Syllabus
Empirical Asset Pricing (PHDBA 239FC)
Part II: Bonds and and Term Structure Models

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Version: January 24, 2025

Class Schedule:	Tuesday, 1:00pm–4:00pm, Mar-11, Mar-18, Apr-8, Apr-15, Apr-29.
	Friday, 9:00am–12:00pm, Mar-21, May-2
Class Location:	Cheit Hall, C330
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Office hours:	By appointment

Course Description

In the second part of the Ph.D. course "Empirical Asset Pricing," the focus is on the term structure of interest rates. We will review basic concepts of fixed income markets and securities, including bond pricing, duration, the yield curve, returns, and risk premia. Then we will study classic and modern models of the term structure of interest rates, with a focus on the affine class of models, and learn various techniques for estimating them, and examine the performance of different models across various dimensions. Finally, we will turn to two important macro-finance topics: First, the relationships between interest rates, the macroeconomy, and monetary policy; and second, joint models of stocks and bonds. After successful completion of this second part of the course, you will have a robust understanding of important stylized facts in bond markets and the underlying empirical methods, and you will be in a good position to embark on your own research on fixed income markets and macro-finance.

Problem Sets

There will be problem sets, roughly one every other week. Some of the questions will require you to carry out empirical analysis or simulations using statistical software packages on your computer. Please use Python, R or Matlab for these questions rather than software with "canned" routines (e.g., Stata). It is okay to work in groups with your classmates, but you must turn in individual solutions. Late assignments are unacceptable and will not be graded.

Term Paper

You are required to write one short term paper. The length should not exceed ten pages, including tables and figures. You can choose one of three options:

- One option is to write a *referee report*, a critical assessment of an unpublished and current working paper. Imagine that you are a referee for this paper, which has just been submitted for publication to a top-tier finance or economics journal. Your job is to convey to the editor your scientific, impartial opinion of the strengths and weaknesses of the paper. Please read Berk, Harvey, and Hirshleifer (2017) for additional guidance on how to write referee reports.
- You can also do a *replication study*. Your goal is to replicate the key results in an empirical paper (published article or working paper), using the same data and methods as the authors. You should not reproduce every single table and figure of the paper, but instead focus on the most important exhibits that demonstrate the main results. If the replication is straightforward, for example because of a publicly available replication package, you should conduct some robustness tests and see whether the results are sensitive to some of the choices in the empirical design (sample period, regression specification, estimation method, etc.)
- You third option is to do your own *empirical project*. It should be closely related to an existing empirical paper. Your goal is to extend the analysis of the paper in an interesting way, for example, by using new data or new econometric methods.

You should find a paper that interests you, and then send me your choice. If you need additional suggestions for papers, let me know. Make sure to confirm your choice of paper with me before writing your own paper/report.

The term paper is due on Wednesday, **May 7**.

Final Exam

There will be a final exam at the end of this half of the course. Exact date and time to be confirmed.

Grading Policy

Final exam 60%; problem sets 20%; class participation/term paper 20%. You will receive a single letter grade based on your performance on both halves of the course.

Prerequisites

This course is intended for 2nd year Ph.D. students in finance and economics.

- **Required**: Discrete-Time Asset Pricing (PHDBA239A), Continuous-Time Asset Pricing (PHD239B), Econometrics (ECON240A and ECON240B)

- **Recommended**: Aggregate Economics (ECON234A), Time Series Econometrics (ECON241B), Applied Macroeconomics (ECON236B).

Course Materials

Textbooks

- **Required**: Cochrane, John H., 2005, *Asset Pricing*, revised edition (Princeton University Press, Princeton, NJ) (AP).
- **Required**: Campbell, John Y., Andrew W. Lo, and A. Craig MacKinlay, 1997, *The Econometrics of Financial Markets* (Princeton University Press, Princeton, NJ) (CLM).

- **Recommended**: Campbell, John Y., 2018, *Financial Decisions and Markets: A Course in Asset Pricing* (Princeton University Press, Princeton, NJ).
- **Recommended**: Hamilton, James D., 1994, *Time Series Analysis* (Princeton University Press, Princeton, NJ).

