Macroeconomics II Part II, Lecture II: RBC: accounting, measurement, extensions

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Last time

- We set up and learned how to solve the vanilla RBC model
- The calibrated model can seemingly explain several business cycle moments...
- .. but fails in some key aspects
- Today, we will dig deeper into understanding the RBC mechanisms and how the model can be improved

Agenda

1. Business cycle accounting
2. Measuring technology shocks
3. Two extensions to adress the the labor wedge
    - Employment lotteries
    - GHH preferences

Business cycle accounting

- The plain vanilla RBC model provides an efficient benchmark
- Other BC models can be compared to this benchmark
  - A succesful model is a model that does something better than the vanilla RBC model in terms of explaining the data
- For this purpose, it is useful to develop methods that make it more precise what the vanilla RBC model does well and what it does not so well
- One such method is called Business Cycle Accouting
- Developed by Chari-Kehoe-McGrattan (Ecmtra, 2007), further elaborated in Brinca-Chari-Kehoe-McGrattan (HB Macro, 2016)

The idea

- Taking the parameters as given, the RBC model describes relationships between variables that we can measure in the data
- Thus, with given parameters and time series of these variables, we can see exactly which of these relationships fails and by how much
- Let's see how it works

RBC log-linear equilibrium

- Setting TFP shocks to zero $\hat{a}_t = 0$, our log-linear system is

$$
\begin{aligned}
\hat{w}_t &= \hat{c}_t + \varphi n_t \\
\hat{c}_t &= -\beta R^r E_t \hat{r}^r_{t+1} + E_t \hat{c}_{t+1} \\
\hat{y}_t &= \frac{C}{Y}\hat{c}_t + \frac{I}{Y}\hat{i}_t \\
\hat{y}_t &= \alpha \hat{k}_t + (1-\alpha)\hat{n}_t \\
\hat{k}_{t+1} &= (1-\delta)\hat{k}_t + \delta \hat{i}_t \\
\hat{r}^r_t &= -(1-\alpha)(\hat{k}_t - \hat{n}_t) \\
\hat{w}_t &= \alpha(\hat{k}_t - \hat{n}_t)
\end{aligned}
$$

  where steady state R^r, C, I, Y are determined by the model parameters

- Using that

$$
\begin{aligned}
\hat{r}^r_t &= \hat{y}_t - \hat{k}_t, \\
\hat{w}_t &= \hat{y}_t - \hat{n}_t,
\end{aligned}
$$

  we can eliminate $\hat{r}^r_t, \hat{w}_t$ from the system

RBC log-linear equilibrium

- The reduced system is

$$
\begin{aligned}
\hat{y}_t &= \hat{c}_t + \varphi(1 + n_t) \\
\hat{c}_t &= -\beta R^r E_t(\hat{y}_{t+1} - \hat{k}_{t+1}) + E_t \hat{c}_{t+1} \\
\hat{y}_t &= \frac{C}{Y}\hat{c}_t + \frac{I}{Y}\hat{i}_t \\
\hat{y}_t &= \alpha \hat{k}_t + (1-\alpha)\hat{n}_t
\end{aligned}
$$

- This system describes a relationship between NIPA variables Y, C, K, I and hours worked N - stuff we know how to measure in the data

- Q: By how much does these relationship break in the data?

-

RBC log-linear equilibrium

- The reduced system is

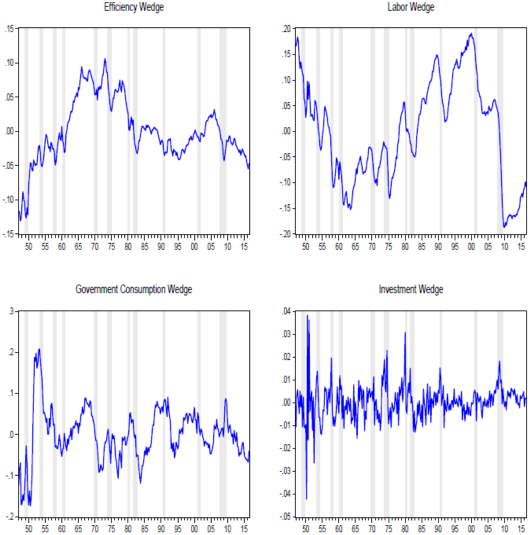
$$
\begin{aligned}
\hat{y}_t &= \hat{c}_t + \varphi(1 + n_t) + \hat{\psi}_t^N \\
\hat{c}_t &= -\beta R E_t(\hat{y}_{t+1} - \hat{k}_{t+1}) + E_t \hat{c}_{t+1} + \hat{\psi}_t^I \\
\hat{y}_t &= \frac{C}{Y}\hat{c}_t + \frac{I}{Y}\hat{i}_t + \hat{\psi}_t^G \\
\hat{y}_t &= \alpha \hat{k}_t + (1 - \alpha)\hat{n}_t + \hat{\psi}_t^A
\end{aligned}
$$

- This system describes a relationship between NIPA variables Y, C, K, I and hours worked N - stuff we know how to measure in the data

- Q: By how much does these relationship break in the data?

