national well-being

Policy planning in modern states increasingly recognises that national economic growth does not fully represent citizen's well-being. Macro-economic accounting, especially GDP as the most commonly used measure of growth, does not cover all the dimensions of a nation's progress towards well-being. Even though economic welfare is one of the key prerequisites of citizens' well-being, there is a need for more comprehensive, richer and more direct measures that can directly target well-being for efficient policymaking. *OECD Better Life Index* that combines a wide variety of metrics from economy to housing and health being a prominent example of going beyond just GDP. IIASA, in collaboration with Israel's National Economic Council, has launched an exploratory project to aiming at enhancing our systemic understanding of national well-being. We attempt to reveal and analyse underlying mechanisms and causal links, as well as external drivers and uncertainties which all together form the national well-being. The enhanced systemic understanding is expected, *inter alia*, to shed light on what factors are critical in defining national well-being and what critical feedback loops policy makers should pay attention to. We employ systems mapping as the main methodology in this project. In the current, first stage of the analysis, we identify main components of the national well-being system as well as causal relationships between them. We work across four "resources" for future well-being: natural capital, economic capital, social capital and human capital. We rely on an extensive literature review to define the systems boundaries, relevant elements and connections, and complement it by participatory modelling exercises with experts and stakeholders in Israel. As a by-product of this activity, systems mapping exercise also facilitates achieving a mutual understanding between stakeholders with different views on the matter.

Elena Rovenskaya *is the Programme Director of the Advanced Systems Analysis (ASA) Programme at the International Institute for Applied Systems Analysis (IIASA). Her scientific interests lie in the fields of optimization, decision sciences and mathematical modeling of complex socio-environmental systems. Dr. Rovenskaya graduated in 2003, from the Faculty of Physics, Lomonosov Moscow State University, Russia. She received her PhD in 2006 from the Faculty of Computational Mathematics and Cybernetics of the same university. The title of her PhD thesis was "On solving the problem of finding the optimal compatibility parameter value for a class of equations in a normalized space." Since 2006, she has been working at the Faculty of Computational Mathematics and Cybernetics as a researcher (since 2013 - on leave). Also since 2006 she has been collaborating with IIASA. In 2013, she was appointed the ASA Program Director. In this function, Dr. Rovenskaya is leading a team of 35+ scientists who focus the latest*

developments in applied mathematics and modeling to develop, test, and make available new quantitative and qualitative methods to address problems that arise in the policy analysis of complex socio-environmental systems. ASA activities focus on methods used to support decisions in the presence of uncertain and volatile input data, ambiguous stakeholder interests, and complex underlying systems.

14:30 - 16:00 **Session 7: Young Researchers**

Moderator: Alan Kirman, Chief Advisor to the NAEC Initiative

Speakers:

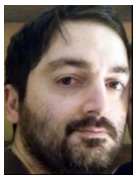
- Eugenio Caverzasi, Post-Doctoral Researcher, Università Politecnica delle Marche
  Inequality and Finance in a Rent Economy

The present paper aims at offering a contribution to the understanding of the interactions betweenfinance and inequality. We investigate the ways through which income and wealth inequality may haveinfluenced the development of modern financial systems in advanced economies, the US economy firstand foremost, and how modern financial systems have then fed back on income and wealth distribution.We focus in particular on securitisation and on the production of complex structured financial products.We analyse this topic by elaborating a hybrid Agent-Based Stock-Flow-Consistent (AB-SFC)macroeconomic model, encompassing heterogenous (i.e. households) and aggregate sectors. Theinnovative hybrid approach allows to exploit the strengths of both modelling methods, while maintainingthe economic intuition clear. The SFC approach provides a thorough representation of sectors' balancesheets evolution and interrelations. While the AB approach allows to study the evolution of distributionaldynamics and the endogenous unfolding of the events from the micro to the macro level. Our findingssuggest that the increase in economic growth, favoured by the higher levels of credit supply coming with securitisation, may determine a more unequal and financially unstable economic system. We also findthat a lower degree of tax progressiveness and wider wage inequality further polarise income and wage distribution, and reduce economic growth.

