416-2 Empirical Macroeconomics

Identification, Heterogeneity, Aggregation

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Lecture 1: Course overview & introduction

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416-2 Empirical Macro, Winter 2025

Course overview

- Course on **empirical macroeconomics**:
  - how to identify dynamic causal effects in macro
  - how to use micro data to better understand macro phenomena
- **Time-series & cross-sectional** methods to study aggregate and disaggregate effects of macro policies & shocks
- Show how empirical evidence can inform theory and vice versa
- **Applications**: monetary policy, fiscal policy, energy price shocks and climate policy

Course goals

1. Introduce students to important papers and research questions with high empirical content and relevance to macroeconomics, broadly defined
2. Introduce students to a variety of empirical methods and data sources – micro and macro – that can be used to test, calibrate and develop models of interest for macroeconomics and related fields
3. Inspire students to think hard about best practices in empirical work, and how to combine creativity, tools, and high standards to produce credible and successful research
4. Assist students in building up an empirical toolbox that can be used as a basis for future research
5. Provide guidance on how to identify research questions and effectively convey and present research

My approach and what I expect of you

- I want to give you a **bird's eye view** of the current state of the literature
  - Get an idea what data sources and what strategies are available to identify the parameters of interest
- And then focus in on a few papers (2-3 per class) in detail
  - You will be asked to read these carefully before class
  - Try to read critically and come to class with an eye towards new research questions
  - Ask questions, participate, challenge me, etc.

Evaluation and prerequisites

Requirements and grading

1. Class participation (10%)
2. Take-home assignments (40%)
   - Referee report
   - Assignments centered around replication and extension of empirical macro papers
3. Research project (50%)
   - Objective: begin substantive research work on empirical macro project (does not need to be a full-fledged paper)
   - Deadlines: discuss idea (January 22), in-class presentations (February 26), proposal submission (March 22)

Prerequisites: 1st-year PhD course material (macro & econometrics)

Readings and resources

- The class will be largely organized around readings of (recent) papers
  - Readings are communicated on the reading list and are split into essential (*) and additional/background readings
- Lecture notes will be posted before class. They will be organized by topic and not strictly correspond to individual lectures
- Some of the materials draw on the excellent resources by Wolf, Chodorow-Reich, Nakamura-Steinsson, and Guren, which you are also welcome to consult:
  - `https://www.christiankwolf.com/teaching`
  - `https://scholar.harvard.edu/chodorow-reich/classes/economics-2410hfc-advanced-topics-applied-macroeconomics`
  - `https://eml.berkeley.edu/~jsteinsson/teaching.html`
  - `https://people.bu.edu/guren/`

Outline

Motivation

- **Big questions** in (short- to medium-run) macro
  - What are the origins of business cycles?
  - Why can seemingly small shocks can have large effects?
  - And why are responses so persistent?
  - What is the role of policy, in particular monetary, fiscal and climate policy?
  - And what are the distributional consequences?
- These are naturally empirical questions
- To find answers, **identification** is key
  - Identification turns correlations into **causal relationships**

The identification challenge

- Identification in economics is often **challenging** because we lack the right counterfactuals
- Particularly the case in macro where we *can't run experiments* and where
    - general equilibrium effects are crucial
    - dynamics are all-important
    - expectations have powerful effects

The credibility revolution

- The 1970s and 1980s were a dark age for empirical economics
- Leamer (1983) observed "*hardly anyone takes anyone else's data analysis seriously*" and urged researchers to "*take the con out of econometrics*"
  - Lack of credible identification
  - Lack of robustness
  - Lack of transparency
- Impetus for so-called credibility revolution in empirical economics ...

The credibility revolution

- . . . which was recognized in the 2021 nobel prize

The state of empirical macro in the 2000s

- Many macroeconomists have abandoned traditional empirical work
- Dominant approach **theory-centric**, e.g. quantitative experiments using dynamic stochastic general equilibrium models in spirit of Kydland and Prescott, 1996
- Structural vector autoregression models often criticized
  - Lack of credible identification
  - Lack of robustness
  - Lack of transparency

A credibility revolution in macro?