- Reformulated Q: How large are the wedges?

Wedges in the data



From Eric Sims' lecture notes, using detrended data from John Fernald and same parameter values as in Lecture 1

Wedges: interpretation

- Efficiency wedge is the same thing as the Solow residual
  - We treated this as an input to the model
- We need large fluctuations in the labor wedge
  - $\Rightarrow$ Indicates that something is not right about the labor market equilibrium in the model
- We do not need large fluctuations in the investment wedge
  - This is surprising, the RBC theory of consumption/investment seems very rudimentary...
- Large fluctuations in the government consumption wedge comes as no surprise
  - We know that both exports/imports and the government expenditure fluctuate a lot over the business cycle
  - Should perhaps not be interpreted as a failure, we simply didn't attempt to get this right
  - For a benchmark "international RBC model", see Backus-Kehoe-Kydland (JPE 1992)

Wedges: interpretation II

- Notice that prices do not appear in this accounting method

- The labor market wedge could stem either from
  1. $W_t \neq$ Marginal rate of substitution (MRS) between consumption and leisure, or
  2. $W_t \neq$ Marginal product of labor (MPL)

- Similarly, the investment wedge could stem either from
  1. $R_t^r \neq$ MRS between consumption today and tomorrow, or
  2. $R_t^r \neq$ MPK

- Nothing stops us from extending the accounting method to include prices
  - One attempt: Karabarbounis (RED 2014), finds that LM wedge is mostly due to $W_t \neq MRS$
  - However, there is more uncertainty regarding measurement of prices compared to NIPA variables
  - Wage fluctuations could, for example, be heavily influenced by cyclical selection

- However, without including prices, we gain little information about which economic relationship that accounts for the wedges

Measuring technology shocks

Are Solow residuals are reasonable measure of technology shocks?

- We apparently need a large fluctuations in the efficiency wedge to explain the data
- Kydland-Prescott's original approach: interpret the efficiency wedge (or Solow residuals) as exogenous technology shocks
- Reasonable that technological progress fluctuates around trend, and that Solow residuals captures some of this
- However, not reasonable that these *detrended* fluctuations can be negative with -5% or -10% percent $\Rightarrow$ implies huge technological regress!
  - Solow residuals implies that technological regress 40 % of time in post-war US data (King-Rebelo, HBmacro 1999)
- Technology concerns how factors of production are used for producing specific individual products ("blue-prints"); TFP is an abstract measurement concept
  - TFP can capture many things
  - Two examples: capacity utilization and missallocation

Cleaning "Solow residuals"

- Capacity utilization: In reality, firms adjust the usage of their predetermined factors of production over the business cycle
  - True for both labor and capital
  - Capacity utilization often treated as a key statistic for measuring the state of the business cycle
  - Low utilization $\Rightarrow$ lower TFP
  - How to clean Solow residuals from utilization? Go and measure utilization!
    - Burnside-Eichenbaum-Rebelo (EER 1996) uses detrended log electricity usage z_t as a measure of capital utilization, measures technology shocks as

$$a_t = y_t - (1-\alpha)n_t - \alpha(z_t + k_t)$$

    - Basu-Fernald-Kimball (AER 2006) and Fernald (2014) uses input data to adjust sectoral solow residuals from capacity utilization, then aggregate sector-level productivity to TFP
    - Both find a technology series with 20-25 % less volalility than original Solow residuals

- Missallocation: Suppose the some of the factors of production N_t, K_t are allocated to "under-performing" firms
  - This will also look like low TFP in the data
  - If missallocation moves with the business cycle, this will "contaminate" Solow residuals
  - Cyclical missallocation is actually a key prediction of the New-Keynesian model, introduced in Lecture III
  - I've not seen it applied in the RBC literature, but general measurement framework provided in Hsieh-Klenow (QJE 2009)

Simulation results with 25 % lower TFP volatility (HP-filtered)

