Macroeconomics A

Lecture 3 - Business Cycle Facts and RBC Model

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Geneva Graduate Institute, Fall 2024

Business Cycles

The questions:

- Why do we have aggregate fluctuations (booms & recessions)?
- What can we do against them?

To answer these questions, we need to construct models that are accurate in both their qualitative and quantitative predictions.
$\Rightarrow$ very ambitious!

Undergraduate macro

Economy divided into three markets: labor market, money market, goods market.

- IS: $Y = \underbrace{A(Y, r, T, Y'^e, r'^e, T'^e)}_{\text{Demand for Goods}} + G$
- LM: $M = P \cdot L(Y, i)$
- PC: $\pi = \pi^e + \underbrace{f(Y, z)}_{\text{Deviation of Output from MR level}}$

where Y'^e is the expected output in the *next* period and
$r = i - \pi^e$ is the real expected interest rate

Assumptions / implications of this model

- in the short run the price level, P is given $\Rightarrow$
  hence IS & LM determines output
  demand matters & many factors affect demand
- in the medium run $\pi^e = \pi$, so $f(Y, z) = 0 \Rightarrow$ output at the natural level
- money affects output in the short run, not in the medium run
- money growth affects inflation and the nominal rate one-for-one in the medium run
- a fiscal expansion increases output in the short run, may decrease it in the medium run
- expectations matter: an anticipated fiscal contraction can be expansionary
  effect of money depends on i, π^e, i', π'^e

Strength and weakness of these models

Strengths

- provides a simple way of thinking about *general equilibrium* (complicated)
- implicit micro-foundations: life cycle, q theory,...
- time-tested shortcuts (but often not based on empirical evidence)

Weaknesses:

- Static, not dynamic
- not really made for quantitative analysis (quantitative attempts very short-lived)
- need explicit micro-foundations: hard to do welfare analysis without that (Lucas critique: curves may not be invariant to policy)

Dynamic Stochastic General Equilibrium (DSGE) models

- D some things don't make sense in static models (for example: investment)
  relatively short-term analysis
- S shocks hit the economy, and force it off the balanced growth path (BGP) $\Rightarrow$
  fluctuations do not mean dis-equilibrium, this is the reaction of the economy to an outside shock
- G E this is macro
  - the models are based on
    - perfectly/monopolistically competitive markets
    - optimizing agents

    $\Rightarrow$ the economy is in equilibrium
  - **micro-founded** models

There are different schools of thought...

SUBSTANTIVE DIFFERENCES

METHODOLOGICAL DIFFERENCES

	supply shocks	demand shocks rigidity	
simple models/ qualitative insights	$A \cdot L^{\alpha} K^{1-\alpha}$ growth model	SALT WATER contributed what is important RIGIDITY	$\rightarrow$ aim: see the mechanisms very clearly
complex models quantitative matching	FRESH WATER contributed the METHODOLOGY	now there is more harmony in macro	$\rightarrow$ transparency is the cost

$\downarrow$

we are going to start here, because it is easier

Path to get there:

1. real business cycle (RBC) models
2. introduce money
3. introduce nominal rigidities - New Keynesian (NK) models

Some predictions in the end are not very different from the IS-LM. However, better sense

- of the role of distortions
- of optimal policy

Big disadvantage: usually need the computer to solve the models

Business Cycle Facts I.

We'll study properties of quarterly **detrended macro time series**:

$$x_t = log(X_t) - log(X_t^*)$$

is the percentage deviation of variable X from its trend, X^*

how is the trend defined?

- first linear
- now more sophisticated filters: Baxter-King ("Bandpass") filter, Hodrick-Prescott ("HP") filter

Linear: just run OLS regression and use residuals. Bandpass/HP filter: programs are available

Business Cycle Facts II.

look at the highest correlation with GDP

$$\rho(x_t, y_{t+k}) \quad k = -6, -5, ..., 0, ...5, 6$$

- if $\rho > 0$, then x is pro-cyclical
- if $\rho < 0$, then x is counter-cyclical
- if $k < 0$, then x lags behind output
- if $k > 0$, then x leads output

$\rho(x_t, x_{t+k})$ is called the *autocorrelation function* (as a function of k) of the stochastic process x_t.

Business Cycle Facts III.