Eugenio Caverzasi *is a Pos-Doctoral Researcher at the Department of Economics and Social Sciences of the Università Politecnica delle Marche | Università degli Studi di Ancona · His research interests include Agent-based models Financialisation; Monetary Keynesianism; Post-Keynesian; Stock-Flow Consistent Modelling and projects on Macro-Finance, Financial Firms, and 'Shadow Banking'. He has a PhD in Economics from the Università degli Studi di Pavia.*

- Amir Sani, Researcher
  A Resting Time Policy for the Limit-order Book

Regulation must ensure markets are efficient, fair, orderly and transparent through policies that minimise market malpractice. Gaming the limit order book through flash orders, wash trades, spoofing and quote stuffing compromises market integrity. Existing policy options attempt to limit these abusive practices by regulating the entire universe of traders, potentially impacting efficient market transactions. The policy challenges in regulating these predatory activities, while maintaining efficient markets is exacerbated by technological advancements in algorithmic and high-frequency trading. Regulatory policies must adapt to this technological innovation to create a level playing field. One popular policy option is to institute minimum resting times on all trades, which promise to reduce volatility, increase liquidity and minimise these predatory gaming strategies. Unfortunately, minimum resting times may cause wider spreads and a reduction in displayed liquidity. Here, we present a resting time policy based on an Agent-Based Limit Order Book Model that reduces predatory gaming strategies, while minimising volatility and maximising liquidity.



Amir Sani is a Machine learning researcher working on surrogate models, adaptive sampling and forecasting. He is a post doctoral researcher at the Centre d'Economie de la Sorbonne, Paris, and Imperial College London. He has over 15 years of business and investment experience and has advised several startups that have reached sustained profitability. His current consulting work focuses on machine learning solutions to tough business and IT problems that lack direct solutions and require careful thought.

- Guido de Blasio, Economist, Directorate General for Economics, Statistics and Research Bank of Italy
  Machine learning in the service of policy targeting: The case of public credit guarantees

We use Machine Learning (ML) predictive tools to propose a policy-assignment rule designed to increase the effectiveness of a public guarantee programme. We apply ML on credit register data to predict not

only the firms' probability of default, but also their chance to be financially constrained. The study elaborates on the case of Italy's Guarantee Fund and demonstrates, by means of ex-post evaluation methods, that the programme effectiveness can be increased by targeting firms predicted to be both creditworthy and credit constrained. We discuss the problems in using ML for the implementation of public policies, such as transparency and manipulation.

Guido de Blasio *is Deputy Division Chief in the Regional Analysis Division of the Directorate General for Economics, Statistics and Research at the Bank of Italy. He has held visiting fellow and researcher positions at the London School of Economics, the International Monetary Fund, Georgetown University, and the World Bank. He has a PhD in Economics from the University of Siena, Florence and Pisa and a Masters in Banking and Finance from the Uiversity of Siena, Post-graduate School of Banking. His areas of expertise include Regional science and urban economics; Place-based policies; Applied econometrics and machine learning; South of Italy.*

- Ermanno Catullo, Researcher, Università Politecnica delle Marche
  Forecasting in a complex environment: maching learning sales expectations in a SFC Agent based simulation model

Adopting machine learning techniques, even in a complex economic system, it is possible to model agents with expectations that are not bi-ased and show a certain degree of accuracy. We analyse the micro and macro e_ects of introducing into an agent based simulation model _rms that are able to formulate e_ective sales forecasts. The model reproducesa simulated economy, where macro dynamics are the results of the inter-action of agents (households, _rms and banks) following adaptive rules in a stock ow consistent setting (Caiani et al., 2018). Firms make expectations on the variations of their sales in order to ori- entate production and price decisions. We tested di_erent computational methods to make sales forecasts: a genetic algorithm (GA), an autoregressive model (AR) and a naive approach (where predictions are equal to the previous realisation).The GA and the AR methods are able to provide expectations with average errors that converge to zero and with a good level of accuracy. Firms that adopt these last two predictive methods (GA and AR) are able to increase their pro_ts without augmenting their riskiness (failure rate). However, on the aggregate level, higher _rm pro_tability is associated with higher mark-ups, that results in a weaker dynamic of real wages in both the GA and AR implementations. Thus, the wage shareshrinks a_ecting negatively the aggregate demand. In the long run, higher pro_ts come at the price of higher unemployment levels and lower output growth. The model could be feasible to test the relations between policy interventions and agents' expectations.