	SD		Rel. SD		Corr Y_t		Autocorr	
	Data	Model	Data	Model	Data	Model	Data	Model
Y_t	0.017	0.011	1.00	1.00	1.00	1.00	0.85	0.72
C_t	0.009	0.005	0.53	0.40	0.76	0.95	0.79	0.78
I_t	0.047	0.031	2.76	2.73	0.79	0.99	0.87	0.72
N_t	0.019	0.004	1.12	0.33	0.88	0.98	0.90	0.72
W_t	0.009	0.008	0.53	0.66	0.10	0.996	0.73	0.74
R_t	0.004	0.011	0.24	1.0	0.00	0.97	0.42	0.71
A_t	0.012	0.09	0.71	0.80	0.76	0.999	0.75	0.72

- Reducing TFP volatility by 25 % does not affect any correlations, but reduces volalitility of all variables by 25 % - why?
- Implication: the model needs to add more endogenous amplification to fit the data
  - Put differently: the model cannot explain the efficiency wedge any more

Taking stock

- A standard calibration of the vanilla RBC model with a reasonable technology shock process has quite a few problems with matching the data

- The lack of empirical fit is manifested in large fluctuations in the labor wedge and the efficiency wedge (and also government consumption wedge)
  - Relatedly, too little amplification and lack of persistence
  - Does not produce reasonable fluctuations in hours worked
  - $\Rightarrow$ we need more internal propagation, and part of it should come from larger response in hours worked

- Also, recall the problems of getting the price moments right

- Lets start by adressing the labor wedge and the efficiency wedge
  - Problem set 5: endogenous capacity utilization to adress efficiency wedge
  - Remainder of this lecture: adressing the labor wedge

Two extensions to adress the the labor wedge

The role of the Frish elasticity

- The vanilla RBC model needs more amplification, and it should come through hours worked
- How to increase response of hours worked? Lets zoom in on the labor market equilibrium:
- Household intratemporal first order condition describes the labor supply curve (Do diagram on whiteboard):

Labor supply:

Labor demand:

-

The role of the Frish elasticity

- The vanilla RBC model needs more amplification, and it should come through hours worked
- How to increase response of hours worked? Lets zoom in on the labor market equilibrium:
- Household intratemporal first order condition describes the labor supply curve (Do diagram on whiteboard):

$$\begin{aligned} \text{Labor supply:} \qquad & \hat{w}_t = \hat{c}_t + \varphi n_t \\ \text{Labor demand:} \qquad & \hat{w}_t = \hat{a}_t + \alpha(\hat{k}_t - \hat{n}_t) \end{aligned}$$

- When productivity increases, we get larger response in hours either with larger subsitution effect or smaller income effect

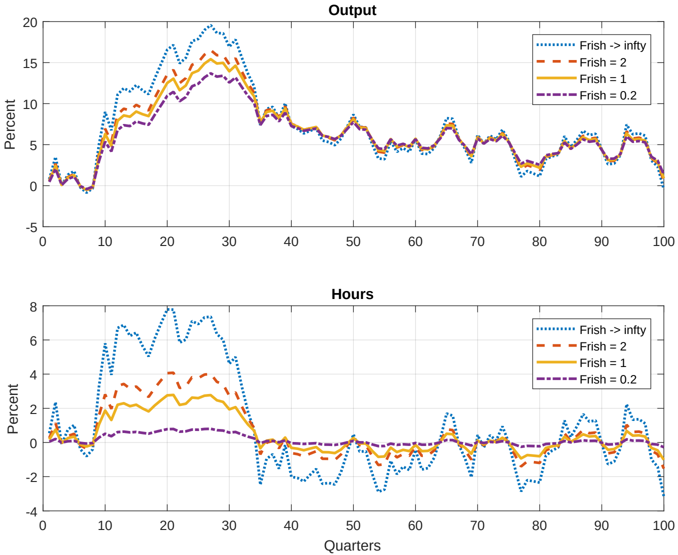
The substitution effect

- Holding the marginal utility of consumption constant, i.e. $c_t = 0$, $\eta = 1/\varphi$ measures the elasticity of hours w.r.t. wages
  - Put differently, it measures the substitution effect of wages on labor supply

- We call η the Frish elasticity

- Our baseline calibration had $\eta = 1$

Varying the Frish elasticity



Is a large Frisch elasticity reasonable?

