

Contents

Acknowledgments xxi

Preface to the fourth edition xxiii

Part I: Imperialism of Recursive Methods

1. Overview 3

1.1. Warning. 1.2. A common ancestor. 1.3. The savings problem. 1.3.1. Linear quadratic permanent income theory. 1.3.2. Precautionary saving. 1.3.3. Complete markets, insurance, and the distribution of wealth. 1.3.4. Bewley models. 1.3.5. History dependence in standard consumption models. 1.3.6. Growth theory. 1.3.7. Limiting results from dynamic optimal taxation. 1.3.8. Asset pricing. 1.3.9. Multiple assets. 1.4. Recursive methods. 1.4.1. Dynamic programming and the Lucas Critique. 1.4.2. Dynamic programming challenged. 1.4.3. Imperialistic response of dynamic programming. 1.4.4. History dependence and “dynamic programming squared”. 1.4.5. Dynamic principal-agent problems. 1.4.6. More applications.

Part II: Tools

2. Time Series

29

2.1. Two workhorses. 2.2. Markov chains. 2.2.1. Stationary distributions. 2.2.2. Asymptotic stationarity. 2.2.3. Forecasting the state. 2.2.4. Forecasting functions of the state. 2.2.5. Forecasting functions. 2.2.6. Enough one-step-ahead forecasts determine P . 2.2.7. Invariant functions and ergodicity. 2.2.8. Simulating a Markov chain. 2.2.9. The likelihood function. 2.3. Continuous-state Markov chain. 2.4. Stochastic linear difference equations. 2.4.1. First and second moments. 2.4.2. Summary of moment formulas. 2.4.3. Impulse response function. 2.4.4. Prediction and discounting. 2.4.5. Geometric sums of quadratic forms. 2.5. Population regression. 2.5.1. Multiple regressors. 2.6. Estimation of model parameters. 2.7. The Kalman filter. 2.8. Estimation again. 2.9. Vector autoregressions and the Kalman filter. 2.9.1. Conditioning on the semi-infinite past of y . 2.9.2. A time-invariant VAR. 2.9.3. Interpreting VARs. 2.10. Applications of the Kalman filter. 2.10.1. Muth's reverse engineering exercise. 2.10.2. Jovanovic's application. 2.11. The spectrum. 2.11.1. Examples. 2.12. Example: the LQ permanent income model. 2.12.1. Another representation. 2.12.2. Debt dynamics. 2.12.3. Two classic examples. 2.12.4. Spreading consumption cross section. 2.12.5. Invariant subspace approach. 2.13. Concluding remarks. A. Linear difference equations. 2.A.1. A first-order difference equation. 2.A.2. A second-order difference equation. 2.15. Exercises.

3. Dynamic Programming

105

3.1. Sequential problems. 3.1.1. Three computational methods. 3.1.2. Cobb-Douglas transition, logarithmic preferences. 3.1.3. Euler equations. 3.1.4. A sample Euler equation. 3.2. Stochastic control problems. 3.3. Concluding remarks. 3.4. Exercise.

4. Practical Dynamic Programming

115

4.1. The curse of dimensionality. 4.2. Discrete-state dynamic programming. 4.3. Bookkeeping. 4.4. Application of Howard improvement algorithm. 4.5. Numerical implementation. 4.5.1. Modified policy iteration. 4.6. Sample Bellman equations. 4.6.1. Example 1: calculating expected

utility. 4.6.2. Example 2: risk-sensitive preferences. 4.6.3. Example 3: costs of business cycles. 4.7. Polynomial approximations. 4.7.1. Recommended computational strategy. 4.7.2. Chebyshev polynomials. 4.7.3. Algorithm: summary. 4.7.4. Shape-preserving splines. 4.8. Concluding remarks.

5. Linear Quadratic Dynamic Programming

129

5.1. Introduction. 5.2. The optimal linear regulator problem. 5.2.1. Value function iteration. 5.2.2. Discounted linear regulator problem. 5.2.3. Policy improvement algorithm. 5.3. The stochastic optimal linear regulator problem. 5.3.1. Discussion of certainty equivalence. 5.4. Shadow prices in the linear regulator. 5.4.1. Stability. 5.5. A Lagrangian formulation. 5.6. The Kalman filter again. 5.7. Concluding remarks. A. Matrix formulas. 5.9. Exercises.

