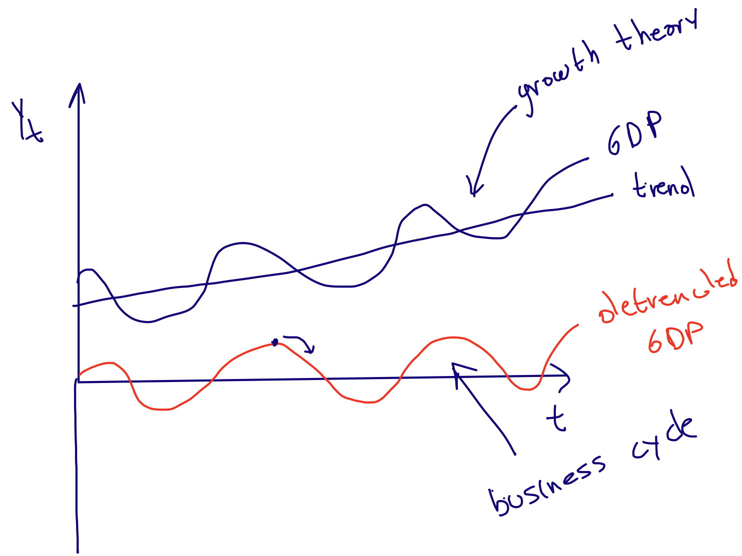
BUSINESS CYCLES ANALYSIS

Business cycles: short-term fluctuations of the economy around its long-term trend

Keynesian tradition:

- Changes in aggregate demand generate temporary imbalances in the economy
- Short-term static models (IS / LM) + Phillips curve
- Analysis of specific episodes



New-Keynesian

Neoclassical approach:

- Fluctuations as equilibrium reactions of the economy in the face of exogenous shocks (of supply or demand) — technology
- Extensions of the neoclassical growth model with stochastic shocks — RBC
- Analysis of statistical regularities of the time series

Business Cycle Representation

Distinguishing long-term growth (trend) from short-term fluctuations (cycles) in the data

We can decompose the observed times series for the variable Y_t:

$$Y_t = Y_t^g \times Y_t^c \qquad t = 1, ...T$$

Y_t^g : trend component

Y_t^c : cyclical component

In logs:

$$y_t = y_t^g + y_t^c$$

$\{y_t\}_{t=1}^{T} \leftarrow$ original series

Hodrick-Prescott Filter (*HP*): to find a series y_t^g that minimizes

$$\sum_{t=1}^{T}\left(y_t - y_t^g\right)^2 + \lambda \sum_{t=1}^{T}\left[\left(y_{t+1}^g - y_t^g\right) - \left(y_t^g - y_{t-1}^g\right)\right]^2$$

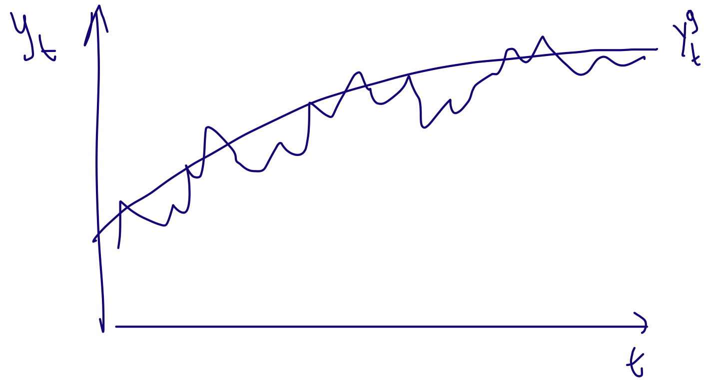
The parameter λ measures the weight given to smoothness of y_t^g in relation to its proximity to y_t

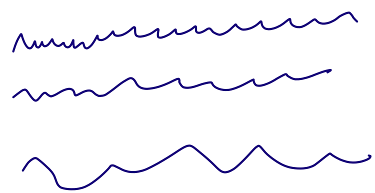
- If $\lambda = 0$, y_t^g is equal to y_t

- If $\lambda \to \infty$, y_t^g tends to a straight line

For quarterly data, the value recommended is $\lambda = 1600$ (monthly $\lambda = 14,400$, annual $\lambda = 100$)

Once y_t^g is found, the cyclical component is obtained as $y_t^c = y_t - y_t^g$





Statistical Properties of the Cycles

The next step is to find regularities in the behavior of the cyclical components for the main macro variables ($\tilde{x}_t$: logarithm of the cyclical component of X)