Survey Articles

- Piazzesi, Monika, 2010, Affine term structure models, in Yacine Aït-Sahalia, and Lars Peter Hansen, eds., *Handbook of Financial Econometrics*, volume 1, 691–766 (North Holland, Elsevier).
- Duffee, Gregory R., 2013b, Forecasting interest rates, in Graham Elliott, and Allan Timmerman, eds., *Handbook of Economic Forecasting*, volume 2A, 385–426 (Elsevier).
- Duffee, Gregory R., 2013a, Bond pricing and the macroeconomy, in Milton Harris, George M. Constantinides, and Rene M. Stulz, eds., *Handbook of the Economics of Finance*, volume 2B, 907–967 (Elsevier).
- Gürkaynak, Refet S., and Jonathan H. Wright, 2012, Macroeconomics and the term structure, *Journal of Economic Literature* 50, 331–367.

Further Reading

- Veronesi, Pietro, 2010, *Fixed Income Securities* (Wiley, Hoboken, NJ).
- Hull, John C., 2014, *Options, Futures, and Other Derivatives*, 9th edition (Pearson, New Jersey).
- Tuckman, Bruce, and Angel Serrat, 2011, *Fixed Income Securities: Tools for Today's Markets*, third edition (Wiley, New York).
- James, Jessica, and Nick Webber, 2000, *Interest Rate Modelling: Financial Engineering* (Wiley, New York).
- Andersen, Leif B. G., and Vladimir Piterbarg, 2010, *Interest Rate Modeling* (Atlantic Financial Press, New York).
- Brigo, Damiano, and Fabio Mercurio, 2006, *Interest Rate Models — Theory and Practice: With Smile, Inflation and Credit*, second edition (Springer, New York).
- Filipović, Damir, 2009, *Term-Structure Models: A Graduate Course* (Springer, New York).
- Duffie, Darrell, 2001, *Dynamic Asset Pricing Theory*, third edition (Princeton University Press, Princeton, New Jersey).
- Singleton, Kenneth J., 2006, *Empirical Dynamic Asset Pricing: Model Specification and Econometric Assessment* (Princeton University Press, Princeton, NJ).

Tentative Schedule and Reading List

This schedule is preliminary and is subject to change.

Topic 1: Fixed-income Securities and the Yield Curve

- Basics of bond pricing
- Types of fixed-income securities
- Duration and convexity
- Basic empirical facts
- Fitting the yield curve
- Principal component analysis

Required: CLM Ch. 10.

Recommended: Campbell (2018, ch. 8.1–8.2); Veronesi (2010, Ch. 1–5), Litterman and Scheinkman (1991); Nelson and Siegel (1987); Svensson (1994).

Topic 2: Expectations Hypothesis and Risk Premia

- Bond risk premia
- Expectations hypothesis and Jensen's inequality
- Testing the expectations hypothesis
- Economic fundamentals and risk premia
- Persistence and unit roots
- Subjective vs. statistical risk premia
- Bond risk premia and machine learning

Required: Campbell and Shiller (1991); Dai and Singleton (2003, Section 3); Cochrane and Piazzesi (2005)

Recommended: Campbell and Shiller (1987); Campbell (1995); Stambaugh (1999); Piazzesi et al. (2015); Nagel and Xu (2023); Bianchi et al. (2021)

Topic 3: Introduction to Dynamic Term Structure Models

- Tree-based models
- Brownian Motion and stochastic calculus
- SDEs, PDEs, and SDFs in continuous time
- Continuous-time short-rate models

Required: CLM Ch. 11 up to 11.1;

Recommended: Veronesi (2010, Ch. 9–11, 14–15), Ho and Lee (1986); Black, Derman, and Toy (1990); Vasicek (1977); Cox, Ingersoll, and Ross (1985).

Topic 4: Affine Term Structure Models

- SDF and bond prices
- Single-factor models
- Canonical affine Gaussian model
- Normalization, identification, invariant transforms
- Stochastic volatility models, Dai-Singleton classification
- Relevance of no-arbitrage restrictions

Required: CLM Ch. 11; Cochrane (2005, Ch. 19); Ang and Piazzesi (2003); Dai and Singleton (2000); Duffee (2002); Joslin et al. (2011, JSZ).