6. Search and Unemployment

157

6.1. Introduction. 6.2. Preliminaries. 6.2.1. Nonnegative random variables. 6.2.2. Mean-preserving spreads. 6.3. McCall's model of intertemporal job search. 6.3.1. Characterizing reservation wage. 6.3.2. Effects of mean-preserving spreads. 6.3.3. Allowing quits. 6.3.4. Waiting times. 6.3.5. Firing. 6.4. A lake model. 6.5. A model of career choice. 6.6. Offer distribution unknown. 6.7. An equilibrium price distribution. 6.7.1. A Burdett-Judd setup. 6.7.2. Consumer problem with noisy search. 6.7.3. Firms. 6.7.4. Equilibrium. 6.7.5. Special cases. 6.8. Jovanovic's matching model. 6.8.1. Recursive formulation and solution. 6.8.2. Endogenous statistics. 6.9. A longer horizon version of Jovanovic's model. 6.9.1. The Bellman equations. 6.10. Concluding remarks. A. More numerical dynamic programming. 6.A.1. Example 4: search. 6.A.2. Example 5: a Jovanovic model. 6.12. Exercises.

Part III: Competitive Equilibria and Applications

7. Recursive Competitive Equilibrium: I

225

7.1. An equilibrium concept. 7.2. Example: adjustment costs. 7.2.1. A planning problem. 7.3. Recursive competitive equilibrium. 7.4. Equilibrium human capital accumulation. 7.4.1. Planning problem. 7.4.2.

Decentralization. 7.5. Equilibrium occupational choice. 7.5.1. A planning problem. 7.5.2. Decentralization. 7.6. Markov perfect equilibrium. 7.6.1. Computation. 7.7. Linear Markov perfect equilibria. 7.7.1. An example. 7.8. Concluding remarks. 7.9. Exercises.

8. Equilibrium with Complete Markets

249

8.1. Time 0 versus sequential trading. 8.2. The physical setting: preferences and endowments. 8.3. Alternative trading arrangements. 8.3.1. History dependence. 8.4. Pareto problem. 8.4.1. Time invariance of Pareto weights. 8.5. Time 0 trading: Arrow-Debreu securities. 8.5.1. Equilibrium pricing function. 8.5.2. Optimality of equilibrium allocation. 8.5.3. Interpretation of trading arrangement. 8.5.4. Equilibrium computation. 8.6. Simpler computational algorithm. 8.6.1. Example 1: risk sharing. 8.6.2. Implications for equilibrium computation. 8.6.3. Example 2: no aggregate uncertainty. 8.6.4. Example 3: periodic endowment processes. 8.6.5. Example 4. 8.7. Primer on asset pricing. 8.7.1. Pricing redundant assets. 8.7.2. Riskless consol. 8.7.3. Riskless strips. 8.7.4. Tail assets. 8.7.5. One-period returns. 8.8. Sequential trading. 8.8.1. Arrow securities. 8.8.2. Financial wealth as an endogenous state variable. 8.8.3. Reopening markets. 8.8.4. Debt limits. 8.8.5. Sequential trading. 8.8.6. Equivalence of allocations. 8.9. Recursive competitive equilibrium. 8.9.1. Endowments governed by a Markov process. 8.9.2. Equilibrium outcomes inherit the Markov property. 8.9.3. Recursive formulation of optimization and equilibrium. 8.9.4. Computing an equilibrium with sequential trading of Arrow-securities. 8.10. j -step pricing kernel. 8.10.1. Arbitrage-free pricing. 8.11. Term structure of yields on risk-free claims. 8.11.1. Constructing yields. 8.12. Recursive version of Pareto problem. 8.13. Concluding remarks. Appendices: Departures from key assumptions. A. Heterogenous discounting. B. Heterogenous beliefs. 8.B.1. Example: one type's beliefs are closer to the truth. 8.B.2. Equilibrium prices reflect beliefs. 8.B.3. Mispricing? 8.B.4. Learning. 8.B.5. Role of complete markets. C. Incomplete markets. 8.C.1. An example economy. 8.C.2. Asset payoff correlated with i.i.d. aggregate endowment. 8.C.3. Beneficial market incompleteness. 8.18. Exercises.

9. Overlapping Generations

331

9.1. Endowments and preferences. 9.2. Time 0 trading. 9.2.1. Example equilibria. 9.2.2. Relation to welfare theorems. 9.2.3. Nonstationary equilibria. 9.2.4. Computing equilibria. 9.3. Sequential trading. 9.4. Money. 9.4.1. Computing more equilibria with valued fiat currency.