- A surge in empirical work in macro in recent years
- More emphasis on **research design**
    - narrative approach (Romer and Romer, 1989, 2004, 2010; Ramey and Shapiro, 1998; Ramey, 2011; Hamilton, 2003; Kilian, 2008)
    - high-frequency identification (Kuttner, 2001; Gürkaynak, Sack, and Swanson, 2005; Gertler and Karadi, 2015; Nakamura and Steinsson, 2018; Känzig, 2022, 2021)
    - external information (Blanchard and Perotti, 2002; Mertens and Ravn, 2013; Stock and Watson, 2012; Baumeister and Hamilton, 2019; Caldara, Cavallo, and Iacoviello, 2019; Antolín-Díaz and Rubio-Ramírez, 2018)
    - cross-section (Mian and Sufi, 2014; Nakamura and Steinsson, 2014; David, Dorn, and Hanson, 2013; Beraja, Hurst, and Ospina, 2019)
- More transparency (Uhlig, 2005; Fry and Pagan, 2011; Baumeister and Hamilton, 2015)

Outline

1. Macroeconomic shocks – a brief history of thought

    Big questions and identification challenge

    What is a shock?

    Approach and objects of interest

Shocks shocks shocks

- As previously mentioned, identification in macro is hard
- Therefore we have to typically impose a bit *more structure* than in applied micro
- In particular, we use the concept of **structural shocks**:
    - As opposed to the effect of variable x on y, e.g. the effect of schooling on labor income, we think of the effect of a shock ε on y
    - For instance, the effects of a monetary policy shock on output
    - This is a much easier problem than identifying the effect of higher interest rates on output, where the answer will crucially depend on what is driving the change in rates
    - As we will see, it is also much easier to find instruments for shocks than for macro variables, where the **exclusion restriction** is almost certainly never satisfied

What is a shock?

Definition (Structural shock)

Structural shocks are primitive exogenous forces that are uncorrelated with each other and have a meaningful economic interpretation (Bernanke, 1986)

Properties (from Ramey 2016)

- **exogenous** wrt the other current and lagged endogenous variables in the model
- **uncorrelated** with other exogenous shocks – otherwise, we cannot identify the unique causal effects of one exogenous shock relative to another
- represent either **unanticipated** movements in exogenous variables or **news** about future movements in exogenous variables

What is a shock?

Examples

- Monetary policy shocks (conventional, unconventional)
- Fiscal policy shocks (government spending, tax shocks)
- Technology shocks (surprise, news shocks)
- Commodity price shocks (oil, gas, metals)
- Other policy (climate, energy)
- Temperature
- ...

Impulse-propagation framework

- **Objective**: explain properties of macroeconomic aggregates y_t
- Think of path of observed macro variables as arising from **past and current shocks**

$$y_t = \sum_{l=0}^{\infty} \underbrace{\Theta_l}_{\text{propagation}} \times \underbrace{\varepsilon_{t-l}}_{\text{impulse}} \tag{1}$$

  - In time-series jargon this is a structural VMA(∞), where ε_t are structural shocks
  - Can be extended to account for deterministics and measurement error
  - In next class, we will see the connection to a fundamental theorem in time series, the so-called Wold decomposition theorem
- Business cycles are the consequence of **fundamental shocks** that move the system through the **dynamic causal effects** Θ
- Framework also known as Slutzky-Frisch paradigm

Relation to potential outcome framework

- Close relation to **randomized controlled experiments** in applied micro
- Consider the example of monetary policy
  - FOMC sets the Fed funds rate according to a rule, perturbed by a randomly chosen amount
- Let $\varepsilon_{1,t}$ denote the random treatment at date t
- Then causal effect on the value of a variable y_2, h periods ahead of a unit intervention in ε_1 is

$$E_t[y_{2,t+h}|\varepsilon_{1,t} = 1] - E_t[y_{2,t+h}|\varepsilon_{1,t} = 0] \tag{2}$$

Relation to potential outcome framework

- Assuming linearity, the h-lag treatment effect is the population coefficient from the regression

$$y_{2,t+h} = \Theta_{21,h}\varepsilon_{1,t} + u_{t+h} \tag{3}$$

- Because $E[u_{t+h}|\varepsilon_{1,t}] = 0$, we have $\Theta_{21,h} = E_t[y_{2,t+h}|\varepsilon_{1,t} = 1] - E_t[y_{2,t+h}|\varepsilon_{1,t} = 0]$
    - were $\varepsilon_{1,t}$ observed, we could estimate by OLS
    - **Problem**: typically not observed
    - One possible solution: find an instrument for $\varepsilon_{1,t}$
    - Alternative: assume invertibility and impose additional economic restrictions to identify structural VMA representation

