Course description: **Heterogeneous Agent Macro**

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Description: This course introduces you to the research frontier macroeconomic models, where agents are heterogeneous and face uninsurable idiosyncratic shocks. Such models play a central role in contemporary discussions on both long-run issues, regarding e.g. inequality, taxation and social security, and short-run issues, regarding e.g. the causes of business cycles and the effectiveness on monetary and fiscal policy. You will learn to both solve and simulate simple versions of such models, and interpret the results from full-scale models used in research papers.

The courses have three components. The first part of the course is on stationary equilibrium Bewley-Huggett-Aiygari models, and the roles of uninsurable risk and demographics for the determination of the equilibrium interest rate and inequality. The second part of the course is on the analysis of transitional dynamics in sequence space, and feature discussions on the dynamics of income and wealth inequality and the secular trend of the neutral interest rate. The third part is on Heterogeneous Agent New Keynesian models with pricing frictions, where heterogeneity in the marginal propensity to consume and fluctuations in risk due to e.g. unemployment are important for understanding business-cycle fluctuations.

The analytical and numerical methods you learn in this course is generally applicable to questions in public finance, labor economics, trade and industrial organizations, where heterogeneity plays an important role.

Course page: sites.google.com/view/numeconcph-het-agent-macro

Preparation: The course relies heavily on programming in Python to give a hands-on approach to working with heterogeneous agent models. It is therefore strongly recommended that participants prepare as follows:

1. Install Python and VSCode as explained here.
2. Watch the lecture videos on Python (~ 10 hours) here.
3. Go through the associated lecture notebooks here.

Lectures

- **Lecture 0. Introduction**
  Overview: Heathcote et al. (2009); Kaplan and Violante (2018); Cherrier et al. (2023).

- **Lecture 1. Consumption-saving**
  Central: Carroll (1997); Druedahl (2021)
  More economics: Modigliani and Brumburg (1954); Friedman (1957); Deaton (1991); Carroll (1992, 2006); Kaplan and Violante (2014); Kaplan et al. (2014); Jørgensen (2017); Carroll et al. (2021); Guvenen et al. (2021); Fagereng et al. (2021); Harmenberg and Oberg (2021); Druedahl et al. (2021); Druedahl and Martinello (2022). More computational: Carroll (2006); Iskhakov et al. (2017); Druedahl and Jørgensen (2017); Harmenberg (2021); Rendahl (2022). Deep learning: Maliar et al. (2021); Azinovic et al. (2022); Kase et al. (2022); Han et al. (2021).

- **Lecture 2. Stationary equilibrium**
  Central: Aiyagari (1994); Hubmer et al. (2021)
  GEModelTools: Druedahl (2024a,f,c). Histogram simulation: Young (2010); Tan (2020); Ocampo and Robinson (2022).

- **Lecture 3. Transitional dynamics**
  Central: Boppart et al. (2018); Auclert et al. (2021a).
  GEModelTools: Druedahl (2024a,f,c). More on policy: McKay and Wolf (2023); Dávila and Schaab (2023).

- **Lecture 4. HANK**
  Central: Werning (2015); Kaplan et al. (2018); Auclert et al. (2023); Broer et al. (2023a).
  GEModelTools: Druedahl (2024d,e,b,g,h). More HANK: Bayer et al. (2019); Hagedorn et al. (2019); Auclert et al. (2020, 2021b); Druedahl et al. (2022). More zero-liquidity: McKay et al. (2017); Acharya and Dogra (2020); Broer et al. (2020); Bilbiie (2021); Ravn and Sterk (2021); Broer et al. (2023b).

Code-packages

1. **EconModel:**
   github.com/NumEconCopenhagen/EconModel
   github.com/NumEconCopenhagen/EconModelNotebooks

2. **ConSav:**
   github.com/NumEconCopenhagen/ConsumptionSaving
   github.com/NumEconCopenhagen/ConsumptionSavingNotebooks

3. **GEModelTools:**
   github.com/NumEconCopenhagen/GEModelTools
   github.com/NumEconCopenhagen/GEModelToolsNotebooks

References

Acharya, S. and Dogra, K. (2020). Understanding HANK: Insights From a PRANK. *Econometrica*, 88(3):1113–1158.

Aiyagari, S. R. (1994). Uninsured Idiosyncratic Risk and Aggregate Saving. *The Quarterly Journal of Economics*, 109(3):659–684.

Auclert, A., Bardóczy, B., Rognlie, M., and Straub, L. (2021a). Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models. *Econometrica*, 89(5):2375–2408.