9.4.2. Equivalence of equilibria. 9.5. Deficit finance. 9.5.1. Steady states and the Laffer curve. 9.6. Equivalent setups. 9.6.1. The economy. 9.6.2. Growth. 9.7. Optimality and the existence of monetary equilibria. 9.7.1. Balasko-Shell criterion for optimality. 9.8. Within-generation heterogeneity. 9.8.1. Nonmonetary equilibrium. 9.8.2. Monetary equilibrium. 9.8.3. Nonstationary equilibria. 9.8.4. The real bills doctrine. 9.9. Gift-giving equilibrium. 9.10. Concluding remarks. 9.11. Exercises.

10. Ricardian Equivalence

379

10.1. Borrowing limits and Ricardian equivalence. 10.2. Infinitely lived agent economy. 10.2.1. Optimal consumption/savings decision when $b_{t+1} \geq 0$. 10.2.2. Optimal consumption/savings decision when $b_{t+1} \geq \tilde{b}_{t+1}$. 10.3. Government finance. 10.3.1. Effect on household. 10.4. Linked generations interpretation. 10.5. Concluding remarks.

11. Fiscal Policies in a Growth Model

391

11.1. Introduction. 11.2. Economy. 11.2.1. Preferences, technology, information. 11.2.2. Components of a competitive equilibrium. 11.3. The term structure of interest rates. 11.4. Digression: sequential version of government budget constraint. 11.4.1. Irrelevance of maturity structure of government debt. 11.5. Competitive equilibria with distorting taxes. 11.5.1. The household: no-arbitrage and asset-pricing formulas. 11.5.2. User cost of capital formula. 11.5.3. Household first-order conditions. 11.5.4. A theory of the term structure of interest rates. 11.5.5. Firm. 11.6. Computing equilibria. 11.6.1. Inelastic labor supply. 11.6.2. The equilibrium steady state. 11.6.3. Computing the equilibrium path with the shooting algorithm. 11.6.4. Other equilibrium quantities. 11.6.5. Steady-state \bar{R} . 11.6.6. Lump-sum taxes available. 11.6.7. No lump-sum taxes available. 11.7. A digression on back-solving. 11.8. Effects of taxes on equilibrium allocations and prices. 11.9. Transition experiments with inelastic labor supply. 11.10. Linear approximation. 11.10.1. Relationship between the λ_i 's. 11.10.2. Conditions for existence and uniqueness. 11.10.3. Once-and-for-all jumps. 11.10.4. Simplification of formulas. 11.10.5. A one-time pulse. 11.10.6. Convergence rates and anticipation rates. 11.10.7. A remark about accuracy: Euler equation errors. 11.11. Growth. 11.12. Elastic labor supply. 11.12.1. Steady-state calculations. 11.12.2. Some experiments. 11.13. A two-country model. 11.13.1. Initial conditions. 11.13.2. Equilibrium steady state values. 11.13.3. Initial equilibrium values. 11.13.4. Shooting algorithm.

11.13.5. Transition exercises. 11.14. Concluding remarks. A. Log linear approximations. 11.16. Exercises.

12. Recursive Competitive Equilibrium: II

471

12.1. Endogenous aggregate state variable. 12.2. The stochastic growth model. 12.3. Lagrangian formulation of the planning problem. 12.4. Time 0 trading: Arrow-Debreu securities. 12.4.1. Household. 12.4.2. Firm of type I. 12.4.3. Firm of type II. 12.4.4. Equilibrium prices and quantities. 12.4.5. Implied wealth dynamics. 12.5. Sequential trading: Arrow securities. 12.5.1. Household. 12.5.2. Firm of type I. 12.5.3. Firm of type II. 12.5.4. Equilibrium prices and quantities. 12.5.5. Financing a type II firm. 12.6. Recursive formulation. 12.6.1. Technology is governed by a Markov process. 12.6.2. Aggregate state of the economy. 12.7. Recursive formulation of the planning problem. 12.8. Recursive formulation of sequential trading. 12.8.1. A “Big K , little k ” device. 12.8.2. Price system. 12.8.3. Household problem. 12.8.4. Firm of type I. 12.8.5. Firm of type II. 12.9. Recursive competitive equilibrium. 12.9.1. Equilibrium restrictions across decision rules. 12.9.2. Using the planning problem. 12.10. Concluding remarks. A. The permanent income model revisited. 12.A.1. Reinterpreting the single-agent model. 12.A.2. Decentralization and scaled prices. 12.A.3. Matching equilibrium and planning allocations. 12.A.4. Interpretation.