Historical digression

- Prior to 20th century, dominant view of business cycles was the **metronomic view**
  - According to this view, each boom deterministically creates the conditions leading to the next bust
  - However, the deterministic models had a hard time matching the observed fluctuations
- This changed in early 20th century with seminal work by **Slutzky, Yule and Frisch**
- The key insight was that moving sums of random variables could produce series that looked very much like the movements of actual economic time series
- To understand origins of business cycles, we have to search for **sources of shocks**

Rules versus shocks

- In our empirical analysis of **macro policy** we will study policy shocks
- What are such **policy shocks**?
  - Idealized interpretation: innovation to policy rules $\perp$ to all other structural impulses, e.g.
    $$i_t = f(\Omega_t) + \varepsilon_t^m$$
    where i_t is the policy instrument, Ω_t is the time-t information set, $f(\cdot)$ is the policy rule and ε_t^m is the policy shock
  - But central bankers don't flip coins. Alternative interpretations: change in preferences, measurement error in prelim data, strategic response to private-sector expectations, ...
- We care about **rules**, not **shocks**. So why the focus on shocks?
  - IV intuition: random variation in it identifies causal effects of it on the economy
  - We will make precise the idea that the dynamic causal effects of shocks allow us to predict the effects of changes in rules (link between shocks and counterfactuals)

Outline

1. Macroeconomic shocks – a brief history of thought

   Big questions and identification challenge

   What is a shock?

   Approach and objects of interest

Objects of interest

Let ε_t be a vector of shocks and y_t be a vector of macro vars. We want to learn about:

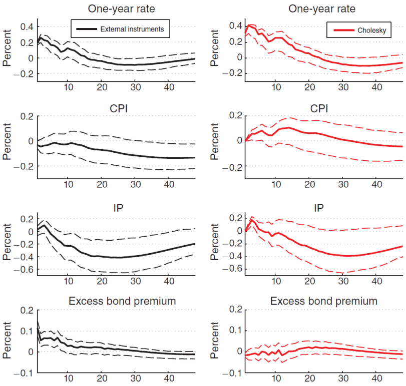
1. **Dynamic causal effects**

$$IRF_{i,j,h} = \Theta_{ij,h} \equiv \mathbb{E}_t[y_{i,t+h}|\varepsilon_{j,t} = 1] - \mathbb{E}_t[y_{i,t+h}|\varepsilon_{j,t} = 0], \qquad h = 0, 1, 2, \ldots$$

- Note: we will largely care only about relative dynamic causal effects
  E.g. how does output respond to a monetary shock that moves the FFR by 100bp
- Sometimes it is also interesting to know the size of a shock, i.e. how big is a one-standard deviation shock

Objects of interest

Example: IRFs of macro and financial variables to monetary policy shock (Gertler and Karadi, 2015)



First-stage regression:
F: 21.55; Robust F: 17.64; R^2: 7.76 percent; Adjusted R^2: 7.40 percent

Objects of interest

Let ε_t be a vector of shocks and y_t be a vector of macro vars. We want to learn about:

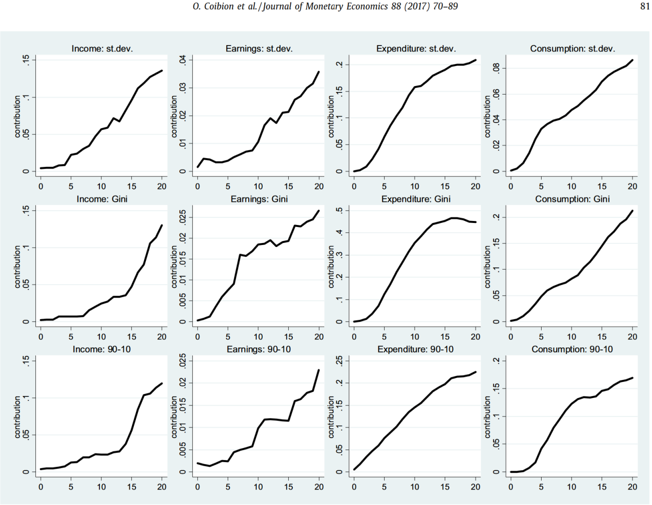
2. **Shock importance** for average cyclical fluctuations

$$FEVD_{i,j,h} \equiv 1 - \frac{Var(y_{i,t+h} | \{\varepsilon_{t-l}\}_{l=0}^{\infty}, \{\varepsilon_{j,t+l}\}_{l=1}^{h})}{Var(y_{i,t+h} | \{\varepsilon_{t-l}\}_{l=0}^{\infty})}$$
$$= \frac{\sum_{m=0}^{h-1} \Theta_{ij,m}^2}{\sum_{j=1}^{n_\varepsilon} \sum_{m=0}^{h-1} \Theta_{ij,m}^2}$$