Series	Standard deviation	Correlation with GDP	Lag
y	1.66	1	0
c	1.26	0.9	0
i	4.97	0.9	0
g	2.49	0.15	-6
hours	1.61	0.9	-1
n	1.39	0.8	-1
tfp	2.29	0.9	-1
$\frac{w}{P}$	0.64	0.16	0

- everything quite pro-cyclical
- except: government spending $\rightarrow$ does not seem to support the statement that the cause if BC is gov spending
- real wage is mildly pro-cyclical $\rightarrow$ big problem in many models aggregation bias: average wage evolves differently than the wage of a continuously employed worker

Source: Stock and Watson (1999)

Business Cycle Facts IV.

Standard deviations (unit of measure is percentage deviation from trend) $\Rightarrow$ they are comparable

- GDP is more volatile than consumption
- investment is much more volatile than GDP
- government spending is pretty volatile
- working hours is almost exactly as volatile as GDP
- vast majority of the volatility of working hours is explained by the employment volatility
  $\rightarrow$ weird, because it should be cheaper to adjust the working hours of employees than to hire/fire people
- TFP is very volatile
  $\rightarrow$ school of thoughts disagree whether this is a cause or consequence of business cycles

Some other facts (numbers not here)

- There is significant heterogeneity in output volatilities across sectors and in wages across worker groups
- Equity returns are large and volatile relative to risk-free returns ($\Rightarrow$ macro-finance puzzles)
- Most macro aggregates displayed decreased volatility from the 1980's onwards (the "Great Moderation")
- The capital stock is rather smooth compared to other series (but: hard to measure, changes in measurement!)
- The trade balance is highly volatile and procyclical
- All major macro aggregates display significant serial correlation. $\rightarrow$ Is this because shocks are autocorrelated, or because of a propagation mechanism that endogenously smoothes the response of macro variables to a shock?

Basic model

Start with the most basic model, has to contain

- uncertainty - productivity shocks
- consumption/saving choice

$\Rightarrow$ Ramsey model, but stochastic, due to technological shocks

- add a labor/leisure choice as well

Many limitations: infinite horizon, no heterogeneity, no money
Good starting point: analyze the effect of shocks, propagation mechanisms, consumption smoothing

Production function

$$Y_t = K_t^{\alpha} (A_t L_t)^{1-\alpha} \quad 0 < \alpha < 1$$

goal: match the data
in the data the capital share is acyclical: $\Rightarrow$ Cobb-Douglas

Technological progress

$$A_t = A_t^* \widetilde{A}_t$$

- deterministic component

$$A_t^* = G^t \overline{A}$$

  long-run non-stochastic log-linear trend, $G > 1$

- shock process is an autoregressive process of order 1

$$\ln(\widetilde{A}_t) = \rho \ln(\widetilde{A}_{t-1}) + \varepsilon_{A,t}$$

  $E(\varepsilon_{A,t}) = 0$ and is iid (independent and identically distributed across time)

Capital accumulation

$$K_{t+1} = (1-\delta)K_t + Y_t - C_t$$

Household objective function

$$U = E_t \sum_{i=0}^{\infty} \beta^i U(C_{t+i}, 1 - L_{t+i})$$

C_t is consumption and L_t is the fraction of time spent working $(0 < L_t < 1)$
$U_1, U_2 > 0$ and $U_{11}, U_{22} < 0$

Solving this problem

Just like last week: household maximizes utility subject to budget constraint:

$$\max E_t \sum_{i=0}^{\infty} \beta^i U(C_{t+i}, 1 - L_{t+i})$$

$$\begin{aligned} \text{s.t. } S_{t+i} + C_{t+i} &= \widetilde{R}_{t+i} K_{t+i} + W_{t+i} L_{t+i} \\ K_{t+i+1} &= (1-\delta) K_{t+i} + S_{t+i} \\ K_{t+i} &\geq 0;\ K_0 > 0 \end{aligned}$$

Lagrangian:

$$\begin{aligned} \mathcal{L} =& E_t \sum_{i=0}^{\infty} \beta^i U(C_{t+i}, 1 - L_{t+i}) - \\ & E_t \sum_{i=0}^{\infty} \beta^i \lambda_{t+i} (K_{t+i+1} - (1-\delta) K_{t+i} - \widetilde{R}_{t+i} K_{t+i} - W_{t+i} L_{t+i} + C_{t+i}) \end{aligned}$$

Our exercise here:

Imagine the following:

- the economy is initially on its non-stochastic BGP
- there is a sudden realization of $\varepsilon_{A,t} \neq 0$
- this moves the economy away from its non-stochastic BGP
- over time the economy moves back to its BGP
- interpret the economy's deviation from the BGP as a business cycle
- does it look like what we see in the data?