Auclert, A., Rognlie, M., Souchier, M., and Straub, L. (2021b). Exchange Rates and Monetary Policy with Heterogeneous Agents: Sizing up the Real Income Channel. NBER Working Paper 28872.

Auclert, A., Rognlie, M., and Straub, L. (2020). Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model. NBER Working Paper 26647.

Auclert, A., Rognlie, M., and Straub, L. (2023). The Intertemporal Keynesian Cross. NBER Working Paper 25020, National Bureau of Economic Research.

Azinovic, M., Gaegauf, L., and Scheidegger, S. (2022). Deep Equilibrium Nets. *International Economic Review*, 63(4):1471–1525.

Bayer, C., Luetticke, R., Pham-Dao, L., and Tjaden, V. (2019). Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk. *Econometrica*, 87(1):255–290.

Bilbiie, F. O. (2021). Monetary Policy and Heterogeneity: An Analytical Framework. Working Paper.

Boppart, T., Krusell, P., and Mitman, K. (2018). Exploiting MIT shocks in heterogeneous-agent economies: the impulse response as a numerical derivative. *Journal of Economic Dynamics and Control*, 89:68–92.

Broer, T., Druedahl, J., Harmenberg, K., and Öberg, E. (2023a). Fiscal stimulus policies according to HANK-SAM. Working Paper.

Broer, T., Druedahl, J., Harmenberg, K., and Öberg, E. (2023b). The Unemployment-Risk Channel in Business-Cycle Fluctuations. CEPR Discussion Paper 16639.

Broer, T., Harbo Hansen, N.-J., Krusell, P., and Oberg, E. (2020). The New Keynesian Transmission Mechanism: A Heterogeneous-Agent Perspective. *The Review of Economic Studies*, 87(1):77–101.

Carroll, C. D. (1992). The buffer-stock theory of saving: Some macroeconomic evidence. *Brookings Papers on Economic Activity*, 2:61–156.

Carroll, C. D. (1997). Buffer-Stock Saving and the Life Cycle/Permanent Income Hypothesis. *The Quarterly Journal of Economics*, 112(1):1–55.

Carroll, C. D. (2006). The Method of Endogenous Gridpoints for Solving Dynamic Stochastic Optimization Problems. *Economics Letters*, 91(3):312–320.

Carroll, C. D., Holm, M. B., and Kimball, M. S. (2021). Liquidity constraints and precautionary saving. *Journal of Economic Theory*, 195:105276.

Cherrier, B., Duarte, P., and Saïdi, A. (2023). Household heterogeneity in macroeconomic models: a historical perspective. *European Economic Review*, page 104497.

Deaton, A. (1991). Saving and liquidity constraints. *Econometrica*, 59(5):1221–1248.

Druedahl, J. (2021). A Guide on Solving Non-Convex Consumption-Saving Models. *Computational Economics*, 58(3):747–775.

Druedahl, J. (2024a). Documentation for GEModelTools. Technical report.

Druedahl, J. (2024b). GEModelTools: A HANK-SAM model. Technical report.

Druedahl, J. (2024c). GEModelTools: HANC with Government. Technical report.

Druedahl, J. (2024d). GEModelTools: HANK with Sticky Prices. Technical report.

Druedahl, J. (2024e). GEModelTools: HANK with Sticky Wages. Technical report.

Druedahl, J. (2024f). GEModelTools: Heterogenous Agent NeoClassical Model (HANC). Technical report.

Druedahl, J. (2024g). GEModelTools: Two-Asset Model with Capital. Technical report.

Druedahl, J. (2024h). GEModelTools: Two-Sector I-HANK model. Technical report.

Druedahl, J., Graber, M., and Jørgensen, T. H. (2021). High Frequency Income Dynamics. CEBI Working Paper 08/21.

Druedahl, J. and Jørgensen, T. H. (2017). A general endogenous grid method for multi-dimensional models with non-convexities and constraints. *Journal of Economic Dynamics and Control*, 74:87–107.

Druedahl, J. and Martinello, A. (2022). Long-Run Saving Dynamics: Evidence from Unexpected Inheritances. *The Review of Economics and Statistics*, 104(5):1079–1095.

Druedahl, J., Ravn, S. H., Sunder-Plassmann, L., Sundram, J. M., and Waldstrøm, N. (2022). The Transmission of Foreign Demand Shocks. Working Paper.

Dávila, E. and Schaab, A. (2023). Optimal Monetary Policy with Heterogeneous Agents: Discretion, Commitment, and Timeless Policy. Working Paper.

