Introduction

Thomas H. Jørgensen

2025

Outline

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- **Teacher:** Thomas H. Jørgensen
  (Associate Professor, University of Copenhagen)

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  Dynamic programming in Python
- **Prerequisite:**
  Introduction to Programming and Numerical Analysis

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- Plan for today:
  1. Course description
  2. Programming in Python
  3. Introduction to Dynamic Programming

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  ~2 hours lecture
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- **Material:**
  `https://github.com/ThomasHJorgensen/HouseholdBehaviorCourse`

Course Plan (preliminary)

Introduction

1. Introduction
2. Dynamic Programming and Structural Estimation

Part 1: Labor Supply

3. Static and Dynamic labor supply
4. Dynamic labor supply and human capital

.. *No lecture: Work on assignment / read papers*

5. Career costs of children
6. Household Labor Supply and Taxation
7. Household Labor Supply and Child-Related Transfers

Part 2: Family Formation and Dissolution

8. Models of Household Behavior
9. Divorce Law and Intra-Household Bargaining
10. Marriage and Divorce
11. Fertility and labor supply
12. [online] Taxes, Transfers and Intra-Household Inequality

Outroduction

13. Children and Time Allocation

Assignments and Exam

- **Exam** (Portfolio):
  1. 3 individual assignments.
     + peer feedback.
  2. 48 hour individual take-home exam.
     Model formulation, code modification, simulations, economic interpretations.

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- 3 individual **assignments** (hand-in on Absalon)
  1. Based on our dynamic **labor supply** model
     Deadline: March 14
  2. Based on our dynamic **bargaining** model
     Deadline: April 11
  3. **Free**: Formulate a research question + model + data.
     Deadline: May 9
     Deadline for peer feedback: May 16
- All feedback can be used to improve assignments before exam date

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1. This Course
2. Models
3. Programming in Python
4. Dynamic Programming

Models! What are they good for!?

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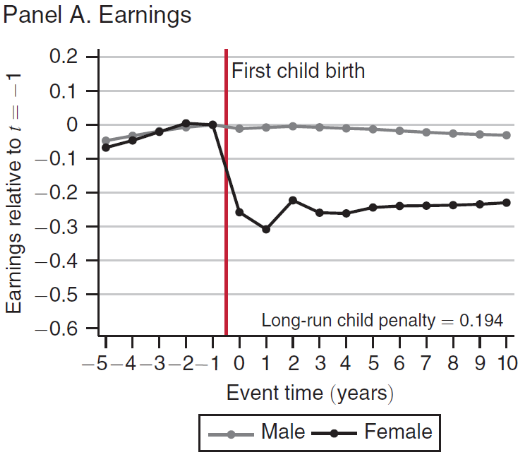
Example: "Child penalty" (Kleven, Landais and Søgaard, 2019)



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  Example: "Career costs of children" (Adda, Dustmann and Stevens, 2017)
  "We estimate a dynamic life cycle model of labor supply, fertility, and savings, incorporating occupational choices, with specific wage paths and skill atrophy that vary over the career. This allows us to understand the trade-off between occupational choice and desired fertility, as well as sorting both into the labor market and across occupations. We **quantify** the life cycle career costs associated with children, how they **decompose** into loss of skills during interruptions, lost earnings opportunities, and selection into more child-friendly occupations. We analyze the **long-run effects of policies** that encourage fertility and show that they are considerably smaller than short-run effects."

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> *"All models are wrong, but some are useful"*
>
> *George E.P. Box*

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  $\Rightarrow$ policy advice can not rely on estimated behavioral rules (reduced-form estimates using existing variation)

  $\Rightarrow$ we need to estimate *structural (deep) parameters*

  "Invariance of parameters in an economic model is not, of course, a property which can be assured in advance, but it seems reasonable to hope that neither tastes nor technology vary systematically with variations in counter-cyclical policies." (Lucas, 1977)

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→ Tight link between **research question** and model formulation.

Learning Objectives

See all at the Course page

- **Knowledge:**
  Define, formulate and interpret *models* of household behaviour
  Account for backwards induction and how to *solve* dynamic programming models

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- **Skills:**
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- **Competences:**
  Discuss and evaluate *research* on household behavior over the life cycle
  Modify computer *code* to analyze small changes to simple models

How to read a research paper (in this course)

- Each lecture will be based on 1 mandatory (*) **research paper**
  What is the main *research question*?
  What is the *(empirical) motivation*?
  What are the central *mechanisms in the model*?
  What is the *simplest model* in which we could capture these?
  Challenging: Research frontier.