Recommended: Campbell (2018, ch. 8.3); Adrian et al. (2013, ACM); Bauer et al. (2014); Bauer and Rudebusch (2016); Dai and Singleton (2002, 2003); Hamilton and Wu (2012, HW); Kim and Wright (2005); Kim and Orphanides (2012); Wu and Xia (2016).

Topic 5: Estimation of DTSMs

- Maximum Likelihood Estimation
- Regression-based methods
- Bayesian methods
- Measurement error
- Simulation methods
- Nonparametric methods

Required: Piazzesi (2010).

Recommended: Pearson and Sun (1994); Chen and Scott (2003); Santa-Clara (1995); Duffee and Stanton (2008, 2012); Aït-Sahalia (1996); Stanton (1997).

Topic 6: Real Interest Rates and Macroeconomic Fundamentals

- Fisher equation and Fisher effect
- Pricing of real vs. nominal bonds
- Inflation swaps and TIPS-Treasury Bond Puzzle
- Reduced-form macro-finance models of the yield curve
- Consumption-based/equilibrium models of the yield curve
- Evidence on unspanned macro risk, spanning puzzle
- Shifting trends and structural change

Required: Ang et al. (2008); Campbell et al. (2017); Campbell and Viceira (2001); Gürkaynak et al. (2010); Bauer and Hamilton (2018); Duffee (2011); Piazzesi and Schneider (2007).

Recommended: Campbell (2018, ch. 8.4); Abrahams et al. (2016); Campbell et al. (2009); d'Amico et al. (2018); Christensen et al. (2010); Fleckenstein et al. (2014); Kozicki and Tinsley (2001); Mishkin (1992); Rose (1988). Bauer and Rudebusch (2020, 2017); Cieslak and Povala (2015); Hördahl et al. (2006); Joslin et al. (2013, 2014); Ludvigson and Ng (2009); Rudebusch and Wu (2008); Rudebusch and Swanson (2012); Wachter (2006).

Topic 7: Term Structures of Equity and Interest Rates

- Changing comovement of stock and bond returns, the "Fed model"
- Joint modeling of stocks and bonds with affine term structure models
- Determinants of equity and bond risk premia
- Dividend strips/futures and equity yields

Required: Bekaert et al. (2009); Lettau and Wachter (2011); van Binsbergen et al. (2012).

Recommended: Campbell (2018, ch. 9.4), Adrian et al. (2015); Bekaert and Engstrom (2010); van Binsbergen et al. (2013); Koijen et al. (2017); Lettau and Wachter (2007).

References

Abrahams, Michael, Tobias Adrian, Richard K. Crump, Emanuel Moench, and Rui Yu, 2016, Decomposing real and nominal yield curves, *Journal of Monetary Economics* 84, 182–200.

Adrian, Tobias, Richard K. Crump, and Emanuel Moench, 2013, Pricing the term structure with linear regressions, *Journal of Financial Economics* 110, 110–138.

Adrian, Tobias, Richard K. Crump, and Emanuel Moench, 2015, Regression-based estimation of dynamic asset pricing models, *Journal of Financial Economics* 118, 211–244.

Aït-Sahalia, Yacine, 1996, Nonparametric pricing of interest rate derivative securities, *Econometrica* 64, 527–560.

Andersen, Leif B. G., and Vladimir Piterbarg, 2010, *Interest Rate Modeling* (Atlantic Financial Press, New York).

Ang, Andrew, Geert Bekaert, and Min Wei, 2008, The term structure of real rates and expected inflation, *Journal of Finance* 63, 797–849.

Ang, Andrew, and Monika Piazzesi, 2003, A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables, *Journal of Monetary Economics* 50, 745–787.

Bauer, Michael D., and James D. Hamilton, 2018, Robust bond risk premia, *Review of Financial Studies* 31, 399–448.

Bauer, Michael D., and Glenn D. Rudebusch, 2016, Monetary policy expectations at the zero lower bound, *Journal of Money, Credit and Banking* 48, 1439–1465.

Bauer, Michael D., and Glenn D. Rudebusch, 2017, Resolving the spanning puzzle in macro-finance term structure models, *Review of Finance* 21, 511–553.

Bauer, Michael D., and Glenn D. Rudebusch, 2020, Interest rates under falling stars, *American Economic Review* 110, 1316–1354.