13. Asset Pricing Theory

503

13.1. Introduction. 13.2. Euler equations. 13.3. Martingale theories of consumption and stock prices. 13.4. Equivalent martingale measure. 13.5. Equilibrium asset pricing. 13.6. Stock prices without bubbles. 13.7. Computing asset prices. 13.7.1. Example 1: logarithmic preferences. 13.7.2. Example 2: finite-state version. 13.7.3. Example 3: growth. 13.8. Term structure of interest rates. 13.9. State-contingent prices. 13.9.1. Insurance premium. 13.9.2. Man-made uncertainty. 13.9.3. The Modigliani-Miller theorem. 13.10. Government debt. 13.10.1. The Ricardian proposition. 13.10.2. No Ponzi schemes. A. Harrison-Kreps (1978) heterogeneous beliefs. 13.A.1. Optimism and Pessimism. 13.A.2. Equilibrium price function. 13.A.3. Comparisons of equilibrium price functions. 13.A.4. Single belief prices. 13.A.5. Pricing under heterogeneous beliefs. 13.A.6. Insufficient funds. B. Gaussian asset-pricing model. 13.13. Exercises.

14.1. Introduction. 14.2. Interpretation of risk-aversion parameter. 14.3. The equity premium puzzle. 14.4. Market price of risk. 14.5. Hansen-Jagannathan bounds. 14.5.1. Law of one price implies that $EmR = 1$. 14.5.2. Inner product representation of price functional. 14.5.3. Admissible stochastic discount factors. 14.6. Failure of CRRA to attain HJ bound. 14.7. Non-expected utility. 14.7.1. Another representation of the utility recursion. 14.7.2. Stochastic discount factor. 14.7.3. Twisted probability distributions. 14.8. Reinterpretation of the utility recursion. 14.8.1. Risk aversion versus model misspecification aversion. 14.8.2. Recursive representation of probability distortions. 14.8.3. Entropy. 14.8.4. Expressing ambiguity aversion. 14.8.5. Ambiguity averse preferences. 14.8.6. Market price of model uncertainty. 14.8.7. Measuring model uncertainty. 14.9. Costs of aggregate fluctuations. 14.10. Reverse engineered consumption heterogeneity. 14.11. Affine risk prices. 14.11.1. An application. 14.11.2. Affine term structure of yields. 14.12. Risk-neutral probabilities. 14.12.1. Asset pricing in a nutshell. 14.13. Distorted beliefs. 14.14. Concluding remarks. A. Riesz representation theorem. B. Computing stochastic discount factors. C. A log normal bond pricing model. 14.C.1. Slope of yield curve. 14.C.2. Backus and Zin's stochastic discount factor. 14.C.3. Reverse engineering a stochastic discount factor. 14.18. Exercises.

15. Economic Growth

631

15.1. Introduction. 15.2. The economy. 15.2.1. Balanced growth path. 15.3. Exogenous growth. 15.4. Externality from spillovers. 15.5. All factors reproducible. 15.5.1. One-sector model. 15.5.2. Two-sector model. 15.6. Research and monopolistic competition. 15.6.1. Monopolistic competition outcome. 15.6.2. Planner solution. 15.7. Growth in spite of nonreproducible factors. 15.7.1. "Core" of capital goods produced without nonreproducible inputs. 15.7.2. Research labor enjoying an externality. 15.8. Concluding remarks. 15.9. Exercises.

16. Optimal Taxation with Commitment

661

16.1. Introduction. 16.2. A nonstochastic economy. 16.2.1. Government. 16.2.2. Household. 16.2.3. Firms. 16.3. The Ramsey problem. 16.4. Zero capital tax. 16.5. Primal approach to the Ramsey problem. 16.5.1. Constructing the Ramsey plan. 16.5.2. Revisiting a zero capital tax. 16.6. Taxation of initial capital. 16.7. Nonzero capital tax due to incomplete taxation. 16.8. A stochastic economy. 16.8.1. Government.

16.8.2. Household. 16.8.3. Firms. 16.9. Indeterminacy of debt and capital taxes. 16.10. A Ramsey plan under uncertainty. 16.11. Ex ante capital tax varies around zero. 16.11.1. Sketch of the proof of Proposition 2. 16.12. A stochastic economy without capital. 16.12.1. Computational strategy. 16.12.2. More specialized computations. 16.12.3. Time consistency. 16.13. Examples of labor tax smoothing. 16.13.1. Example 1: $g_t = g$ for all $t \geq 0$. 16.13.2. Example 2: $g_t = 0$ for $t \neq T$ and nonstochastic $g_T > 0$. 16.13.3. Example 3: $g_t = 0$ for $t \neq T$, and g_T is stochastic. 16.13.4. Time 0 is special with $b_0 \neq 0$. 16.14. Lessons for optimal debt policy. 16.15. Taxation without state-contingent debt. 16.15.1. Future values of $\{g_t\}$ become deterministic. 16.15.2. Stochastic $\{g_t\}$ but special preferences. 16.15.3. Example 3 revisited: $g_t = 0$ for $t \neq T$, and g_T is stochastic. 16.16. Nominal debt as state-contingent real debt. 16.16.1. Setup and main ideas. 16.16.2. Optimal taxation in a nonmonetary economy. 16.16.3. Optimal policy in a corresponding monetary economy. 16.16.4. Sticky prices. 16.17. Relation to fiscal theories of the price level. 16.17.1. Budget constraint versus asset pricing equation. 16.17.2. Disappearance of quantity theory? 16.17.3. Price level indeterminacy under interest rate peg. 16.17.4. Monetary or fiscal theory of the price level? 16.18. Zero tax on human capital. 16.19. Should all taxes be zero? 16.20. Concluding remarks. 16.21. Exercises.

