School of Economics, University of Surrey
September 3rd - September 8th, 2018

The Science and Art of DSGE Modelling

Two Parallel Dynare- and Matlab-Based Courses
Four One-Day Stand-Alone Options

The Courses will be followed by a One-Day Conference

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1 Introduction

The Centre for International Macroeconomic Studies (CIMS) in the School of Economics, University of Surrey will a hold a 5-day summer course, September 3th - September 7th 2018 followed by a one-day Conference. The first four days will consist of two parallel courses: one will be a *foundations course* aimed at early researchers with some knowledge of Real Business Cycle (RBC) or Dynamic Stochastic General Equilibrium (DSGE) macroeconomic models, but little or no experience of Dynare. This course assumes a basic knowledge of Matlab and will begin with the basics of Dynare and proceed to the construction, in stages, of a closed economy NK DSGE model. It will then progress to the estimation of the model by Bayesian methods and finish by showing how the model can be used to study optimal monetary policy.

The second *advanced course* is aimed at more established researchers who are already fluent in Dynare and Matlab. This course will be useful to anyone who is engaged in practical macroeconomic modelling work, especially if they are interested in working with models that are either computationally expensive to simulate, highly nonlinear, or infinite dimensional thanks to heterogeneous agents. The basic and advanced courses will run in parallel for four days from September 3rd - September 6rd.

Then on day five, 7th September, all participants from both streams will be able to choose one from *four one-day advanced courses* covering financial frictions, optimal policy, occasionally binding constraints with simple non-linear estimation and emerging open economies. These all stand-alone courses and participants will be able to register only for this day. Details are provided below. For all these courses, notes and model codes will be distributed to participants.

Finally on Saturday 8th September we will hold a *one-day Conference*. All participants on the Courses are invited to submit a paper on some aspect of DSGE modelling to be presented in either full Conference or Poster sessions.

Profiles for the instructors and details of the Courses are as follows.

2 Instructors

Cristiano Cantore is a Senior Lecturer in the School of Economics at the University of Surrey. He graduated from the Bocconi University (Milan, Italy) in 2004. He then completed his MSc degree in Economics at Pompeu Fabra University (Barcelona, Spain). In 2006, he started the PhD in Economics at University of Kent where he was awarded an ESRC Scholarship. Cristiano's PhD focussed on financial frictions and capital labour substitution in dynamic stochastic general equilibrium (DSGE) models. Cristiano has also worked at the OECD and at the ECB as a trainee and visited the Bank of Spain in 2012 as a research fellow. In September 2009 he was appointed as full time Lecturer and in 2013 he was promoted to Senior Lecturer at the University of Surrey. His research fields mainly include macroeconomic theory, computational economics, monetary economics and production theory.

Szabolcs Deak is a full-time Research Fellow in the School of Economics at the University of Surrey. He joined the School in September 2013 to support the research activities of the ESRC funded project "Agent-Based and DSGE Macroeconomic Models: A Comparative Study". He received his Masters degree in Economics from the University of Szeged (Hungary) in 1999 and worked there as a full-time Lecturer from 1999 to 2005. He went on to study Economics at post-graduate level from 2006 at Bocconi University (Milan, Italy), receiving his PhD in 2011. He previously worked at the Monetary Policy Research Division of the European Central Bank (Frankfurt am Main, Germany) and held a Jean Monnet Postgraduate Fellowship at the European University Institute (Florence, Italy).

Vasco Gabriel is a former Head of the School of Economics at the University of Surrey. He graduated in Economics from the Technical University of Lisbon in 1995, where he was awarded the ICEP prize. He received a masters degree in Econometrics in 1998 from the same institution. In 2002, he completed his PhD in Economics at Birkbeck College, University of London. He taught at the University of Minho, Portugal, before being appointed as a Lecturer at the University of Surrey in 2004 and Senior Lecturer in 2010. Vasco's main field of specialization is Macroeconometrics, focusing on the application of non-linear methods, as well as general inference issues in macro models. He has published extensively in these areas including publications in Economic Letters,

the Journal of Macroeconomics, the Journal of Money, Credit and Banking and the Oxford Handbook of the Indian Economy.