Bauer, Michael D., Glenn D. Rudebusch, and Jing Cynthia Wu, 2014, Term premia and inflation uncertainty: Empirical evidence from an international panel dataset: Comment, *American Economic Review* 104, 1–16.

Bekaert, Geert, and Eric Engstrom, 2010, Inflation and the stock market: Understanding the "Fed Model", *Journal of Monetary Economics* 57, 278–294.

Bekaert, Geert, Eric Engstrom, and Yuhang Xing, 2009, Risk, uncertainty, and asset prices, *Journal of Financial Economics* 91, 59–82.

Berk, Jonathan B., Campbell R. Harvey, and David Hirshleifer, 2017, How to write an effective referee report and improve the scientific review process, *Journal of Economic Perspectives* 31, 231–244.

Bianchi, Daniele, Matthias Büchner, and Andrea Tamoni, 2021, Bond risk premiums with machine learning, *The Review of Financial Studies* 34, 1046–1089.

Black, Fischer, Emanuel Derman, and William Toy, 1990, A one-factor model of interest rates and its application to Treasury bond options, *Financial Analysts Journal* 46, 33–39.

Brigo, Damiano, and Fabio Mercurio, 2006, *Interest Rate Models — Theory and Practice: With Smile, Inflation and Credit*, second edition (Springer, New York).

Campbell, John Y., 1995, Some lessons from the yield curve, *Journal of Economic Perspectives* 9, 129–152.

Campbell, John Y., 2018, *Financial Decisions and Markets: A Course in Asset Pricing* (Princeton University Press, Princeton, NJ).

Campbell, John Y., Andrew W. Lo, and A. Craig MacKinlay, 1997, *The Econometrics of Financial Markets* (Princeton University Press, Princeton, NJ).

Campbell, John Y., and Robert J. Shiller, 1987, Cointegration and tests of present value models, *Journal of Political Economy* 95, 1062–1088.

Campbell, John Y., and Robert J. Shiller, 1991, Yield spreads and interest rate movements: A bird's eye view, *Review of Economic Studies* 58, 495–514.

Campbell, John Y., Robert J. Shiller, and Luis M. Viceira, 2009, Understanding inflation-indexed bond markets, *Brookings Papers on Economic Activity* 79–120.

Campbell, John Y., Adi Sunderam, and Luis M. Viceira, 2017, Inflation bets or deflation hedges? The changing risks of nominal bonds, *Critical Finance Review* 6, 263–301.

Campbell, John Y., and Luis M. Viceira, 2001, Who should buy long-term bonds?, *American Economic Review* 91, 99–127.

Chen, Ren-Raw, and Louis Scott, 2003, Multifactor Cox-Ingersoll-Ross models of the term structure: Estimates and tests from a Kalman filter model, *Journal of Real Estate Finance and Economics* 27, 143–172.

Christensen, Jens H. E., Jose A. Lopez, and Glenn D. Rudebusch, 2010, Inflation expectations and risk premiums in an arbitrage-free model of nominal and real bond yields, *Journal of Money, Credit and Banking* 42, 143–178.

Cieslak, Anna, and Pavol Povala, 2015, Expected returns in Treasury bonds, *Review of Financial Studies* 28, 2859–2901.

Cochrane, John H., 2005, *Asset Pricing*, revised edition (Princeton University Press, Princeton, NJ).

Cochrane, John H., and Monika Piazzesi, 2005, Bond risk premia, *American Economic Review* 95, 138–160.

Cox, John C., Jonathan E. Ingersoll, Jr., and Stephen A. Ross, 1985, A theory of the term structure of interest rates, *Econometrica* 53, 385–407.

Dai, Qiang, and Kenneth J. Singleton, 2000, Specification analysis of affine term structure models, *Journal of Finance* 55, 1943–1978.

Dai, Qiang, and Kenneth J. Singleton, 2002, Expectation puzzles, time-varying risk premia, and affine models of the term structure, *Journal of Financial Economics* 63, 415–441.

Dai, Qiang, and Kenneth J. Singleton, 2003, Term structure dynamics in theory and reality, *Review of Financial Studies* 16, 631–678.

d'Amico, Stefania, Don H. Kim, and Min Wei, 2018, Tips from TIPS: The informational content of Treasury inflation-protected security prices, *Journal of Financial and Quantitative Analysis* 53, 395–436.

