Preface

Given the huge number of responses and comments to the first edition of our book, we felt obliged to come up with the second edition within such a short period of time. Stochastic Dynamic General Equilibrium modeling is certainly among the most rapidly changing fields in economics and we try to cover the most recent developments.

In this edition, we reorganize and extend the presentation of solution methods in the former Chapters 1 through 4 and add major new material. Different from the first edition Chapter 1 serves as introduction, but does not present any solution techniques. It covers deterministic and stochastic representative agent models, elaborates on their calibration and evaluation, and ends with a characterization of the solution methods presented in Chapters 2 through 6. Chapter 2 now includes a section on the second-order approximation of policy functions, the extended deterministic path algorithm in Chapter 3 is applied to an open economy model with a unit root, and we consider various techniques to speed up value function iteration in Chapter 4. In the second part of the book on heterogenous agent economies we split the former Chapter 7 on overlapping generations (OLG) models. The solution of OLG models with perfect foresight is now covered in Chapter 9, where we also consider different ways to compute the transitional dynamics of these models. A new application deals with a model of the demographic transition. OLG models with aggregate and individual uncertainty are solved in Chapter 10.

Computer Code. As one of our main ambition, we keep the essential feature of this book to make all our programs that we used for the computations available on our website `www.wiwi.uni-`

augsburg.de/vwl/maussner/. Therefore, the reader does not need to download any program code from other websites in order to replicate any of our findings, for example, on the statistics and characteristics of business cycle models or the dynamics of the distribution function in heterogeneous-agent economies. In the email correspondence with our readers this very feature of our book has often been pointed out as a crucial one by the graduate students in order to get started with his or her own research. If you are endowed with the programs for all the basic models of the business cycle, growth, and the distribution that we cover in this book, it is easy to start modifying them and work on your own projects.

Numerical methods are introduced one after the other and every new method is illustrated with the help of an example. This book and its accompanying web page is particularly designed for those students with little or no prior computing experience. We start from the scratch and deliberately concentrate on models that are formulated in discrete time so that we are able to bypass the technical complexities that arise when stochastic elements are introduced into continuous time optimizing models. The computer code is available either in Gauss or Fortran or both. The former computer language is almost identical to Matlab and can be translated without any effort. This way, the reader of this book can easily learn advanced programming techniques and, starting from very simple problems, she or he learns to apply them to more complex models, for example, a stochastic growth model with heterogeneous households.

Dynamic General Equilibrium Models. Dynamic General Equilibrium (DGE) models have become the workhorses of modern macroeconomics. Whatever textbook on advanced macroeconomics you consider you will find three kinds of models: the Solow model, the Ramsey model, and the overlapping generations model. The elementary versions of all three models can be studied with paper and pencil methods. But as soon as the researcher starts asking important questions of economic policy, these methods break down.

There are three questions researcher are most interested in. The first concerns transitional dynamics. For example, in growth theory, we are interested in the question of how countries converge to their long-run equilibrium, or, in public finance, we want to understand the behavior of the economy after an enduring tax cut. The second kind of problem concerns economic fluctuations that are caused by supply and demand shocks. Notably stochastic versions of the Ramsey model have been applied successfully to the study of business cycle dynamics. In these models demand and supply shocks trigger intra- and intertemporal substitution between leisure, consumption, and asset holdings and generate patterns in time series that mimic those found in macroeconomic data. The third issue, which has only received limited attention in the recent textbook literature, concerns models with heterogenous agents. Important applications of heterogeneous-agent economies can be found in the theory of income distribution, in the theory of asset pricing or in the field of public finance, to name but a few. To address any of these economic problems that are formulated as a DGE model, the researcher needs to apply computational methods.

Scope. The book is aimed at graduate students or advanced undergraduates. It may be used for both class-room and self study. It contains a great deal of new research both in the field of computational economics and in the field of macroeconomic theory. In essence, this book makes the following contributions:

1. The book tells the student in a simple way starting from a very basic level how to compute dynamic general equilibrium models. The emphasis is not on formal proofs, but rather on applications with codes and algorithms. Students should be able to start to program their own applications right away. Only some prior knowledge of statistics, linear algebra, and analysis is necessary. The relevant material from numerical analysis is gathered in a separate chapter for those readers who are unfamiliar with these techniques.
2. We also emphasize some problems of the practitioner that have only received limited if any attention at all in the recent text-

book literature. For example, we make an extensive effort to discuss the problem of finding a good initial value for the policy function in complex models so that the algorithm converges to the true solution. Likewise, we discuss the problem of modeling the dynamics of the distribution of the individual state variable in heterogeneous-agent economies in detail. Like econometrics, for example, numerical analysis is also as much an art as a science, and a young researcher in this field may often wonder why his or her particular computer program does not converge to an equilibrium value or fails to produce a sound solution. In other word, experience is important for the solution of numerical problems and our aim is to share as many as possible of our practical knowledge.