Part IV: Savings Problems and Bewley Models

17. Self-Insurance

759

17.1. Introduction. 17.2. The consumer's environment. 17.3. Non-stochastic endowment. 17.3.1. An ad hoc borrowing constraint: non-negative assets. 17.3.2. Example: periodic endowment process. 17.4. Quadratic preferences. 17.5. Stochastic endowment process: i.i.d. case. 17.6. Stochastic endowment process: general case. 17.7. Intuition. 17.8. Endogenous labor supply. 17.9. Concluding remarks. A. Supermartingale convergence theorem. 17.11. Exercises.

18. Incomplete Markets Models

785

18.1. Introduction. 18.2. A savings problem. 18.2.1. Wealth-employment distributions. 18.2.2. Reinterpretation of the distribution λ . 18.2.3. Example 1: a pure credit model. 18.2.4. Equilibrium computation. 18.2.5. Example 2: a model with capital. 18.2.6. Computation of equilibrium.

18.3. Unification and further analysis. 18.4. The nonstochastic savings problem when $\beta(1+r) < 1$. 18.5. Borrowing limits: natural and ad hoc. 18.5.1. A candidate for a single state variable. 18.5.2. Supermartingale convergence again. 18.6. Average assets as a function of r . 18.7. Computed examples. 18.8. Several Bewley models. 18.8.1. Optimal stationary allocation. 18.9. A model with capital and private IOUs. 18.10. Private IOUs only. 18.10.1. Limitation of what credit can achieve. 18.10.2. Proximity of r to ρ . 18.10.3. Inside money or free banking interpretation. 18.10.4. Bewley's basic model of fiat money. 18.11. A model of seigniorage. 18.12. Exchange rate indeterminacy. 18.13. Interest on currency. 18.13.1. Explicit interest. 18.13.2. The upper bound on $\frac{M}{p}$. 18.13.3. A very special case. 18.13.4. Implicit interest through deflation. 18.14. Precautionary savings. 18.15. Models with fluctuating aggregate variables. 18.15.1. Aiyagari's model again. 18.15.2. Krusell and Smith's extension. 18.16. Concluding remarks. 18.17. Exercises.

Part V: Recursive Contracts

19. Dynamic Stackelberg Problems

839

19.1. History dependence. 19.2. The Stackelberg problem. 19.3. Timing protocol. 19.4. Recursive formulation. 19.4.1. Two Bellman equations. 19.4.2. Subproblem 1. 19.4.3. Subproblem 2. 19.4.4. Timing protocol. 19.4.5. Time inconsistency. 19.5. Large firm facing a competitive fringe. 19.5.1. The competitive fringe. 19.5.2. The large firm's problem. 19.5.3. Numerical example. 19.6. Concluding remarks. 19.7. Exercises.

20. Two Ramsey Problems Revisited

857

20.1. Introduction. 20.2. The Lucas-Stokey economy. 20.2.1. Finding the state is an art. 20.2.2. Intertemporal delegation. 20.2.3. Bellman equations. 20.2.4. Subproblem 1: Continuation Ramsey problem. 20.2.5. Subproblem 2: Ramsey problem. 20.2.6. First-order conditions. 20.2.7. State variable degeneracy. 20.2.8. Symptom and source of time inconsistency. 20.3. Recursive formulation of AMSS model. 20.3.1. Recasting state variables. 20.3.2. Measurability constraints. 20.3.3. Bellman equations. 20.3.4. Martingale replaces state-variable degeneracy. 20.4. Concluding remarks.