How to read a research paper (in this course)

- Each lecture will be based on 1 mandatory (*) **research paper**
  What is the main *research question*?
  What is the *(empirical) motivation*?
  What are the central *mechanisms in the model*?
  What is the *simplest model* in which we could capture these?
  Challenging: Research frontier.

- **How to read** a research paper in this course?
  - **Focus** on the questions above
    How do the questions interact and inform each other?
  - Try **not to get stuck** in too many details!
    (we can discuss some in class if you want)
  - Research papers often include many **"bells and whistles"**
  - Read ~**40 min before** each lecture.
    See reading-guide for each lecture

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Programming in Python

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  $\rightarrow$ We need numerical methods

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  Learn by implementing!
  Appreciate bottlenecks and challenges
  Better understanding of frontier research
  Set you free...!

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  Set you free...!

- **Goal** is to keep things simple!
  No fancy numerical tricks (at least in beginning)
  Code should be "intuitive"
  $\rightarrow$ slow...

Programming in Python

- **Setup** *Visual Studio Code* as
  Introduction to Programming and Numerical Analysis
  `https://sites.google.com/view/numeconcph-introprog/`
- **Installation** guide:
  `https://sites.google.com/view/numeconcph-introprog/guides/installation`
- **Packages** (all by Jeppe Druedahl):
  EconModel
  consav
  See "`01. Introduction to EconModel and consav.ipynb`"

Outline

Introduction to Dynamic Programming (DP)

- **Agents maximize** expected discounted sum of utility throughout life
  Maximize wrt. $\{\mathcal{C}_t\}_{t=1}^{T}$
  Forward looking $\rightarrow$ dynamic
  Assume *optimal* behavior in all periods

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- **Agents maximize** expected discounted sum of utility throughout life
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  Assume *optimal* behavior in all periods
- **Bellman Equation**:

$$V_t(\mathcal{S}_t) = \max_{\mathcal{C}_t} U(\mathcal{C}_t, \mathcal{S}_t) + \beta \mathbb{E}[V_{t+1}(\mathcal{S}_{t+1}) | \mathcal{C}_t, \mathcal{S}_t]$$

s.t.

$$\mathcal{S}_{t+1} \sim F(\mathcal{C}_t, \mathcal{S}_t)$$

  - $V_t(\mathcal{S}_t)$: Indirect utility, Value today of *states*, $\mathcal{S}_t$ (all relevant info).
  - $U(\mathcal{C}_t, \mathcal{S}_t)$: flow-utility
  - $\beta \mathbb{E}[V_{t+1}(\mathcal{S}_{t+1}) | \mathcal{C}_t, \mathcal{S}_t]$: expected discounted value of next-period
  - $\mathcal{S}_{t+1} \sim F(\mathcal{C}_t, \mathcal{S}_t)$: transition *density* of states (fcn of $\mathcal{C}_t$!)
    (there might be other constraints)

Backwards Induction

- Solved by **backwards induction**

  1. Start with last/terminal period, T (no future)

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2. Go to second-to-last (we now know period-T optimal behavior for all $\mathcal{S}_T$)

$$V_{T-1}(\mathcal{S}_{T-1}) = \max_{\mathcal{C}_{T-1}} U(\mathcal{C}_{T-1}, \mathcal{S}_{T-1}) + \beta \mathbb{E}[V_T(\mathcal{S}_T) | \mathcal{C}_{T-1}, \mathcal{S}_{T-1}]$$

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3. Continue backwards...

Introduction to Numerical Dynamic Programming (DP)

- **On a computer**, everything is discrete $\rightarrow$ arrays $+$ loops

Introduction to Numerical Dynamic Programming (DP)

- **On a computer**, everything is discrete $\rightarrow$ arrays + loops
- ***Numerical*** Dynamic Programming
  - Backwards induction on arrays
  - Grids
  - Interpolation
  - Integration
- See "`02. Consumption-Saving Model.ipynb`"

Next Time

- **Next time:**
  Dynamic programming with *uncertainty*
  Structural *estimation*

- **Literature:**
  Gourinchas and Parker (2002): "Consumption Over the Life Cycle"
  - **Read** before lecture
  - **Reading guide:**
    Section 1: Introduction – *Key* (page 50 is not that important)
    Section 2: Model – *Key*, we will discuss. Do not get stuck.
    Section 3: Estimation method (SMM). *Key*, we will discuss.
    Section 4: First stage calibrations. Skim fast.
    Section 5: Data. Skim fast.
    Section 6: Results. Focus on 6.1. Figures 5 and 7 are main results.

References I

ADDA, J., C. DUSTMANN AND K. STEVENS (2017): "The Career Costs of Children," *Journal of Political Economy*, 125(2), 293–337.

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