Duffee, Gregory R., 2002, Term premia and interest rate forecasts in affine models, *Journal of Finance* 57, 405–443.

Duffee, Gregory R., 2011, Information in (and not in) the term structure, *Review of Financial Studies* 24, 2895–2934.

Duffee, Gregory R., 2013a, Bond pricing and the macroeconomy, in Milton Harris, George M. Constantinides, and Rene M. Stulz, eds., *Handbook of the Economics of Finance*, volume 2B, 907–967 (Elsevier).

Duffee, Gregory R., 2013b, Forecasting interest rates, in Graham Elliott, and Allan Timmerman, eds., *Handbook of Economic Forecasting*, volume 2A, 385–426 (Elsevier).

Duffee, Gregory R., and Richard Stanton, 2008, Evidence on simulation inference for near unit-root processes with implications for term structure estimation, *Journal of Financial Econometrics* 6, 108–142.

Duffee, Gregory R., and Richard Stanton, 2012, Estimation of dynamic term structure models, *Quarterly Journal of Finance* 2.

Duffie, Darrell, 2001, *Dynamic Asset Pricing Theory*, third edition (Princeton University Press, Princeton, New Jersey).

Filipović, Damir, 2009, *Term-Structure Models: A Graduate Course* (Springer, New York).

Fleckenstein, Matthias, Francis A. Longstaff, and Hanno Lustig, 2014, The TIPS-Treasury bond puzzle, *Journal of Finance* 69, 2151–2197.

Gürkaynak, Refet S., Brian P. Sack, and Jonathan H. Wright, 2010, The TIPS yield curve and inflation compensation, *American Economic Journal: Macroeconomics* 2, 70–92.

Gürkaynak, Refet S., and Jonathan H. Wright, 2012, Macroeconomics and the term structure, *Journal of Economic Literature* 50, 331–367.

Hamilton, James D., 1994, *Time Series Analysis* (Princeton University Press, Princeton, NJ).

Hamilton, James D., and Jing Cynthia Wu, 2012, Identification and estimation of Gaussian affine term structure models, *Journal of Econometrics* 168, 315–331.

Ho, Thomas S. Y., and Sang Bin Lee, 1986, Term structure movements and pricing interest rate contingent claims, *Journal of Finance* 41, 1011–1029.

Hördahl, Peter, Oreste Tristani, and David Vestin, 2006, A joint econometric model of macroeconomic and term-structure dynamics, *Journal of Econometrics* 131, 405–444.

Hull, John C., 2014, *Options, Futures, and Other Derivatives*, 9th edition (Pearson, New Jersey).

James, Jessica, and Nick Webber, 2000, *Interest Rate Modelling: Financial Engineering* (Wiley, New York).

Joslin, Scott, Anh Le, and Kenneth J. Singleton, 2013, Why Gaussian macro-finance term structure models are (nearly) unconstrained factor-VARs, *Journal of Financial Economics* 109, 604–622.

Joslin, Scott, Marcel Priebsch, and Kenneth J. Singleton, 2014, Risk premiums in dynamic term structure models with unspanned macro risks, *Journal of Finance* 69, 1197—1233.

Joslin, Scott, Kenneth J. Singleton, and Haoxiang Zhu, 2011, A new perspective on Gaussian dynamic term structure models, *Review of Financial Studies* 24, 926–970.

Kim, Don H., and Athanasios Orphanides, 2012, Term structure estimation with survey data on interest rate forecasts, *Journal of Financial and Quantitative Analysis* 47, 241–272.

Kim, Don H., and Jonathan H. Wright, 2005, An arbitrage-free three-factor term structure model and the recent behavior of long-term yields and distant-horizon forward rates, FEDS Paper 2005-33, Federal Reserve Board.

Koijen, Ralph, Hanno Lustig, and Stijn van Nieuwerburgh, 2017, The cross-section and time-series of stock and bond returns, *Journal of Monetary Economics* 88, 50–69.

Kozicki, Sharon, and Peter A. Tinsley, 2001, Shifting endpoints in the term structure of interest rates, *Journal of Monetary Economics* 47, 613–652.