Ermanno Catullo *is an Associate Researcher in Economics and Statistics in the Department of Economics and Social Sciences of the Università Politecnica delle Marche, Italy. He specialises in Applied Economics; Agent Based Modelling and Agent-Based Computational Economics. He graduated in development economics from the University of Florence, he has a Master Coripe in Polictical Economy and and received his doctorate in Economics from the University of Torino. He has been a Researcher at the Institute for Foreign Trade (ICE) and worked at the IRER, Institute of Research of the Lombardy Region.*

- Jannes Klaas, Quantative Researcher, University of Oxford, Said Business School
  If stress-tests are predictable, are they still useful?

Stress tests have become an important part of banking regulation. Given that enough stress-tests have been run since their introduction, it has become feasible to train advanced machine learning algorithms to predict their outcomes. A key finding has been that the pass/fail outcome of a stress test is predictable from a small number of macroeconomic variables as well as variables concerning an institutions financial health. Our work examines how well previously proposed machine learning systems generalise by testing models trained on 2011 and 2014 data on the 2016 and 2018 stress test. We examine how models for predicting stress tests compare to models predicting bank failure andother financial crisis forecasting models.We then conduct an error analysis to find quantitative andqualitative similarities in institutions whose stress tests outcomes were not correctly predicted from the proposed variables. Using this data, we examine which new information a stress test delivers that was not predictable from existing knowledge. We discuss if stress tests reveal enough new information to be useful or if they could be replaced with much cheaper and much more frequent machine learning driven assessment of a banks performance in an adverse scenario. Our research addresses the question of how machine-learning can be used to improve regulatory instruments, policy and macroeconomic forecasting to prevent financial crises.

Jannes Klaas *is a Quantative Researcher with a Master in Financial Economics from the Said Business School, University of Oxford. He is on the education team of the Oxford University Artificial Intelligence Society and he has also taught courses in machine learning for finance at the Turing Society, Rotterdam. He is the author of "*Machine Learning for Finance: Data algorithms for the markets and deep learning from the ground up for financial experts and economics*"*

- Luca Eduardo Fierro, PhD candidate, Marche Polytechnic University
  We are the Robots and We (May) Come in Peace

The paper investigates the macroeconomic effects of automation and it contributes to the job polarisation literature. To address the issues at hand we designed a SFC-ABM whose key ingredients can be summurised as: (i) the model allows for two substitutable kinds of capital items, robots and "traditional" machines. We also assume the former to be *labor saving* and *skill biased* with respect to the latter; (ii) workers' heterogeneity in the skills dimension, we assume three skill groups: low, middle and high-skilled workers; (iii) we model two final good sectors, manufactory and *personal* services. The former employs machines of both types and workers from each skill group, the latter do not use machines and hires low-skilled low-wage workers only. Allowing for robots in the model triggers a stuctural change and a job polarisation process. Indeed, robots lower costs of production, and so prices, in the manufactory sector. This frees income for consumption generating positive spill overs for the service sector (*structural change effect*). We also observe growth in low and high skilled jobs, coupled with decreasing or stagnating middle skilled jobs (*job polarisation effect*). The growth of high skilled jobs is achieved by design, insofar robots are assumed to be skill biased. On the other hand, the growth in low skilled jobs is a by-product of the *structural change effect*. This is because as the service sector grows, new low skilled jobs are created.

Luca Eduardo Fierro *is pursuing a PhD in Economics at Marche Polytechnic University. His research focuses on Agent-Based models for Macroeconomics. As part of his PhD, Luca is studying the macroeconomic effects of labour tasks automation and the role of expectations and learning in ABMs. His broader research interests are monetary and fiscal policy, labour market, and income distribution.*

- Kerstin Hötte, PhD Student, Bielefeld University - Department of Business Administration and Economics
  How to accelerate green technology diffusion? An agent-based approach to directed technological change with coevolving absorptive capacity