- Variance relative to output: $\underline{S.D.(\tilde{x}_t)} / \underline{S.D.(\tilde{y}_t)}$

  $\Rightarrow$Indicates whether the variable X fluctuates more or less than output

- Correlation with output: $Corr(\tilde{x}_t, \tilde{y}_t)$

  $\Rightarrow$Indicates whether the variable X it is procyclical or countercyclical

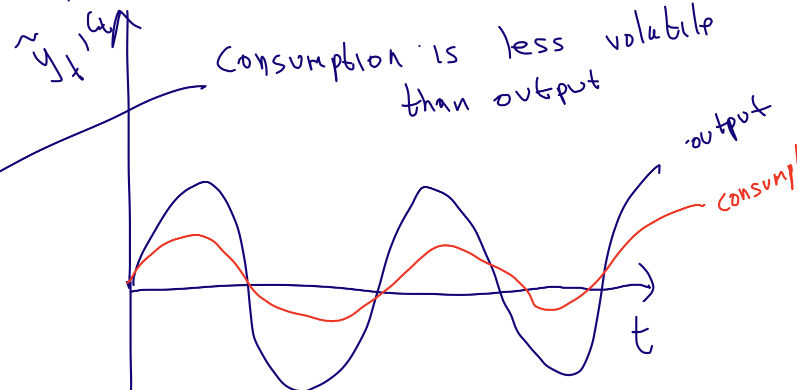
- Correlations with lags: $Corr(\tilde{x}_{t \pm s}, \tilde{y}_t)$

  $\Rightarrow$Indicates whether the variable X anticipates or lags the cycle

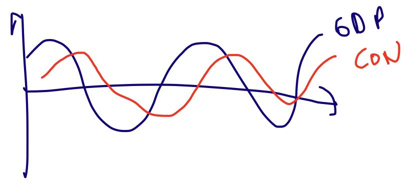
output

consumption

Consumption is less volatile than output



consumption is pro-cyclical



Consumption lags GDP

ble 1.1
ycllcal Behavior of the U.S. Economy: Deviations from Trend of Key Variables, 1954:I–1991:II

		Cross-Correlation of Output with:										
Variable	*SD%*	$x(-5)$	$x(-4)$	$x(-3)$	$x(-2)$	$x(-1)$	x	$x(+1)$	$x(+2)$	$x(+3)$	$x(+4)$	$x(+5)$
ıtput component												
GNP	1.72	.02	.16	.38	.63	.85	1.0	.85	.63	.38	.16	−.02
›nsumption expenditures												
CONS	1.27	.25	.42	.57	.72	.82	.83	.67	.46	.22	−.01	−.20
CNDS	0.86	.22	.40	.55	.68	.78	.77	.64	.47	.27	.06	−.11
CD	4.96	.24	.37	.49	.65	.75	.78	.61	.38	.11	−.13	−.31
vestment												
INV	8.24	.04	.19	.38	.59	.79	.91	.76	.50	.22	−.04	−.24
INVF	5.34	.08	.25	.43	.63	.82	.90	.81	.60	.35	.09	−.12
INVN	5.11	−.26	−.12	.05	.30	.57	.79	.88	.83	.60	.46	.24
INVR	10.7	.42	.55	.65	.72	.74	.63	.39	.11	−.14	−.33	−.43
Ch. INV	17.3	−.03	.07	.22	.38	.53	.67	.51	.27	.04	−.15	−.30
overnment purchases												
GOVT	2.04	.03	−.01	−.03	−.01	−.01	.04	.08	.11	.16	.25	.32
xports and imports												
EXP	5.53	−.48	−.42	−.29	−.10	.15	.37	.50	.54	.54	.52	.44
IMP	4.88	.11	.19	.31	.45	.62	.72	.71	.52	.28	.04	−.18
abor input based on household survey												
HSHOURS	1.59	−.06	.09	.30	.53	.74	.86	.82	.69	.52	.32	.11
HSAVGHRS	0.63	.04	.16	.34	.48	.63	.62	.52	.37	.23	.09	−.05

real wages

Taken from: Cooley and Prescott (1995)

Kydland and Prescott (1990) find the following regularities for the United States:

- Consumption, investment, employment and real wages are pro-cyclical ✓
- Consumption and real wages are less volatile than output ✓
- Investment is more volatile than output and employment has the same volatility as output
- The price level is countercyclical
- Monetary aggregates are pro-cyclical, but do not lead the cycle