Tom Holden is a Lecturer in the School of Economics at the University of Surrey. He received his undergraduate degree in Mathematics and Philosophy from the University of Oxford in 2005. He went on to study Economics there at post-graduate level from 2006, receiving his MPhil in 2008 and completing his doctoral thesis in 2011. He joined the University of Surrey as a full-time lecturer in September 2011. He previously held a stipendiary lectureship at Trinity College, Oxford. His research interests are primarily in macroeconomic theory with a focus on producing DSGE models that are more consistent with the low and medium frequency time-series evidence. He is also working on learning, occasionally binding constraints, rational inattention and heterogeneous agent models.

Paul Levine is a Professor in the School of Economics at the University of Surrey. He received a first-class BSc and a PhD, both in Mathematics, from the University of Manchester and an MSc in economics (distinction) at Queen Mary, London. In 1984 he became a senior research officer at the Centre for Economic Forecasting, London Business School and was appointed Professor of Economics at the University of Leicester in 1989. In 1994 he moved to the University of Surrey where he now leads the Centre for International Macroeconomic Studies (CIMS). He has acted as a consultant and/or visiting researcher at the IMF, the ECB, the central banks of Peru and Nigeria, and the World Bank. His main research is on the use of empirically-based DSGE models for the study of macroeconomic policy. He has published over 100 refereed articles or chapters and 2 books.

Antonio Mele is a Lecturer in the School of Economics at the University of Surrey. He graduated from the Bocconi University (Milan, Italy) in 2001. He then completed his DEA in Econometrics and Economic Theory at Université de Toulouse 1 in 2003, then he went to Universitat Pompeu Fabra (Barcelona, Spain) obtaining a MSc in Economics in 2004 and the PhD in Economics in 2009. Before joining University of Surrey, he was a Postdoctoral Research Fellow at Nuffield College at University of Oxford (2009-2012), where he taught a course in Computational Macroeconomics. His research fields are dynamic contracts, macroeconomic theory, computational economics, monetary economics and learning.

Afrasiab Mirza is a Lecturer in Banking and Finance at the Department of Economics at the University of Birmingham. He holds a BSc in Physics from the University of

Toronto (Toronto, Canada) and a PhD in Economics from Queens University (Kingston, Canada) obtained in 2014. Afrasiabs PhD focused on applying dynamic contract theory to financial regulation. His primary research fields are financial economics, contract theory, general equilibrium, and computational economics. He is currently working on how to design robust optimal monetary and financial policies across DSGE models based on their relative forecasting performance.

Ricardo Nunes is a Professor in the School of Economics at the University of Surrey. He graduated from Universitat Pompeu Fabra (Barcelona, Spain) obtaining a MSc in Economics in 2003 and a PhD in Economics in 2007. After graduating he spent 10 years in the Federal Reserve System under various roles. In 2007 he joined the Board of Governors of the Federal Reserve System, where he worked as an economist and senior economist. In 2014 he moved to the Federal Reserve Bank of Boston working as a senior economist and policy advisor. He was also a visiting researcher at the Bank of Portugal and the IMF and has given talks at various central banks. His main research is on monetary and fiscal policy. He has published extensively in these areas including the Quarterly Journal of Economics, Journal of Monetary Economics, Journal of Economic Theory, Journal of European Economic Association, among others.

Joseph Pearlman is a Professor in the Department of Economics at City University, London. He graduated from Cambridge University with a BA Mathematics (2nd Class) in 1972, and then an MSc (distinction) in 1974 followed by a PhD in Control Theory in 1977, both from Imperial College. He later completed a part-time MSc in Economics from LSE in 1986. He had ESRC funding for a sabbatical at the Centre for Economic Forecasting at London Business School 1988-89. His general Research Interests are: Macroeconomic Policy; Growth Theory; International Trade and Growth. He has had articles published in the European Economic Review, Economic Journal, Journal of Economic Dynamics and Control, Journal of Economic Theory, Oxford Economic Papers, and the Journal of Development Economics.