To avoid possibly irreversible climate risks it is decisive to accelerate the diffusion of climate friendly technologies. Path dependence of technological change is an explanation for sluggish diffusion even if a technology is superior in the long run. This paper studies directed technological change in the presence of supply- and demand sided barriers to diffusion. Firms choose between different technology types when acquiring capital goods and build up type-specific technological know-how needed to exploit the productive potential of capital. Path dependence arises from cumulative knowledge stocks manifested in the productivity of supplied capital and firms' capabilities. Increasing returns arise from positive feedback loops of market induced innovation and learning by doing. This paper studies how relative knowledge stocks explain path dependence and emerging simulated and empirical macroeconomic patterns of technology diffusion. I show how the effectiveness of different climate policies depends on the type and strength of diffusion barriers using a macroeconomic agent-based model. Environmental taxes can outweigh lower productivity and subsidies perform better if lacking capabilities hinder firms to adopt a sufficiently mature technology. Subsidies that stimulate the creation of green markets may reinforce increasing returns to adoption and contribute to the convergence to a green technological regime. Investment subsidies may have an undesired side-effect of increased technological uncertainty.

Kerstin Hötte *is currently doing a Ph.D. in Agent-based Computational Economics at Bielefeld University, Sorbonne Paris-1, with the dissertation topic: Macroeconomic, evolutionary analyses of green technology diffusion, technological complementarities and learning. She has an M.Sc. in Agricultural and Food Economics from the University of Bonn and a B.Sc. in International Economics and South East Asian Studies from the University of Tübingen.*

Her doctoral thesis investigates the barriers and drivers of technology diffusion within an agent-based macroeconomic simulation framework, focusing on endogenous learning dynamics and the transferability of technological knowledge across different technology types. A follow-up project is to seek an empirical motivation for the technological specifity of knowledge capital based on patent-citation and input-output linkages in a networked economy.

- Nicolas Woloszko, Economist, OECD Economics Department
  Adaptive Trees, a novel method for economic forecasting

The present research introduces an innovative approach to macroeconomic forecasting based on both existing machine learning techniques and original contributions to the field. We created a forecasting algorithm – dubbed Adaptive Trees – that is specifically tailored for macroeconomic forecasting, and addresses non-linearity and non-ergodicity of the economy, as well as the problem of high dimensionality in a context of scarce data. We produced forecasting simulations in pseudo-real time for all major economies. Our forecasting algorithm proved more reliable than benchmark forecasts and displayed a much better ability to anticipate turning points.

Nicolas Woloszko *is an Economist in the Growth, Resilience and G20 unit of the Structural Surveillance Divison in the Economics Department of the OECD. He specialises in building machine learning algorithms for economic forecasting and policy analysis. He is qualified in Engineering and Data Science from the French École Nationale de la Statistique et de l'Administration Économique" (ENSAE); Normalien in Economy and Sociology from the École Normale Supérieure Paris-Saclay; and a Master 2 in Sociology and Statistics from EHESS - Ecole des Hautes Etudes en Sciences Sociales.*

- Eleonora Mavroeidi, Economist, OECD Economics Department
  Connectivity Counts: How is The Geography of International Trade Linkages Changing and What is the Effect on International Shock Transmission?

This paper studies the evolution of interconnectivity and centrality of international trade before and after the global financial crises and the variation in the contagion of pre and post-crisis trade shocks. Using network analysis of the OECD inter-country input-output (ICIO) data reveals that changes in the geographical patterns of global value chains (GVCs) during the period 2005-2015 were primarily driven by the increased centrality in the production chain of China and its industries, as well as service sectors across countries. Such changes together with increased participation in GVCs in 2015 and the evolution towards fewer but larger international clusters, imply that trade restriction shocks transmit faster and the cost of negative shocks will be higher than before. Lastly, the impact varies across countries. Shocks in more central countries, such as China and the United States, results in a larger and faster contagion in 2015 compared to 2005, as well as compared to less central economies.

Eleonora Mavroeidi *is currently working as an Eocnomist in the Macroeconomic Analysis Division of the Economics Department of the OECD exploring the effect of structural economic policies and their dependence on macroeconomic settings as well as quantifying international spillovers. Previously, she worked at the International Department of the Bank of England, as well as the Research Department at the International Monetary Fund and the World Bank focusing on economic modelling, international macroeconomics and trade, and recently researching on the effectiveness of trade agreements, the impact of migration on investment flows as well as policy options for small open economies in a world of secular stagnation. Eleonora, holds a Masters in Economics from Brown University, and a Masters and Bachelor in Mathematics from University of Warwick.*