IS-LM model

demand ↓ ⇒ consumption ↓

⇒ output ↓ → P ↓

⇒ labor (demand) ↓

nominal wages rigid ⇒ real wages ↑ counter-cyclical

There are some specific regularities for emerging economies, such as Mexico (see *Neumeyer and Perri, 2005*):

- The cycles of developed and developing countries are strongly *synchronized*
- Fluctuations are on average higher than in developed countries
- Consumption fluctuates **more** than output
- The interest rate and the current account are countercyclical and very volatile

Neumeyer – Perri → Interest rate shocks

Aguiar – Gopinath → trend shocks

A Simple Real Business Cycles Model

Neoclassical growth model with:

- Consumption-leisure decision

- Exogenous technological change

- Technology shocks to the production function

The model is consistent with the stylized growth facts for the United States

Kydland and Prescott (1982): *Can this model also reproduce the cycles?*

Production function:

shocks

$A_{t+1} = (1+g) A_t$

$$Y_t = e^{z_t} F\left(K_t, A_t L_t\right)$$

exogenous technological shock

z_t : technology shock that affects total factor productivity; follows an AR(1) process:

$$z_{t+1} = \rho z_t + \varepsilon_{t+1}$$

where ε_t is white noise with variance σ^2

A_t: technological level that affects the productivity of work; grows at the exogenous rate g (technical progress)

L_t : population size ($L_t^s \leq L_t$); grows at the exogenous rate n

$L_{t+1} = (1+n) L_t$

Writing all variables in effective units of labor:

$$\widehat{y}_t = \frac{Y_t}{A_t L_t} \qquad \widehat{k}_t = \frac{K_t}{A_t L_t} \qquad \widehat{c}_t = \frac{C_t}{A_t L_t} \qquad l_t = \frac{L_t^s}{L_t}$$

Production function:

$$\widehat{y}_t = e^{z_t} F\left(\widehat{k}_t, l_t\right)$$

Intertemporal utility function:

$$\sum_{t=0}^{\infty} \beta^t u(\widehat{c}_t, 1 - l_t)$$

Budget constraint and capital accumulation rule:

$$\widehat{c}_t + \widehat{i}_t = \widehat{w}_t l_t + r_t \widehat{k}_t$$

$$(1+n)(1+g)\,\widehat{k}_{t+1} = (1-\delta)\widehat{k}_t + i_t$$

$$\frac{Y_t}{A_t L_t} = e^{z_t} F\left(\frac{K_t}{A_t L_t}, \frac{A L_t^s}{A_t L_t}\right)$$

$$\widehat{y}_t = e^{z_t} F\left(\widehat{k}_t, l_t\right)$$

Social planner's problem (simplified notation):

$$\max \qquad E_0 \sum_{t=0}^{\infty} \beta^t u\left(\widehat{c}_t, 1 - l_t\right)$$

$s.t.$

$$\widehat{c}_t + \widehat{i}_t = e^{z_t} F\left(\widehat{k}_t, l_t\right) \longrightarrow \text{feasibility}$$

$$(1+n)(1+g)\,\widehat{k}_{t+1} = (1-\delta)\,\widehat{k}_t + \widehat{i}_t$$

$$z_{t+1} = \rho z_t + \varepsilon_{t+1} \qquad \varepsilon_t \sim \left(0, \sigma^2\right)$$

The solution of this problem gives us contingent plans for the variables, which depend on the realizations of the technology shocks

A *deterministic* CGE is obtained by shutting down uncertainty, that is, by imposing $z_t = 0$, $\forall t$

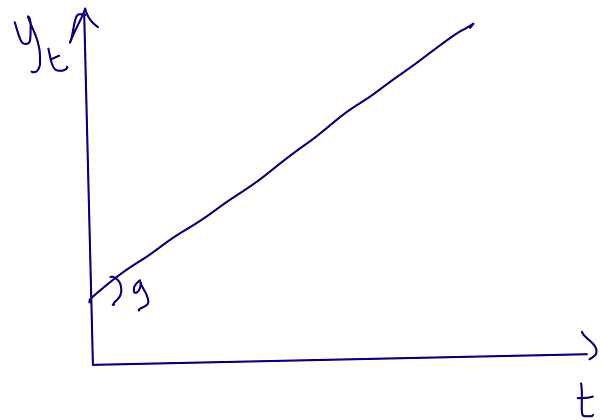
A deterministic stationary state is a deterministic CGE in which:

- Variables in effective units of work ($\widehat{y}_t$, $\widehat{k}_t$, $\widehat{c}_t$, $\widehat{i}_t$, $\widehat{w}_t$);
- The supply of labor per capita (l_t); and
- The rate of return of capital (r_t)

... remain constant over time

$\Rightarrow$ Per-capita variables grow at the rate of technical progress g (*balanced growth path*)

$$y_t = \frac{Y_t}{L_t} = A_t \hat{y}_t$$



Restricting the Model

The previous model is difficult to solve analytically

To use numerical methods you need to specify functional forms and give values to the parameters

Cobb-Douglas production function:

$$F(K, L) = K^{\alpha} L^{1-\alpha}$$

Separable utility function in consumption and leisure:

$$u(c, 1-l) = (1-\phi) \log c + \phi \log(1-l)$$

With these functional forms, the conditions that characterize the deterministic CGE are the Euler equation

$$\frac{\widehat{c}_{t+1}}{\beta \widehat{c}_t} = \frac{r_{t+1} + (1-\delta)}{(1+n)(1+g)}$$

the static condition for the work-leisure decision

$$(1-\phi) \frac{1}{\widehat{c}_t} = \frac{\phi \left(\frac{1}{1-l_t}\right)}{\widehat{w}_t}$$

and the feasibility condition

$$\widehat{c}_t = \widehat{y}_t - (1+n)(1+g) \widehat{k}_{t+1} + (1-\delta) \widehat{k}_t$$

z_t

stochastic process for $A_t = e$

Solow residual

`Calibrating the Model`

Now we choose the values for the parameters: α, ϕ, β, δ, n, g, ρ and σ. Two approaches:

$g \rightarrow \Delta\% \frac{Y}{L} \leftarrow$ pop

- *Structural estimation*: econometrics that takes into account the constraints imposed by the model (Maximum likelihood, method of momentss, Bayesian methods)

- *Calibration*: adjust the parameters of the model so that the path of balanced deterministic growth ($z_t = 0$, $\forall t$) is consistent with some long-term observations for the economy

The right approach depends on the question; the calibration method allows us to learn from the empirical deficiencies of the model

$Y = K^\alpha L^{1-\alpha}$ $\qquad r = \alpha K^{\alpha-1} L^{1-\alpha} = \alpha \frac{Y}{K}$

$(1+g)(1+n) K_{t+1} = (1-\delta) K_t + I_t$

s.s. $\frac{I^*}{Y^*} = [(1+g)(1+n) - (1-\delta)] \frac{K^*}{Y^*}$

Calibrating the previous model:

1. Obtain n as the average population growth rate

2. Obtain g as the average growth rate of output per capita (better if it is output per worker)

3. Given n and g, obtain β using the real interest rate ι and the following steady-state relation:

$$\frac{(1+n)(1+g)}{\beta} = r + (1-\delta) \equiv 1 + \iota$$

4. Obtain α using the return to work participation (wages plus other types of compensation) in total output:

$$1 - \alpha = \frac{wL}{Y}$$

$\alpha = \frac{rK}{Y}$

5. Given n, g, α and β, obtain δ using the savings rate $s \equiv \frac{I}{Y}$ and the steady-state relation:

$$s = (\delta + n + g + ng)\frac{K}{Y} = (\delta + n + g + ng)\frac{\alpha}{r} = \frac{\alpha(\delta + n + g + ng)}{\frac{(1+n)(1+g)}{\beta} - (1-\delta)}$$

$\rightarrow$ infer δ

6. Given α, obtain ϕ using the savings rate s and the fraction of time allocated to the labor market ($l \approx 0.3$) and the steady-state relation:

$$\frac{\phi}{1-\phi} = \left(\frac{1-l}{\hat{c}}\right)\hat{w} = \left(\frac{1-l}{l}\right)\left(\frac{wl}{y}\right)\left(\frac{y}{c}\right) = \left(\frac{1-l}{l}\right)(1-\alpha)\left(\frac{1}{1-s}\right)$$

We also need to calibrate the stochastic process for technology shocks (parameters ρ and σ)

From the AR (1) specification, the main moments for z_t are given by:

$$Ez_t = 0 \qquad Ez_t^2 = \frac{\sigma^2}{1-\rho^2} \qquad Ez_t z_{t-1} = \frac{\rho\sigma^2}{1-\rho^2}$$