- Larger Frish elasticity $\Rightarrow$ more amplification through hours worked
- Problem: most micro-level evidence suggest $\eta \in (0.0, 0.5)$
  - Classics: MacCurdy (JPE, 1981); Ashenfelter (JME, 1984); Angrist (JE, 1991)
  - Evidence reviewed in Chetty-Guren-Manoli-Weber (NBER annual, 2013)
  - Martinez-Saez-Siegenthaler (AER, 2020) exploit tax holiday in Austria, find $\eta = 0.02$
  - Stefanson (2019) and Sigurdsson (20222) exploit tax holiday in Iceland, find $\eta = 0.1 - 0.4$
- Moreover, most variation in hours worked over the business cycle is along the extensive margin, our model does not speak to this
- How to resolve?

Employment lotteries

- Hansen (JME 1985)/Rogerson (JME 1988) insight: indivisible labor disconnects the aggregate from the individual Frisch elasticity
  - In fact, with indivisibility, aggregate Frish elasticity can be *infinitely large*, although micro elasticities might be very small (even 0...)
- Model: Suppose there exist a measure 1 of ex-ante identical households, who have the same MacCurdy preferences:

$$U(C_t, N_t) = \log C_t - \theta \frac{N_t^{1+\varphi}}{1+\varphi}$$

- Assume choice set $N_t = \{0, \bar{N}\}$, but if households could pick freely, they would actually prefer some $N_t^* \in (0, \bar{N})$
- With complete markets, these households can be made better off if they enter a lottery with other households on whether to work or not

Employment lotteries II

- Denote the probability of working π_t
- In expectation, households work $N_t = \pi_t \bar{N}$ hours
- N_t therefore also denotes aggregate hours worked
- Complete markets imply $U_c(C_1, 0) = U_c(C_2, \bar{N})$
- With separable preferences, complete markets simply imply $C_1 = C_2 = C$
- With approriate choice of π_t, households maximize expected utility

Employment lotteries III

- Household per-period utility is

$$
\begin{aligned}
U(C_t, N_t) &= \log C_t - \pi_t \theta \frac{\bar{N}^{1+\varphi}}{1+\varphi} - (1-\pi_t)\frac{\theta \times 0}{1+\varphi} \\
&= \log C_t - \pi_t \theta \frac{\bar{N}^{1+\varphi}}{1+\varphi} \\
&= \log C_t - \frac{N_t}{\bar{N}} \theta \frac{\bar{N}^{1+\varphi}}{1+\varphi} \\
&= \log C_t - B N_t
\end{aligned}
$$

  where $B = \frac{\theta}{\bar{N}} \frac{\bar{N}^{1+\varphi}}{1+\varphi}$

- $\Rightarrow$ the lottery model is thus isomorphic to our rep-agent model

$$
U(C_t, N_t) = \log C_t - \theta \frac{N_t^{1+\varphi}}{1+\varphi}
$$

  with $\varphi = 0$ and with B calibrated to match the same average hours worked

- Now we have that the aggregate Frish elasticity $= \infty$

Employment lotteries: discussion

- Labor markets are obviously not organized through lotteries, but this is more of a technical trick to work anlytically with indivisible labor
  - Indivisible labor $\Rightarrow$ discrete choice problem $\Rightarrow$ F.O.C.s are neither sufficient nor sufficient for characterizing the optimum
  - The lottery convexifies the choice set $\Rightarrow$ we can proceed with our F.O.C.s as usual
- Modern approaches instead assume a fixed cost of working and deals with the non-convexity up front (using numerical methods)
  - Rogerson-Wallenius (JET 2009; AER 2013) show that the same discrepancy between micro-level and macro-level elasticities come out from quantitative life-cycle models
- At a more fundamental level, do we really believe the bulk of fluctuations in hours worked stem from households' labor supply choices? Isn't *involuntary unemployment* the main reason we are concerned with recessions?
- Lectures 5-7 present a theory of unemployment that can be readibly integrated into RBC and other business cycle models

The income effect

- The income effect on labor supply is, with additively separable preferences, not separable from the elasticity of intermtemporal substiution
- Household F.O.C.s:

$$\begin{aligned} \hat{w}_t &= \hat{c}_t + \varphi n_t \\ \hat{c}_t &= -\beta R^r E_t \hat{r}^r_{t+1} + E_t \hat{c}_{t+1} \end{aligned}$$

- If instead assuming CRRA consumption utility $U(C) = \frac{C^{1-\sigma}}{1-\sigma}$:

$$\begin{aligned} \hat{w}_t &= \sigma \hat{c}_t + \varphi n_t \\ \hat{c}_t &= -\beta R^r \frac{1}{\sigma} E_t \hat{r}^r_{t+1} + E_t \hat{c}_{t+1} \end{aligned}$$