16:30 – 17:55 Session 8: Roundtable on New Approaches to Macroeconomic Modelling

Moderator: Laurence Boone, OECD Chief Economist

Speakers:

- John Muellbauer, Senior Research Fellow and Professor of Economics, Nuffield College and Institute for New Economic Thinking

Muellbauer (2018), points out the multiple failings, theoretical and empirical, of New Keynesian DSGE models popular with central banks before the global financial crisis. The roles of debt and of asset prices - especially for housing - in that crisis are now far more widely appreciated. The US Federal Reserve maintains its non-DSGE 'semi-structural' FRB-US model and many central banks, now have, or are developing, such econometric policy models. Although these models give more scope for empirical evidence, they *poorly* represent monetary policy transmission *and* implications for financial stability. For example, they take no account of *shifts* in credit conditions and treat all assets as equally spendable, ignoring *differences between liquid and illiquid assets* and the *time-varying* impact of the housing collateral effect.They also grossly underestimate the negative effects of debt on spending.This paper discusses how household and housing sector models need *radical reform* to relax these assumptions, contradicted by much micro-evidence. Applying a 'latent interactive variable equation system' to aggregate French data on consumption, mortgages and other debt, liquid assets, house prices and permanent income, Chauvin and

Muellbauer (2018) *present a template* for how the household sector of central bank policy models can be built. They show that mortgage credit conditions in France are strongly related to non-performing loans of banks, capturing macroeconomic feedback effects relevant for stress tests of the financial system. Building on such *evidence-based models* highlights cross-country institutional heterogeneity and provides useful pointers for calibrating agent-based models exploiting more granular data.

***Professor John Muellbauer** is a Senior Research Fellow of Nuffield College, Professor of Economics and a Senior Fellow of the Institute for New Economic Thinking at the Oxford Martin School, Oxford University. He is a Fellow of the British Academy, of the Econometric Society and of the European Economic Association and a CEPR Research Fellow. He has been a consultant to the Bank of England, HM Treasury and the UK Department for Communities and Local Government (DCLG). He has been a Visiting Scholar at the Federal Reserve Board and the IMF and was a Wim Duisenberg Visiting Fellow at the ECB in 2012/13. His current research is supported by grants from the Open Society Institute and the Oxford Martin School.*

Recent work includes research on sovereign debt spreads in the Eurozone; research with economists from the Banque de France, Bundesbank and ECB on interactions between finance, housing and the real economy focused on the household sector; with Janine Aron on inflation forecasting and exchange rate pass-through, and for DCLG, on mortgage delinquencies and foreclosures in the UK; with John Duca and Anthony Murphy, both at the Dallas Federal Reserve, on lessons from the role of housing in the financial crisis, on what drives US house prices, and on the implications of the long-term shift in US credit market architecture. His research with colleagues on the impact of credit market liberalisation on consumer debt, spending and housing markets in the UK, US, South Africa and Australia and non-liberalisation in Japan and Germany aims to throw new light on monetary transmission, financial stability and monetary policy. His 1980 paper with Angus Deaton, 'An Almost Ideal Demand System' in the American Economic Review was selected as one of the top twenty papers published in the first one hundred years of that journal.

Before coming to Nuffield College in 1981, John was Professor of Economics at Birkbeck College, London, and Lecturer at Warwick University. He obtained his first degree from Cambridge University, England and his Doctorate from the University of California.

- Matheus Grasselli, Professor of Mathematics, McMaster University and the Fields Institute, Toronto
  Three examples of new approaches to macroeconomic modelling

Modern mainstream macroeconomics seeks to avoid ad hoc assumptions and inconsistent policy prescriptions by being micro-founded, meaning that models of aggregate behaviour ought to be entirely derived from assumptions made on individual agents. The problem with this approach is that, as soon as some mild heterogeneity is introduced in the population of agents, the results of general equilibrium are not guaranteed to hold, as evidenced by the celebrated (albeit negative) Sonnenschein–Mantel–Debreu theorem. An alternative approach inspired by the older Keynesian revolution is to treat macroeconomics as a subject on its own right and consider the phenomenological relationships between aggregate quantities directly. This is the key to the Stock-Flow Consistent models, of which I'll present two examples, one establishing private debt as a link between secular stagnation and inequality and the other exploring the consequences of negative interest rates in a cashless economy.