Jonathan Swarbrick is a Senior Economist at the Bank of Canada in the Model Development Division of the Canadian Economic Analysis Department. Jonathan completed an MSc in Economics at the University of Surrey in 2012 with a distinction and award for finishing top of his class. He went on to study for a PhD at Surrey which he

completed in 2017. Between finishing his PhD and his appointment at the Bank of Canada he was a Research officer in the Centre for International Macroeconomics in the School of Economics in Surrey. His broad research interests include macroeconomic theory, financial economics, and monetary economics. He explores these areas using heterogeneous agent DSGE models and those with occasionally binding constraints.

Bo Yang is a Lecturer in the School of Management at Swansea University. Formerly he was a Lecturer in Xi'an Jiaotong-Liverpool University (XJTLU), Suzhou, China. He graduated from the University of Hull in 2003 and completed his MSc degree in Financial Economics with a Distinction at Queen Mary, University of London. Following the completion of his PhD at the University of Surrey on the topic of DSGE modelling in 2008, Bo was appointed, by Surrey and London Metropolitan University, as a Research Fellow to support the research activities of the EU-funded project MONFISPOL. His research fields include macroeconometrics, monetary economics and Bayesian econometrics, focusing on the applications and quantitative analysis of DSGE models. He has published in the Review of International Economics, the Oxford Handbook of the Indian Economy, Economics Letters and the Economic Journal.

3   Time-Table For all Courses

Registration will take place on day 1 at 9.00-9.30pm. Then for each day (for both Courses and Options) the time-table is as follows:

9.30 - 11.00 am: Session 1
11.00 - 11.30 am: Coffee and Tea
11.30 am -1.00 pm: Session 2
1.00 - 2.15 pm: Lunch
2.15-3.45 pm: Session 3
3.45 - 4.15 pm: Coffee and Tea
4.15 - 5.45pm : Session 4

4 Foundations DSGE Macro-Modelling Course

This Course is aimed at those with some knowledge of RBC and NK models but little or no experience of setting them up in Dynare. The contents of lectures given by Cantore, Gabriel, Levine, Pearlman and Yang over the four days are as follows:

- **Day 1: Dynare Basics and the RBC Model**

    - Instructors: Levine, Cantore

    - Introduction to the 4-Day Course

    - Dynare Basics

    - RBC Model

    - Calibration and Use of an External Steady State

    - Linearisation

    - Exercises in Lab (all day)

- **Day 2: The New Keynesian Model, Stability and Global Sensitivity Analysis**

    - Instructors: Cantore, Levine

    - The New Keynesian Model

    - Stability-Indeterminacy

    - Introduction to the Global Sensitivity Analysis toolbox in Dynare

    - Identification and Pre-estimation Checks

    - Exercises in Lab (all day)

- **Day 3: Bayesian Estimation of the NK Model**

    - Instructors: Gabriel, Yang

    - Preparing the Data including use of various filters

    - An Introduction to Bayesian Methodology

    - More on Identification

    - Direct Estimation of the Non-Linear NK Model

    – Exercises in Lab (all day)

- **Day 4: More on Estimation and Calibration; Optimal Monetary Policy**

    – Instructors: Gabriel, Yang, Levine

    – Direct Estimation of the Non-Linear Model

    – Model Comparisons by Likelihood Races

    – Comparison of Second Moments of Model with Data

    – Calibration and Use of the External Steady State

    – Optimal Monetary Policy for Linear-Quadratic Problems

        ∗ The Ramsey Problem

        ∗ Optimal Time-Consistent Policy

        ∗ Optimized Simple Rules

    – Exercises in Lab (all day)