- Higher elasticity of intermtemporal subsitution $\frac{1}{\sigma} \Leftrightarrow$ smaller income effect on labor supply

What's the effect of having lower income effects? Introducing GHH preferences

- To admit separation, Greenwood-Hercowitz-Huffman (1988) proposed the following preference specification

$$U(C, N) = U(C - V(N))$$

- With this specification, we still have $U_c(C, N) = U'(\cdot)$ but $U_n(C, N) = -U'(\cdot)V'(N)$

- The household's F.O.C. with respect to N_t becomes

$$-\beta^t U'(C_t - V(N_t))V'(N) = W_t \lambda_t$$

  and thus

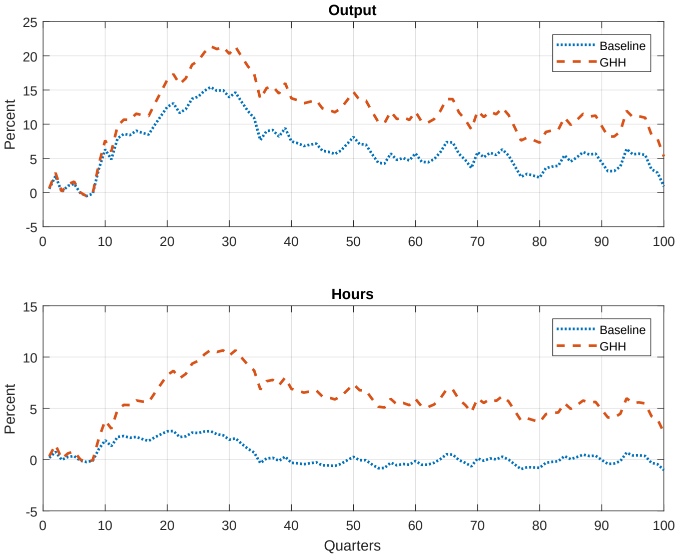
$$V'(N) = W_t$$

- With $V(N) = \frac{N^{1+\varphi}}{1+\varphi}$, we get

$$\hat{w}_t = \varphi n_t$$

- Now, the income effect is zero!

Baseline vs. GHH



Is GHH a reasonable preference specifaction?

- Cesarini-Lindqvist-Notowidigdo-ï¿½stling (AER 2017): labor supply responses to windfall lottery gains very small
- But if this is true, how to resolve with (almost) constant labor supply in the long run?
- Possible explanation: income effects are small in the short run, while still large in the long run
  - Jaimovich-Rebelo (JPE 2009): with habits in household preferences, you can actually achieve this
  - Broer-Harmenberg-Krusell-ï¿½berg (AER:insights 2023): this is what you should expect if households are subject to rigid wage contracts

Rigid-wage contracts a la Broer-Harmenberg-Krusell-ï¿½berg

- "Rigid" wages = wage contracts cannot be contingent on the shock, nor can they be renegoiated once a shock happens

- Instead of having a competitive market for hours in exchange for fixed per-hour wages, suppose we have a competive market for rigid wage-hour contracts: $W(N)$

- If firms have the "right to manage", then conditional on a TFP shock, we get $A_t F'(N_t) = W'(N_t)$
  - Firms equate the marginal rate of transformation to the *marginal wage*

- If the asset market is complete, and aggregate shocks are small relative to idiosyncratic shocks, households marginal utility of consumption is constant when writing the contract
  - Ex ante, households will agree to the contract if $W'(N_t) = -\frac{V'(N_t)}{U'(C)}$ and $\mathbb{E}W(N_t)$ ("base pay") is large enough
  - However, if given the opportunity to rewrite the contract after seeing the shock, households recognize that their consumption has changed, and demand $W'(N_t) = -\frac{V'(N_t)}{U'(C_t)}$.

- $\Rightarrow$ as if GHH within the contract, as if KPR when rewriting the contract
  - Frequency fo recontracting determines how short the short run is

Summing up

- Busines cycle accounting (BCA): useful diagnosis tool $\Rightarrow$ we learned that vanilla RBC is associated with large labor and efficiency wedges
  - It is not reasonable to interpret the entire efficiency wedge as exogenous technological shocks
  - After cleaing Solow residuals from utilization, amplification problem becomes bigger
- Motivated by BCA, we learned that model fit is improved if making labor supply more elastic and muting income effec
  - Highly elastic labor supply a natural implication of indivisble labor
  - Small short-run income effects is a natural implication of rigid wage contracts
- The lessons from lecture II will serve as benchmarks when we introduce models of frictional labor markets
- But first: something about investment