

# Introduction to simulation and estimation of Dynamic Stochastic General Equilibrium models

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## Introduction

In recent years Dynamic Stochastic General Equilibrium (DSGE) models have moved from academic circles and are now playing an important role in the formulation and communication of monetary policy of the majority of Central Banks worldwide.

DSGE models are built on microeconomic foundations and on economic agent's intertemporal optimization behaviour. In DSGE models future uncertain outcomes depends on current agents choices and, crucially, current macroeconomics outcomes are influenced by agent's expectations about the future (*dynamic* and *stochastic* dimensions). The *general equilibrium* dimension highlights the interaction between economic agents and policy-makers.

While traditional macroeconometric forecasting models are vulnerable to the Lucas critique<sup>1</sup>, the role of expectations makes DSGE model not subject to such a critique and makes them a natural benchmark for evaluating the welfare effects of policy changes.

In 1982 Kydland and Prescott's "Time to Build and Aggregate Fluctuations" set the stone of the Real Business Cycle (RBC) literature and it is often considered as the first DSGE model. The RBC theory builds upon the neoclassical growth model, under the assumption of flexible prices, to study the impact of real shocks on business cycle fluctuations. New Keynesian DSGE models (NK) build on the RBC core structure assuming instead that prices are set by monopolistically competitive firms, and cannot be instantaneously and costlessly adjusted. The first paper to introduce this framework was Rotemberg and Woodford (1997) while the monetary policy implications were surveyed in Clarida, Galí and Gertler (1999).

The aim of this course is to provide an hands-on introduction to construction, simulation and estimation of DSGE models using the free software Dynare. Dynare offers a user-friendly and

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<sup>1</sup>They fail to recognize that optimal decision rules of economic agents vary systematically with changes in policy.

intuitive way of describing these models. It is able to perform simulations of the model given a calibration of the model parameters and is also able to estimate these parameters given a dataset.

### References:

- Clarida, R., Galí, J. and Gertler, M. (1999). "The Science of Monetary Policy: A New Keynesian Perspective". *Journal of Economic Literature* 37 (4): 1661-1707.
- Lucas, R.E. Jr. (1976). "Econometric Policy Evaluation: A Critique". *Carnegie-Rochester Conference Series on Public Policy* 1: 19-46.
- Kydland, F.E. and Prescott, E.C. (1982). "Time to Build and Aggregate Fluctuations". *Econometrica* 50 (6): 1345-1370.
- Rotemberg, J. and Woodford, M. (1997). "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy". *NBER Macroeconomics Annual* 12: 297-346.

## Prerequisites

The course is an introductory course mainly aimed at researchers or practitioners in Central Banks, Academia or Investment Banks. No previous exposure to DSGE modelling and Dynare is required. Participants should have basic knowledge of macroeconomics and dynamic optimization at Master or 1<sup>st</sup> year-PhD level. Some prior knowledge of Matlab programming is not necessary but will constitute an advantage.

## Course outline

The course is taught in 4 sessions of 4 hours each. The material will be self-contained.

### Lecture 1: Introduction to Matlab and Dynare.

This lecture will present a self-contained introduction to Matlab and Dynare programming tools in order to give the students the necessary skills to start programming and solving a fair amount of economic problems using a computer. We will discuss basic matrix operations, variable types, control statements, logical indexing, functions, statistical functions, plots, debugging and numerical optimization in Matlab. Then we will introduce Dynare, how to install it in Matlab and highlight its main features for simulation and estimation of DSGE models.

### Readings:

- Dynare. *Manual*.  
[download here](#)

- Mancini Griffoli, T. (2013). *Dynare User Guide*.  
[download here](#)
- Matlab (2014). *Matlab Primer R2014b*.  
[download here](#)

## Lecture 2: DSGE model solution and simulation: An application to the RBC model

This lecture will introduce the construction of DSGE models describing the first-order conditions for economic agents in the form of a set of non-linear difference equations. We will go through the set-up, solution and simulation of the plain vanilla RBC model as in Cooley (1995) chapter 1. We will then discuss and solve a couple of RBC model extensions including indivisible labor and investment specific technical change.

### Readings:

- Cooley, T. (2009). *Frontiers of Business Cycle Research*, Princeton University Press. Chapter 1.
- Hansen, G. (1985). "Indivisible Labor and the Business Cycle", *Journal of Monetary Economics*, 16, 309-327.
- Greenwood, J., Hercowitz, Z. and Krusell, P. (2000). "The role of investment-specific technological change in the business cycle," *European Economic Review*, 44(1), 91-115.

## Lecture 3: NK Models

This lecture will introduce staggered price setting into DSGE models. We will start with a simpler version of the RBC model set up in lecture 2 (abstracting from capital) and add a nominal side to it in order to be able to analyze the effect of nominal rigidities and demand shocks to the business cycle.

### Readings:

- Galí, J. (2008): *Monetary Policy, Inflation, and the Business Cycle*, Princeton University Press.

## **Lecture 4: Bayesian Estimation of DSGE models: an application to the New Keynesian model and to a medium scale DSGE model.**

Finally, this lecture will introduce the students to the basics of Bayesian estimation of DSGE models with most of the emphasis on the practical implementation in Dynare rather than on the theory. We replicate the estimation of the basic New Keynesian models discussed in Rabanal and Rubio-Ramirez (2005) and we will also go through a code that replicates the estimation of the workhorse medium scale DSGE model presented by Smets and Wouters (2007) which represents the core of every DSGE model used for policy analysis in many Central Banks around the world.

### **Readings:**

- Rabanal, P. and Rubio-Ramirez, J. F. (2005). "Comparing New Keynesian models of the business cycle: A Bayesian approach", *Journal of Monetary Economics*, 52 1151-1166.
- Smets, F. and Wouters, F. (2007). "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, American Economic Association, 97(3), 586-606.