Lettau, Martin, and Jessica A Wachter, 2007, Why is long-horizon equity less risky? A duration-based explanation of the value premium, *Journal of Finance* 62, 55–92.

Lettau, Martin, and Jessica A. Wachter, 2011, The term structures of equity and interest rates, *Journal of Financial Economics* 101, 90–113.

Litterman, Robert, and José A. Scheinkman, 1991, Common factors affecting bond returns, *Journal of Fixed Income* 1, 54–61.

Ludvigson, Sydney C., and Serena Ng, 2009, Macro factors in bond risk premia, *Review of Financial Studies* 22, 5027–5067.

Mishkin, Frederic S., 1992, Is the Fisher effect for real? A reexamination of the relationship between inflation and interest rates, *Journal of Monetary Economics* 30, 195–215.

Nagel, Stefan, and Zhengyang Xu, 2023, Dynamics of subjective risk premia, *Journal of Financial Economics* 150, 103713.

Nelson, Charles R., and Andrew F. Siegel, 1987, Parsimonious modeling of yield curves, *Journal of Business* 60, 473–489.

Pearson, Neil D., and Tong-Sheng Sun, 1994, Exploiting the conditional density in estimating the term structure: An application to the Cox, Ingersoll, and Ross model, *Journal of Finance* 49, 1279–1304.

Piazzesi, Monika, 2010, Affine term structure models, in Yacine Aït-Sahalia, and Lars Peter Hansen, eds., *Handbook of Financial Econometrics*, volume 1, 691–766 (North Holland, Elsevier).

Piazzesi, Monika, Juliana Salomao, and Martin Schneider, 2015, Trend and cycle in bond premia, Working Paper, Stanford University and University of Minnesota.

Piazzesi, Monika, and Martin Schneider, 2007, Equilibrium yield curves, in *NBER Macroeconomics Annual 2006, Volume 21*, 389–472 (MIT Press).

Rose, Andrew K., 1988, Is the real interest rate stable?, *Journal of Finance* 43, 1095–1112.

Rudebusch, Glenn D., and Eric T. Swanson, 2012, The bond premium in a DSGE model with long-run real and nominal risks, *American Economic Journal: Macroeconomics* 4, 105–143.

Rudebusch, Glenn D., and Tao Wu, 2008, A macro-finance model of the term structure, monetary policy and the economy, *Economic Journal* 118, 906–926.

Santa-Clara, Pedro, 1995, Simulated likelihood estimation of diffusions with an application to the short term interest rate, Working paper, INSEAD.

Singleton, Kenneth J., 2006, *Empirical Dynamic Asset Pricing: Model Specification and Econometric Assessment* (Princeton University Press, Princeton, NJ).

Stambaugh, Robert F., 1999, Predictive regressions, *Journal of Financial Economics* 54, 375–421.

Stanton, Richard, 1997, A nonparametric model of term structure dynamics and the market price of interest rate risk, *Journal of Finance* 52, 1973–2002.

Svensson, Lars E. O., 1994, Estimating and interpreting forward rates: Sweden 1992–1994, Working Paper 4871, NBER.

Tuckman, Bruce, and Angel Serrat, 2011, *Fixed Income Securities: Tools for Today's Markets*, third edition (Wiley, New York).

van Binsbergen, Jules, Michael Brandt, and Ralph Koijen, 2012, On the timing and pricing of dividends, *American Economic Review* 102, 1596–1618.

van Binsbergen, Jules, Wouter Hueskes, Ralph Koijen, and Evert Vrugt, 2013, Equity yields, *Journal of Financial Economics* 110, 503–519.

Vasicek, Oldrich A., 1977, An equilibrium characterization of the term structure, *Journal of Financial Economics* 5, 177–188.

Veronesi, Pietro, 2010, *Fixed Income Securities* (Wiley, Hoboken, NJ).

Wachter, Jessica, 2006, A consumption based model of the term structure of interest rates, *Journal of Financial Economics* 79, 365–399.

Wu, Jing Cynthia, and Fan Dora Xia, 2016, Measuring the macroeconomic impact of monetary policy at the zero lower bound, *Journal of Money, Credit and Banking* 48, 253–291.