5   Advanced DSGE Macro-Modelling Course

The advanced course is aimed at people who are already fluent in Dynare and Matlab, but are finding that their ambition currently exceeds what they are able to do with these tools. We aim to distribute some of the numerical and computational tricks we have picked up over the course of our careers to enable people to tackle non-standard models. This course will be useful to anyone who is engaged in practical macroeconomic modelling work, especially if they are interested in working with models that are either computationally expensive to simulate, highly nonlinear, or infinite dimensional thanks to heterogeneous agents. Contents of the course to be given by Deak, Ferroni, Holden, Mele and Swarbrick are as follows:

- **Day 1: Advanced MATLAB and Dynare Programming**

    – Instructor: Holden, Deak

    – Advanced MATLAB Programming

        ∗ Vectorisation

* Parallel coding in MATLAB, both with the Parallel Toolbox and freely available tools

* MATLAB at hardware level: cache-management, dynamic compilation etc

* Optimization for MATLAB Coder, aka coding MATLAB as if it were C (avoiding dynamic allocation, etc.)

– Advanced Dynare Programming

* Dynare's macro language

* Efficient Dynare MOD files (state space reduction, model local variables)

* Dynare internals, including the manipulation of impulse responses and simulations

* Hybrid approximate/exact simulation

– Exercises in Lab (all day)

• **Day 2: Estimating Non-Linear Models**

– Instructor: Holden, Deak

– Techniques for estimating non-linear models

* Estimation without filtering and "wedge-accounting"

* Simulated method of moments.

* Non-linear filters. (EKF, UKF, QKF, Particle Filter)

– Testing techniques for estimating non-linear models (afternoon lab session)

* Estimation of the parameters of a simple stochastic growth model by various methods, on data generated from that same model

* Exercises in Lab (all day)

– **Day 3: Applied Dynamic Programming: Global Solution Algorithms**

* Instructor: Mele, Deak

* The basic theory of dynamic programming

* Numerical integration

* Function approximation

* Value function iteration

* Policy function iteration

* Projection methods

* Exercises in Lab (all day)

- **Day 4: Heterogeneous Agents and Occasionally Binding Constraints**

  - Instructor: Deak, Mele

  - Introduction to models with heterogeneous agents

  - Solving heterogenous agent models without aggregate uncertainty: the model of Aiyagari

  - Solving heterogenous agent models with aggregate uncertainty: the Krussell-Smith algorithm

  - Alternative algorithms

  - Exercises in Lab (all day)

6 Day 5: Four Options

Participants must choose one from the following four full-day options:

6.1 Emerging Open Economies

- Instructors: Gabriel, Levine

- Construction of a basic Small Open Economy NK model

- Incorporation of emerging economies features

  - Credit Constrained Consumers

  - A Non-Traded Informal Sector

- Bayesian Estimation

- Policy Rules

  - Monetary interest rate rules

  - Foreign Exchange Intervention

      – Fiscal Policy

- Exercises in Lab (all day)

6.2   Financial Frictions

- Instructors: Mirza, Pearlman

- Modeling Approaches to Financial Frictions in DSGE Models

- Bayesian Estimation and Comparison of Models

- Conventional and Unconventional Monetary Policy

- Implications of Financial Frictions for Optimal Policy

- Exercises in Lab (all day)

6.3   Optimal Policy Applications

- Instructor: Nunes

- Ramsey policy

- Targeting Rules and Instrument Rules

- Time-Inconsistency and Recursive Contracts.

- Imperfect Commitment

- Exercises in Lab (all day)

6.4   Occasionally Binding Constraints and Simple Non-Linear Estimation

- Instructor: Swarbrick

- Perfect-foresight solutions and the extended-path method.

- The stochastic extended-path method.

- The Holden-Paetz hybrid local global method and dynareOBC toolkit.

- The Zero Lower Bound in New Keynesian models

- Financial frictions with occasionally binding borrowing constraints

- Non-linear estimation using the dynareOBC toolkit

- Exercises in Lab (all day)