21.1. Insurance with recursive contracts. 21.2. Basic environment. 21.3. One-sided no commitment. 21.3.1. Self-enforcing contract. 21.3.2. Recursive formulation and solution. 21.3.3. Recursive computation of contract. 21.3.4. Profits. 21.3.5. $P(v)$ is strictly concave and continuously differentiable. 21.3.6. Many households. 21.3.7. An example. 21.4. A Lagrangian method. 21.5. Insurance with asymmetric information. 21.5.1. Efficiency implies $b_{s-1} \geq b_s, w_{s-1} \leq w_s$. 21.5.2. Local upward and downward constraints are enough. 21.5.3. Concavity of P . 21.5.4. Local downward constraints always bind. 21.5.5. Coinsurance. 21.5.6. $P'(v)$ is a martingale. 21.5.7. Comparison to model with commitment problem. 21.5.8. Spreading continuation values. 21.5.9. Martingale convergence and poverty. 21.5.10. Extension to general equilibrium. 21.5.11. Comparison with self-insurance. 21.6. Insurance with unobservable storage. 21.6.1. Feasibility. 21.6.2. Incentive compatibility. 21.6.3. Efficient allocation. 21.6.4. The two-period case. 21.6.5. Role of the planner. 21.6.6. Decentralization in a closed economy. 21.7. Concluding remarks. A. Historical development. 21.A.1. Spear and Srivastava. 21.A.2. Timing. 21.A.3. Use of lotteries. 21.9. Exercises.

22. Equilibrium without Commitment

22.1. Two-sided lack of commitment. 22.2. A closed system. 22.3. Recursive formulation. 22.4. Equilibrium consumption. 22.4.1. Consumption dynamics. 22.4.2. Consumption intervals cannot contain each other. 22.4.3. Endowments are contained in the consumption intervals. 22.4.4. All consumption intervals are nondegenerate (unless autarky is the only sustainable allocation). 22.5. Pareto frontier and ex ante division of the gains. 22.6. Consumption distribution. 22.6.1. Asymptotic distribution. 22.6.2. Temporary imperfect risk sharing. 22.6.3. Permanent imperfect risk sharing. 22.7. Alternative recursive formulation. 22.8. Pareto frontier revisited. 22.8.1. Values are continuous in implicit consumption. 22.8.2. Differentiability of the Pareto frontier. 22.9. Continuation values à la Kocherlakota. 22.9.1. Asymptotic distribution is nondegenerate for imperfect risk sharing (except when $S = 2$). 22.9.2. Continuation values do not always respond to binding participation constraints. 22.10. A two-state example: amnesia overwhelms memory. 22.10.1. Pareto frontier. 22.10.2. Interpretation. 22.11. A three-state example. 22.11.1. Perturbation of parameter values. 22.11.2. Pareto frontier. 22.12. Empirical motivation. 22.13. Generalization. 22.14. Decentralization. 22.15. Endogenous borrowing constraints. 22.16. Concluding remarks. 22.17. Exercises.

23.1. History-dependent unemployment insurance. 23.2. A one-spell model. 23.2.1. The autarky problem. 23.2.2. Unemployment insurance with full information. 23.2.3. The incentive problem. 23.2.4. Unemployment insurance with asymmetric information. 23.2.5. Computed example. 23.2.6. Computational details. 23.2.7. Interpretations. 23.2.8. Extension: an on-the-job tax. 23.2.9. Extension: intermittent unemployment spells. 23.3. A multiple-spell model with lifetime contracts. 23.3.1. The setup. 23.3.2. A recursive lifetime contract. 23.3.3. Compensation dynamics when unemployed. 23.3.4. Compensation dynamics while employed. 23.3.5. Summary. 23.4. Concluding remarks. 23.5. Exercises.

24. Credible Government Policies: I

24.1. Introduction. 24.1.1. Diverse sources of history dependence. 24.2. One-period economy. 24.2.1. Competitive equilibrium. 24.2.2. Ramsey problem. 24.2.3. Nash equilibrium. 24.3. Nash and Ramsey outcomes. 24.3.1. Taxation example. 24.3.2. Black-box example with discrete choice sets. 24.4. Reputational mechanisms: general idea. 24.4.1. Dynamic programming squared. 24.4.2. Etymology of ‘dynamic programming squared’. 24.5. The infinitely repeated economy. 24.5.1. A strategy profile implies a history and a value. 24.5.2. Recursive formulation. 24.6. Subgame perfect equilibrium (SPE). 24.7. Examples of SPE. 24.7.1. Infinite repetition of one-period Nash equilibrium. 24.7.2. Supporting better outcomes with trigger strategies. 24.7.3. When reversion to Nash is not bad enough. 24.8. Values of all SPEs. 24.8.1. Basic idea of dynamic programming squared. 24.9. APS machinery. 24.10. Self-enforcing SPE. 24.10.1. The quest for something worse than repetition of Nash outcome. 24.11. Recursive strategies. 24.12. Examples of SPE with recursive strategies. 24.12.1. Infinite repetition of Nash outcome. 24.12.2. Infinite repetition of a better-than-Nash outcome. 24.12.3. Something worse: a stick-and-carrot strategy. 24.13. Best and worst SPE values. 24.13.1. When v_1 is outside the candidate set. 24.14. Examples: alternative ways to achieve the worst. 24.14.1. Attaining the worst, method 1. 24.14.2. Attaining the worst, method 2. 24.14.3. Attaining the worst, method 3. 24.14.4. Numerical example. 24.15. Interpretations. 24.16. Extensions. 24.17. Exercises.