Fagereng, A., Holm, M. B., and Natvik, G. J. (2021). MPC Heterogeneity and Household Balance Sheets. *American Economic Journal: Macroeconomics*, 13(4):1–54.

Friedman, M. (1957). *A theory of the consumption function*. Princeton university Press for NBER.

Guvenen, F., Karahan, F., Ozkan, S., and Song, J. (2021). What Do Data on Millions of U.S. Workers Reveal About Lifecycle Earnings Dynamics? *Econometrica*, 89(5):2303–2339.

Hagedorn, M., Manovskii, I., and Mitman, K. (2019). The Fiscal Multiplier. NBER Working Paper 25571.

Han, J., Yang, Y., and E, W. (2021). DeepHAM: A Global Solution Method for Heterogeneous Agent Models with Aggregate Shocks.

Harmenberg, K. (2021). Aggregating heterogeneous-agent models with permanent income shocks. *Journal of Economic Dynamics and Control*, 129:104185.

Harmenberg, K. and Oberg, E. (2021). Consumption dynamics under time-varying unemployment risk. *Journal of Monetary Economics*, 118:350–365.

Heathcote, J., Storesletten, K., and Violante, G. L. (2009). Quantitative Macroeconomics with Heterogeneous Households. *Annual Review of Economics*, 1(1):319–354.

Hubmer, J., Krusell, P., and Smith., A. A. (2021). Sources of US Wealth Inequality: Past, Present, and Future. *NBER Macroeconomics Annual*, 35:391–455. Publisher: The University of Chicago Press.

Iskhakov, F., Jørgensen, T. H., Rust, J., and Schjerning, B. (2017). The endogenous grid method for discrete-continuous dynamic choice models with (or without) taste shocks. *Quantitative Economics*, 8(2):317–365.

Jørgensen, T. H. (2017). Life-Cycle Consumption and Children: Evidence from a Structural Estimation. *Oxford Bulletin of Economics and Statistics*, 79(5):717–746.

Kaplan, G., Moll, B., and Violante, G. L. (2018). Monetary Policy According to HANK. *American Economic Review*, 108(3):697–743.

Kaplan, G., Violante, G., and Weidner, J. (2014). The Wealthy Hand-to-Mouth. *Brookings Papers on Economic Activity*, pages 77–138.

Kaplan, G. and Violante, G. L. (2014). A Model of the Consumption Response to Fiscal Stimulus Payments. *Econometrica*, 82(4):1199–1239.

Kaplan, G. and Violante, G. L. (2018). Microeconomic Heterogeneity and Macroeconomic Shocks. *Journal of Economic Perspectives*, 32(3):167–194.

Kase, H., Melosi, L., and Rottner, M. (2022). Estimating Nonlinear Heterogeneous Agents Models with Neural Networks. Federal Reserve Bank of Chicago, WP 2022-26.

Maliar, L., Maliar, S., and Winant, P. (2021). Deep learning for solving dynamic economic models. *Journal of Monetary Economics*, 122:76–101.

McKay, A., Nakamura, E., and Steinsson, J. (2017). The Discounted Euler Equation: A Note. *Economica*, 84(336):820–831.

McKay, A. and Wolf, C. K. (2023). Optimal Policy Rules in HANK. Technical report.

Modigliani, F. and Brumburg, R. (1954). Utility Analysis and the Consumptio Function: An Interpretation of Cross-Section Data. In Kurihara, K. and Brunswick, N., editors, *Post-Keynesian Economics*, pages 338–436. Rutgers University Press.

Ocampo, S. and Robinson, B. (2022). Computing Longitudinal Moments for Heterogeneous Agent Models. Working Paper.

Ravn, M. O. and Sterk, V. (2021). Macroeconomic Fluctuations with HANK & SAM: an Analytical Approach. *Journal of the European Economic Association*, 19(2):1162–1202.

Rendahl, P. (2022). Continuous vs. Discrete Time: Numerical Gains from Trade. Working Paper.

Tan, E. (2020). A fast and low computational memory algorithm for non-stochastic simulations in heterogeneous agent models. *Economics Letters*, 193:109285.

Werning, I. (2015). Incomplete Markets and Aggregate Demand. NBER Working Paper 21448.

Young, E. R. (2010). Solving the incomplete markets model with aggregate uncertainty using the Krusell-Smith algorithm and non-stochastic simulations. *Journal of Economic Dynamics and Control*, 34(1):36–41.