3. Our applications also reflect many recent research from the field of business cycle theory. For example, we compute the standard RBC model, monetary business cycle models, or the business cycle dynamics of the asset market. For this reason, the book is also valuable to both the student and the researcher of business cycles.
4. For this reason, the book is also interesting for researchers both in the field of (income and wealth) distribution theory and in the field of public finance.

The presentation in our book is self-contained and the reading of it is possible without the consultation of other material. The field of computational economics, however, is vast and we do not pretend to survey it. Fortunately, there are several other recent good textbooks that are complementary to ours. Kenneth Judd (1998) is giving a comprehensive survey of computational economics and remains the standard reference, while Miranda and Fackler (2002) have written a book that, like ours, is more directed towards the illustration of examples and algorithms, while their focus, however, is more on continuous time models. Marimon and Scott (1999) have edited a textbook that also illustrates methods in order to compute the stochastic growth model that we have not covered in this book, for example the finite-element method. In our book, we also do not cover the process

of calibration and estimation methods of stochastic DGE models with the help of econometric techniques such as maximum likelihood and method of moments. The textbooks of Canova (2007) and DeJong with Dave (2007) are excellent references for the study of these empirical methods. The textbook by Ljungqvist and Sargent (2004) on recursive macroeconomic theory and the monograph by Stokey and Lucas with Prescott (1989) on recursive methods may serve as a helpful reference for the economic theory and mathematical background applied in this book. McCandless (2008) provides a detailed presentation of various monetary and open economy models and their log-linearization together with the Matlab code, while Galí (2008) gives a concise introduction to the New Keynesian framework with an emphasis on monetary theory.

Organization. The book consists of three parts. Part I studies methods in order to compute representative-agent economies, Part II looks at heterogeneous-agent economies, while we collected numerical and other mathematical tools in part III. In the first Chapter, we introduce the benchmark model which is the stochastic Ramsey model and give an overview of possible solution methods. We compare different methods in the following five chapters with a focus on accuracy, speed and ease of implementation. After the study of the Part I, the reader should be able to choose among the different methods the one that suits the computation of his particular business cycle model best. The second part of the book is devoted to the application of numerical methods to the computation of heterogeneous-agent economies. In particular, we consider the heterogeneous-agent extension of the stochastic growth model on the one hand and the overlapping generations model on the other hand. A detailed description of numerical tools from the field of non-linear equations, approximation theory, differential and integration theory or numerical optimization is delegated to Chapter 11 that, together with Chapter 12 on other mathematical tools, constitutes Part III of the book.

We appreciate that this book cannot easily be covered in one semester, but one can conveniently choose parts of it as the basis of a one-semester course. For example, a course on computa-

tional methods in business cycle theory may choose the Chapters 1 through 5 or 6 where we covered the methods that we judge to be most useful for the computation of representative-agent business cycle and growth models. Chapter 1 introduces the stochastic growth model and gives an overview of the basic techniques for its computation. Chapter 2 reviews local approximation methods which have been predominantly applied in the analysis of business cycle models. Different from the first edition, we now also look at second-order perturbation methods. Chapters 3 and 4 cover the extended deterministic path approach and discrete state space methods. Chapters 5 and 6 present the parameterized expectations approach and projection methods, respectively. While a standard course on business cycles should minimally cover Chapter 1 with the benchmark model and a description of the basic statistics and calibration exercise as well as the first part of Chapter 2 that covers the computation of the linearized model, the instructor of a more specialized course should cover Chapters 1 and 2 and may pick any one of the remaining chapters. A reading list for a course on monetary economics may also include Chapters 1 and 2 of our book as it enables the student to compute the monetary business cycle model presented in Chapter 2 and, in addition, introduces him to the New Keynesian Phillips curve.

Graduate students with prior knowledge of numerical analysis may use Chapters 7 through 10 for an introduction to the computation of heterogeneous-agent economies and the theory of income distribution. Chapter 7 extends the stochastic growth model to a heterogeneous-agent economy and introduces different ways to compute the stationary distribution of wealth. Chapter 8 considers the dynamics of the income and wealth distribution. In Chapters 9 and 10, we look at overlapping generations models. Chapter 9 considers deterministic models. We compute the stationary equilibrium and transition dynamics in the perfect-foresight Auerbach-Kotlikoff model. Chapter 10 introduces individual and aggregate uncertainty in this model. We compute the stationary distribution of wealth in a model with idiosyncratic shocks to individual productivity and the business cycle dynamics in a model with shocks to total factor productivity. Therefore, a one-semester

course in computational public finance that is aimed at the computation of Auerbach-Kotlikoff models can be based on Chapters 1-3, 9 and 10.

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