25. Credible Government Policies: II 1059

25.1. History-dependent government policies. 25.2. The setting. 25.2.1. Household problem. 25.2.2. Government. 25.2.3. Analysis of household's problem. 25.2.4. θ_{t+1} as intermediating variable. 25.3. Recursive approach to Ramsey problem. 25.3.1. Subproblem 1: Continuation Ramsey problem. 25.3.2. Subproblem 2: Ramsey problem. 25.3.3. Finding set Ω . 25.3.4. An example. 25.4. Chang's formulation. 25.4.1. Competitive equilibrium. 25.5. Inventory of key objects. 25.6. Analysis. 25.6.1. Notation. 25.6.2. An operator. 25.7. Sustainable plans. 25.8. Concluding remarks.

26. Two Topics in International Trade 1083

26.1. Two dynamic contracting problems. 26.2. Moral hazard and difficult enforcement. 26.2.1. Autarky. 26.2.2. Investment with full insurance. 26.2.3. Limited commitment and unobserved investment. 26.2.4. Optimal capital outflows under distress. 26.3. Gradualism in trade policy. 26.3.1. Closed-economy model. 26.3.2. A Ricardian model of two countries under free trade. 26.3.3. Trade with a tariff. 26.3.4. Welfare and Nash tariff. 26.3.5. Trade concessions. 26.3.6. A repeated tariff game. 26.3.7. Time-invariant transfers. 26.3.8. Gradualism: time-varying trade policies. 26.3.9. Baseline policies. 26.3.10. Multiplicity of payoffs and continuation values. 26.4. Another model. 26.5. Concluding remarks. A. Computations for Atkeson's model. 26.7. Exercises.

Part VI: Classical Monetary and Labor Economics

27. Fiscal-Monetary Theories of Inflation 1123

27.1. The issues. 27.2. A shopping time monetary economy. 27.2.1. Household. 27.2.2. Government. 27.2.3. Equilibrium. 27.2.4. "Short run" versus "long run". 27.2.5. Stationary equilibrium. 27.2.6. Initial date (time 0). 27.2.7. Equilibrium determination. 27.3. Ten monetary doctrines. 27.3.1. Quantity theory of money. 27.3.2. Sustained deficits cause inflation. 27.3.3. Fiscal prerequisites of zero inflation policy. 27.3.4. Unpleasant monetarist arithmetic. 27.3.5. An "open market" operation delivering neutrality. 27.3.6. The "optimum quantity" of money. 27.3.7. Legal restrictions to boost demand for currency. 27.3.8. *One big open market operation*. 27.3.9. A fiscal theory of the

price level. 27.3.10. Exchange rate indeterminacy. 27.3.11. Determinacy of the exchange rate retrieved. 27.4. An example of exchange rate (in)determinacy. 27.4.1. Trading before sunspot realization. 27.4.2. Fiscal theory of the price level. 27.4.3. A game theoretic view of the fiscal theory of the price level. 27.5. Optimal inflation tax: the Friedman rule. 27.5.1. Economic environment. 27.5.2. Household's optimization problem. 27.5.3. Ramsey plan. 27.6. Time consistency of monetary policy. 27.6.1. Model with monopolistically competitive wage setting. 27.6.2. Perfect foresight equilibrium. 27.6.3. Ramsey plan. 27.6.4. Credibility of the Friedman rule. 27.7. Concluding remarks. 27.8. Exercises.

28. Credit and Currency

1171

28.1. Credit and currency with long-lived agents. 28.2. Preferences and endowments. 28.3. Complete markets. 28.3.1. A Pareto problem. 28.3.2. A complete markets equilibrium. 28.3.3. Ricardian proposition. 28.3.4. Loan market interpretation. 28.4. A monetary economy. 28.5. Townsend's "turnpike" interpretation. 28.6. The Friedman rule. 28.6.1. Welfare. 28.7. Inflationary finance. 28.8. Legal restrictions. 28.9. A two-money model. 28.10. A model of commodity money. 28.10.1. Equilibrium. 28.10.2. Virtue of fiat money. 28.11. Concluding remarks. 28.12. Exercises.