Household behavior I.

inter-temporal FOC

$$U_1(C_t, 1 - L_t) = \beta E_t \left(R_{t+1} U_1(C_{t+1}, 1 - L_{t+1}) \right) \tag{1}$$

where $R_{t+1} \equiv 1 + \tilde{R}_{t+1} - \delta$.

Interpretation (should be familiar)

- decrease consumption by ε, so decrease utility by $U_1(C_t, 1 - L_t)\varepsilon$
- save and get R_{t+1} next period, so an increase in expected utility of $E_t \left(R_{t+1} U_1(C_{t+1}, 1 - L_{t+1}) \right) \varepsilon$

Household behavior II.

intra-temporal FOC

$$U_1(C_t, 1 - L_t)W_t = U_2(C_t, 1 - L_t) \tag{2}$$

Interpretation

- increase work by ε, so decrease in utility by $U_2(C_t, 1 - L_t)\varepsilon$
- extra wage: $W_t\varepsilon \to$ increase consumption $\to$ increase in utility by $U_1(C_t, 1 - L_t)W_t\varepsilon$

$$U_1(C_t, 1 - L_t)W_t = U_2(C_t, 1 - L_t)$$

if W_t constant, then if $(1 - L_t) \downarrow \Rightarrow U_2(C_t, 1 - L_t) \uparrow$
$\Rightarrow$ for intra-temporal FOC to hold need:
$U_1(C_t, 1 - L_t)W_t \uparrow \Rightarrow C_t \downarrow$
$\Leftrightarrow$ work more $\Rightarrow$ consume less from the intra-temporal FOC

Barro and King (1984) insight: to have both consumption and labor pro-cyclical (as in the data) need:

* highly pro-cyclical wage and/or
* high substitutability between leisure and consumption

quantitative question: is the observed pro-cyclicality of the wage enough given the large pro-cyclicality of labor?

Balanced growth restrictions

To progress further we need to specify the utility function of the household.

What can the utility function look like?

Imposing balanced growth path restrictions might help.
What do they mean? And are they reasonable?

in the steady state:

- L, labor is constant $\Rightarrow$ production side: we need labor augmenting technological progress
- C and W are growing at rate G, which is the rate of technological progress

can identify a set of utility functions that allow a BGP when techn is labor augmenting (King, Plosser, Rebelo (1988, JME))

two cases that are often used (where utility is separable in leisure and consumption):

1. $U(C, 1-L) = \ln C + b \ln(1-L)$
   $\rightarrow$ use this today
2. $U(C, 1-L) = \ln C + \theta \frac{(1-L)^{1-\gamma}}{1-\gamma}$
   $\rightarrow$ most used New-Keynesian specification, look at it later on

Using the specification $U(C, 1-L) = \ln(C) + v(1-L)$ we get the following:

- the intra-temporal foc becomes:

$$\frac{W_t}{C_t} = v'(1-L_t)$$

  equalize the marginal utility of leisure to the wage times the marginal value of capital (i.e. λ_t, and therefore the marginal utility of consumption)

- while the inter-temporal foc becomes:

$$1 = E_t\left(\beta R_{t+1}\frac{C_t}{C_{t+1}}\right)$$

  this is the usual condition for consumption

What are the effects of a positive technological shock? It increases current and future R and W.

- consumption
  income effect: people feel richer $\Rightarrow$ consumption up
  substitution effect: saving is worth more $\Rightarrow$ consumption down
  net effect is probably consumption up

- leisure
  income effect: people feel richer $\rightarrow$ they want to enjoy more leisure $\rightarrow$ leisure up
  substitution effect: higher wage $\Rightarrow$ leisure down
  net effect depends on the relative strength of the two forces

* *transitory shock* $\rightarrow$ smaller wealth effect and stronger substitution effect
* *permanent shock* $\rightarrow$ it is possible that consumption goes up and employment goes down

Employment effects another way

combine inter- and intra-temporal conditions and assume that $v(1-L) = b\ln(1-L)$

- the intra-temporal condition is:

$$\frac{W_t}{C_t} = \frac{b}{1-L_t}$$

- using this in the inter-temporal condition we get:

$$1 = E_t\left(\beta R_{t+1}\frac{W_t}{W_{t+1}}\frac{1-L_t}{1-L_{t+1}}\right)$$

* *transitory shock* $\rightarrow W_t \uparrow$ but not $W_{t+1} \Rightarrow (1-L_t)/(1-L_{t+1}) \downarrow$ $\rightarrow$ employment increases today
* *permanent shock* $\rightarrow W_t/W_{t+1}$ pretty much constant $\Rightarrow$ $(1-L_t)/(1-L_{t+1})$ constant as well $\rightarrow$ employment does not change