- **In words**: what share of fluctuations of y_{t+h} comes from shocks $\varepsilon_{j,t}$ (rather than $\varepsilon_{-j,t}$)? This is called the fraction of forecast error variance decomposition
- Will also discuss some other important concepts. Most notably: change the information set from structural shocks $\{\varepsilon_{t-l}\}_{l=0}^{\infty}$ to macro observables $\{y_{t-l}\}_{l=0}^{\infty}$ called the forecast error variance ratio (FVR)

Objects of interest

Example: FEVD of inequality to monetary policy shock (Coibion et al., 2017)



Objects of interest

Let ε_t be a vector of shocks and y_t be a vector of macro vars. We want to learn about:

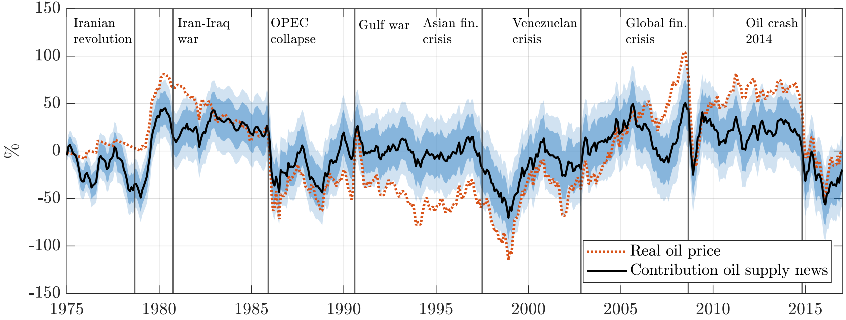
3. Contribution of shocks to particular **historical episodes**

$$HD_{i,j,t} = E[y_{i,t} | \{\varepsilon_{j,t-l}\}_{l=0}^{\infty}] = \sum_{l=0}^{\infty} \Theta_{ij,l} \varepsilon_{j,t-l}$$

- The derived path is then compared with the actual realized time path $y_{i,t}$
- In words: did shock $\varepsilon_{j,t}$ contribute meaningfully to a given historical episode? This is called a historical decomposition

Objects of interest

Example: HD of oil price to oil supply news (Känzig, 2021)



Two complementary approaches

Identification using

- Time-series variation
  - Pro: captures GE effects. Cons: difficult to identify
  - Can map out heterogeneous effects after
- Cross-sectional variation
  - Pro: credible identification. Cons: captures PE or local GE effect
  - Aggregate using structural model or sufficient statistic approach

Course outline

1. Refresher: linear models and time series methods
   - Slutzky–Frisch paradigm
   - Lag operators, linear filters, VARMA, SVMA
   - Autocovariance function, spectrum, Wold decomposition
2. Identification using time-series variation
   (a) Identifying assumptions
      - Background: the SVMA model identification challenge
      - Identification under invertibility: zero restrictions (short-run, long-run), sign/magnitude restrictions, max-share, proxies/external instruments (high-frequency identification, narrative approach), heteroskedasticity
      - Identification without invertibility: instruments/proxies, dynamic residual rotation and Blaschke matrices, FAVARs

Course outline

(b) Estimation strategies
  - Overview: VAR, LP (and intermediate shrinkage techniques)
  - LP/VAR population equivalence
  - Finite-sample recommendations

(c) Pitfalls and practical recommendations
  - Anticipations
  - Trends, lags, outliers and influential observations
  - Counterfactuals
  - Nonlinearities

3. Macro shocks and micro data
  - Overview of data sources: households, firms, . . .
  - Two-step approach: grouping estimators, panel local projections
  - Unified approach: functional VARs

Course outline

4. Identification using cross-sectional variation
   (a) Research designs
      - Difference-in-difference, RDD
      - Shift-share
   (b) What does cross-sectional variation identify?
      - Cross-household/firm analysis & partial equilibrium effects
      - Cross-regional analysis & local general equilibrium effects
      - Local average versus heterogeneous effects
   (c) The "missing intercept"/aggregation
      - Semi-strucutral approach, sufficient statistics
      - Structural approach, moment matching (micro moments, identified moments)
   (d) Bridging theory and empirics
      - Using cross-sectional data to learn about transmission channels
      - Model selection