29. Equilibrium Search, Matching, and Lotteries

1207

29.1. Introduction. 29.2. An island model. 29.2.1. A single market (island). 29.2.2. The aggregate economy. 29.3. A matching model. 29.3.1. A steady state. 29.3.2. Welfare analysis. 29.3.3. Size of the match surplus. 29.4. Matching model with heterogeneous jobs. 29.4.1. A steady state. 29.4.2. Welfare analysis. 29.4.3. The allocating role of wages I: separate markets. 29.4.4. The allocating role of wages II: wage announcements. 29.5. Employment lotteries. 29.6. Lotteries for households versus lotteries for firms. 29.6.1. An aggregate production function. 29.6.2. Time-varying capacity utilization. 29.7. Employment effects of layoff taxes. 29.7.1. A model of employment lotteries with layoff taxes. 29.7.2. An island model with layoff taxes. 29.7.3. A matching model with layoff taxes. 29.8. Kiyotaki-Wright search model of money. 29.8.1. Monetary equilibria. 29.8.2. Welfare. 29.9. Concluding remarks. 29.10. Exercises.

30.1. Introduction. 30.2. Fundamental surplus. 30.2.1. Sensitivity of unemployment to market tightness. 30.2.2. Nash bargaining model. 30.2.3. Shimer's critique. 30.2.4. Relationship to worker's outside value. 30.2.5. Relationship to match surplus. 30.2.6. Fixed matching cost. 30.2.7. Sticky wages. 30.2.8. Alternating-offer wage bargaining. 30.3. Business cycle simulations. 30.3.1. Hall's sticky wage. 30.3.2. Hagedorn and Manovskii's high value of leisure. 30.3.3. Hall and Milgrom's alternating-offer bargaining. 30.3.4. Matching and bargaining protocols in a DSGE model. 30.4. Overlapping generations in one matching function. 30.4.1. A steady state. 30.4.2. Reservation productivity is increasing in age. 30.4.3. Wage rate is decreasing in age. 30.4.4. Welfare analysis. 30.4.5. The optimal policy. 30.5. Directed search: age-specific matching functions. 30.5.1. Value functions and market tightness. 30.5.2. Job finding rate is decreasing in age. 30.5.3. Block recursive equilibrium computation. 30.5.4. Welfare analysis. 30.6. Concluding remarks.

31. Foundations of Aggregate Labor Supply

31.1. Introduction. 31.2. Equivalent allocations. 31.2.1. Choosing career length. 31.2.2. Employment lotteries. 31.3. Taxation and social security. 31.3.1. Taxation. 31.3.2. Social security. 31.4. Earnings-experience profiles. 31.4.1. Time averaging. 31.4.2. Employment lotteries. 31.4.3. Prescott tax and transfer scheme. 31.4.4. No discounting now matters. 31.5. Intensive margin. 31.5.1. Employment lotteries. 31.5.2. Time averaging. 31.5.3. Prescott taxation. 31.6. Ben-Porath human capital. 31.6.1. Time averaging. 31.6.2. Employment lotteries. 31.6.3. Prescott taxation. 31.7. Earnings shocks. 31.7.1. Interpretation of wealth and substitution effects. 31.8. Time averaging in a Bewley model. 31.8.1. Incomplete markets. 31.8.2. Complete markets. 31.8.3. Simulations of Prescott taxation. 31.9. L and S equivalence meets C and K's agents. 31.9.1. Guess the value function. 31.9.2. Verify optimality of time averaging. 31.9.3. Equivalence of time averaging and lotteries. 31.10. Two pillars for high elasticity at extensive margin. 31.11. No pillars at intensive margin. 31.11.1. Special example of high elasticity at intensive margin. 31.11.2. Fragility of the special example. 31.12. Concluding remarks.

Part VII: Technical Appendices

A. Functional Analysis	1373
A.1. Metric spaces and operators. A.2. Discounted dynamic programming. A.2.1. Policy improvement algorithm. A.2.2. A search problem.	
B. Linear Projections and Hidden Markov Models	1385
B.1. Linear projections. B.2. Hidden Markov models. B.3. Nonlinear filtering.	
1. References	1391
2. Subject Index	1425
3. Author Index	1431
4. Matlab Index	1437