Such aggregate models are effective and have the advantage of being much closer to available data, but are still somewhat unsatisfactory, as they neglects explicit decision making mechanisms by individual agents. A different approach is to revert back to agents but abandon the constraints of equilibrium and utility optimization, often relying on numerical simulations to obtain aggregate behaviour. In this talk I describe yet another alternative approach inspired by statistical physics, whereby heterogeneous agents transition between different 'types' according to rates that depend on aggregate variables, thereby providing an interaction between the fast time scale of individual decision making and the slower dynamics of macroeconomic aggregates. I then illustrate the method with a model exhibiting Minskyan financial fragility.

***Matheus Grasselli** is a Professor of Mathematics and Chair of the Mathematics of Statistics Department at McMaster University and the Director of the Centre for Financial Industries at the Fields Institute for Research in Mathematical Sciences in Toronto. He has a PhD from King's College London and has published research papers on information geometry, statistical physics, and numerous aspects of quantitative finance, including interest rate theory, optimal portfolio, real options, executive compensation, and macroeconomics. He is also the author of an undergraduate textbook on numerical methods. He is a regular speaker in both academic and industrial conference around the world and has consulted for CIBC, Petrobras, EDF, and Bovespa. A member of the editorial board of the Journal of Banking and Finance, the*

International Journal of Theoretical and Applied Finance, and the Journal of Dynamics and Games, he is also the founding managing editor of the book series Springer Briefs on Quantitative Finance.

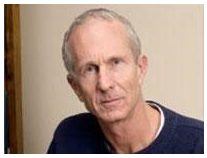
- J. Doyne Farmer, Director of Complexity Economics, Institute for New Economic Thinking and Santa Fe Institute, and Rebuilding Macroeconomics
  Global microeconomics: A complexity economics approach to macroeconomics using fine-grained data

Quantitative models for macroeconomics are typically constructed at an aggregate level. The fact that the available historical time series available for parameter estimation are so short causes serious problems for parameter estimation. On one hand the economy is complex, with many moving parts, so any realistic model necessarily has many free parameters, but on the other hand, there are only roughly 500 bytes of relevant historical data, so at most a few parameters can be successfully estimated. This leads to a "Catch 22": It is impossible to estimate a realistic macroeconomic model at the aggregate level.

Another problem is that we know from experience from many complex systems that understanding their emergent properties requires modeling the interaction of their interacting elements. By definition, this cannot be done using an aggregate model.

I propose that gathering data and modeling the economy at a microscopic level can solve these fundamental problems. To understand production, for example, we should gather data and construct models at the level of individual firms, products and technologies. Understanding households requires a more detailed understanding of demography. Heterogeneous agent DSGE models move in this direction but are limited by the tractability of the required analytic methods. Agent-based simulation models, in contrast, avoid these constraints. This solves two problems at once: There is more data for statistical estimation and it becomes possible to deal with nonlinearities, such as increasing returns, and it becomes possible to capture emergent properties. Doing this successfully requires maintaining enough model parsimony to capture the advantages of additional data, but adding enough model complexity to capture the key nonlinearities and feedback mechanisms that underlie economic behavior.

My talk will explain the problems and their solutions in more quantitative terms. I will present examples that indicate the advantages of this approach, e.g. by demonstrating how going down to a fine-grained level enables successful forecasting of technological progress, and how viewing the production network in more detail enables forecasting the long-term behavior of industrial price indices.



J. Doyne Farmer *is Director of the Complexity Economics programme at the Institute for New Economic Thinking at the Oxford Martin School, Professor in the Mathematical Institute at the University of Oxford, and an External Professor at the Santa Fe Institute. His current research is in economics, including agent-based modeling, financial instability and technological progress. He was a founder of Prediction Company, a quantitative automated trading firm that was sold to the United Bank of Switzerland in 2006. His past research includes complex systems, dynamical systems theory, time series analysis and theoretical biology. During the eighties he was an Oppenheimer Fellow and the founder of the Complex Systems Group at Los Alamos National Laboratory. While a graduate student in the 70's he build the first wearable digital computer, which was successfully used to predict the game of roulette.*

Discussant:

- James Carver, Investment Manager, Baillie Gifford

17:55 **Closing remarks**

William Hynes, NAEC Co-ordinator, OECD