In the data, z_t corresponds to the Solow residual:

$$z_t = \log Y_t - (1-\alpha)\log\left[A_0\left(1+g\right)\right]t - \alpha \log K_t - (1-\alpha)\log L_t$$

Obtaining series for the stock of capital and employment, we can calculate a series for z_t, observe their sampling moments and find the values of A_0, ρ and σ that are consistent with them

$$Y_t = e^{z_t} K_t^{\alpha} AL_t^{1-\alpha}$$

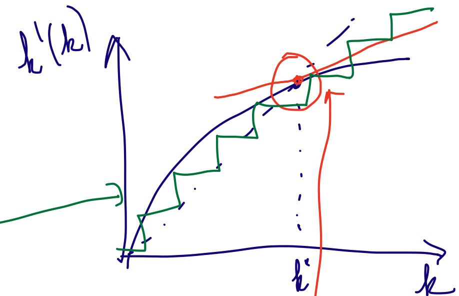
$$\log(Y_t) = z_t + \alpha \log(K_t) + (1-\alpha)\log(L_t)$$

solow residual

$$z_t = \log(Y_t) - \alpha \log(K_t) - (1-\alpha)\log(L_t)$$

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

`Main results`



Once the functional forms and the parameter values are obtained, we can simulate the equilibrium trajectories for the variables of interest

Numerical methods:

- Value-function iteration ✓
- Linearization around the steady-state → DSGE ↳ Dynare

The model is simulated by a large number of periods (10,000), discarding the first 1,000 observations in order to approximate the stochastic steady state

The results obtained simulating the Real Business Cycles model for the United States are summarized in the following table

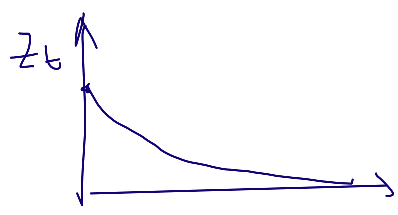
	Model	Data
$S.D.(y)$	1.35%	1.72%
$S.D.(c)$	0.33%	1.27%
$S.D.(i)$	5.95%	8.24%
$S.D.(l)$	0.77%	1.59%
$Corr(y,c)$	0.85	0.83
$Corr(y,i)$	0.99	0.91
$Corr(y,l)$	0.72	0.86

All the variables (both in the data and in the simulation) were adjusted using Hodrick and Prescott to filter the (log of the) cyclical component

$z_t \uparrow \Rightarrow Y_t \uparrow$ → $C_t \uparrow$, $I_t \uparrow$ (savings)

$w_t \uparrow$

L_t ?



The model with technology shocks reproduces well

- The correlations between the main variables observed in the data

  Consumption, investment and hours worked are strongly procyclical

- 70% of the variability observed in the product

- Some relative volatilities

  Investment is more volatile than consumption and hours worked

However, hours worked fluctuate much less than in the data

t

Substitution effect $L_t \uparrow$ > $L_t \uparrow$ intertemporal substitution

Income effect $L_t \downarrow$

Intuition: a positive technology shock ($z_t \uparrow$)

- Increases productivity and output, then income and consumption ✓
- Increases the return to capital, so agents rise investment strongly (intertemporal substitution of consumption)
- Increases wages, so agents offer more hours of work to the market (intertemporal substitution of leisure)

These responses generate the correlation patterns in the variables

Why do the hours worked fluctuate so little?

With the utility function:

$$u(c, 1-l) = (1-\phi)\log c + \phi \log(1-l)$$

the substitution effect and the income effect on the labor supply are canceled (intertemporal substitution only)

But this utility function is necessary to have a balanced growth path

GHH → non-separable eliminate income effect

The low volatility in the hours worked generates a poor magnifying effect on the product

$$Y_t = e^{z_t} F\left(K_t, A_t L_t\right)$$

Criticisms to the Model

- What is a technology shock?

  Are these shocks exogenous?

  How to interpret a negative shock?

- The propagation mechanisms are weak

- What happens with the nominal variables?

- What happens to other sources of fluctuations (demand shocks)?

Some works after the article by Kydland and Prescott have tried to improve the predictions of the Real Business Cycle model

- Hansen (1985): Indivisible work and lotteries

  The technology shock acts on the extensive margin (employment), increasing the elasticity of intertemporal substitution of leisure

  The model manages to reproduce the fluctuations in hours worked in the data

- McGrattan (1994): Fiscal shocks - government spending, taxes

  Taxes distort household decisions

  These shocks generate greater volatility in the variables, for the same technological shock