ECON 815

The Canonical RBC Model

Winter 2014

Model

- infinite horizon: $t = 0, 1, 2, \ldots$
- preferences

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(U(c_t, 1 - n_t) \right) \right]$$

- endowments
  - initial level of capital k_0
  - one unit of time each period
- production
  - firms have a neoclassical production function as before: $z_t F(k_t, n_t)$
  - capital depreciates at rate δ
  - Technology shocks: $\ln z_t = (1 - \rho) \ln \bar{z} + \rho \ln z_{t-1} + \epsilon_t$ with $\rho \in (0, 1)$ and $\epsilon_t \sim \mathcal{N}(0, \sigma)$

Note: z_t is the only exogenous variable in the economy.

Parameters

Preferences:

$$\frac{c^{1-\gamma}}{1-\gamma} + \theta \frac{(1-n)^{1-\eta}}{1-\eta}$$

- elasticities – especially labour supply η (and γ)
- weight θ
- discount factor β

Technology:

- α
- δ
- $\bar{z}$

Shocks (need to be estimated):

- serial autocorrelation ρ
- variance of shock σ

Firm's Problem

$$\max_{k,n} z_t F(k_t, n_t) - w_t n_t - r_t k_t$$

FOC:

$$z_t \alpha \left(\frac{k_t}{n_t}\right)^{\alpha-1} = r_t$$
$$z_t (1-\alpha) \left(\frac{k_t}{n_t}\right)^{\alpha} = w_t$$

Zero profits, but factor prices *depend on the current state* z_t.

Household's Problem

$$\max_{c_t,k_t,n_t} E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\gamma}}{1-\gamma} + \theta \frac{(1-n_t)^{1-\eta}}{1-\eta} \right) \right]$$

subject to

$$c_t + x_t \leq w_t n_t + r_t k_t \text{ for all } t \text{ and } z_t$$

$$k_{t+1} = x_t + (1-\delta) k_t$$

$$k_0 \text{ and } z_0 \text{ given}$$

FOC:

$$\left(\frac{c_t^{-\gamma}}{\theta (1-n_t)^{-\eta}} \right) = \frac{1}{w(z_t)} \text{ for all } t \text{ and } z_t$$

$$1 = E \left[\beta \left(\frac{c_t}{c_{t+1}} \right)^{\gamma} (r_{t+1} + (1-\delta)) \middle| z_t \right] \text{ for all } t \text{ and } z_t$$

$$c_t + k_{t+1} = w_t(z_t) n_t + r_t(z_t) k_t + (1-\delta) k_t \text{ for all } t \text{ and } z_t$$

Steady State

Suppose that $z_t = \bar{z}$ for all t.

From the firm's problem and market clearing, we obtain that the steady state is described by

$$\left(\frac{\bar{c}^{-\gamma}}{\theta(1-\bar{n})^{-\eta}}\right) = \frac{1}{f_n}$$
$$1 = \beta\left(f_k + (1-\delta)\right)$$
$$\bar{c} + \bar{k} = \bar{z}F(\bar{k}, \bar{n}) + (1-\delta)\bar{k}$$

We have three equations in three unknowns that we can solve.

The dynamics are way more tricky.

Why? The intertemporal Euler equations is a non-linear second-order difference equation.

Consumption function

Suppose there is no uncertainty and labour is fixed. Using a first-order Taylor expansion around c_t, we get as an approximation for the Euler equation

$$\frac{c_{t+1} - c_t}{c_t} \approx \frac{1}{\gamma} \left[1 - \frac{1}{\beta \left(r_{t+1} + (1 - \delta) \right)} \right].$$

In steady state, we know that $1 = \beta \left(\bar{r} + (1 - \delta) \right)$. Hence, for δ small,

$$\log \left(\frac{c_{t+1}}{c_t} \right) \approx \frac{1}{\gamma} \left(r_{t+1} - \bar{r} \right).$$

Key Insight: Consumption growth is proportional to deviations from the steady-state interest rate according to the intertermporal elasticity of substitution (γ).

- current (unexpected) productivity shock moves $\log(c_{t+1}/c_t)$ and r_{t+1} in opposite directions
- future (expected) productivity moves $\log(c_{t+1}/c_t)$ and r_{t+1} in the same direction

Labour Supply Decisions

Recall that

$$\left(\frac{c_t^{-\gamma}}{\theta(1-n_t)^{-\eta}}\right) = \frac{1}{w_t}.$$

Now people can change their labour supply in response to shocks which enter through w_t directly.

Usually, we think about an *extensive* and not an intensive margin.

- fraction ψ of people work, others do not
- work is fixed at $h < 1$ hours
- total hours worked is αh
- assume that people insure individual consumption risk

This changes utility to be *linear* in labour

$$\psi\left(\frac{c_t^{1-\gamma}}{1-\gamma} + \theta\frac{(1-h)^{1-\eta}}{1-\eta}\right) + (1-\psi)\left(\frac{c_t^{1-\gamma}}{1-\gamma} + \theta\frac{1^{1-\eta}}{1-\eta}\right) = \frac{c_t^{1-\gamma}}{1-\gamma} + \tilde{\psi}\frac{(1-h)^{1-\eta}}{1-\eta}$$

Solow Residuals and Shocks

Consider the production function

$$Y_t = z_t F(K_t, N_t X_t)$$

where $X_t = \gamma X_{t-1}$ with $\gamma > 1$.

The *Solow residuals* are measured by

$$\log SR_t = \log z_t + (1-\alpha)\log X_t = \log Y_t - \alpha \log K_t - (1-\alpha)\log N_t.$$

We have assumed that $\log z_t$ is AR(1) and that $\log X_t$ has a deterministic trend.

- Solow residuals inherit this trend.
- The productivity shock is just the deviations from this trend.
- We impose a particular structure on these deviations which allows us to identify ρ and σ from the data.

How Do We Proceed Now?

1) How do we pick the parameters for the model?

$\Longrightarrow$ Calibration and Estimation

2) How do we analyze the dynamics of the model?

$\Longrightarrow$ Linear first-order difference equation for the model

3) How do we judge how well the model does?

$\Longrightarrow$ Simulation and Impulse Response Functions

<u>But, what happened to trend growth?</u>

We can detrend a model with growth and work with that model.

Or, we can start out from a model without trend as shown here.

Of course, this requires us to also work with detrended data.