

The Cyclical Behavior of Equilibrium Unemployment and Vacancies Shimer (2005)

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Bellman Equation

Worker

- ▶ Unemployment value

$$U_p = z + \delta \{ f(\theta_p) \mathbb{E}_p W_{p'} + (1 - f(\theta_p)) \mathbb{E}_p U_{p'} \} \quad (1)$$

- ▶ Employment value

$$W_p = w_p + \delta \{ (1 - s) \mathbb{E}_p W_{p'} + s \mathbb{E}_p U_{p'} \} \quad (2)$$

Bellman Equation

Firm

- ▶ Hiring value

$$J_p = p - w_p + \delta(1 - s)\mathbb{E}_p J_{p'} \quad (3)$$

- ▶ Vacancy value

$$V_p = -c + \delta q(\theta_p)\mathbb{E}_p J_{p'} \equiv 0 \quad (4)$$

Productivity

The log of productivity follows AR(1) process

$$\log(p) = \rho \log(p) + \varepsilon \quad (5)$$

where

$$\log(p) \sim N(\mu_\lambda, \sigma_\lambda^2), \quad \varepsilon \sim N(\mu_\varepsilon, \sigma_\varepsilon^2)$$

Optimal Control

Market tightness

- ▶ Control in this problem consists of w_p, θ_p, u_p and the state is p
- ▶ Market tightness θ_p is given by solving the following equation of hire rate from free entry condition

$$q(\theta_p) = \frac{c}{\delta \mathbb{E}_p J_{p'}} \quad (6)$$

- ▶ And market tightness

$$\theta_p = \left(\frac{q(\theta_p)}{\mu} \right)^{-\frac{1}{\eta}} \quad (7)$$

- ▶ Employ Rate is given by

$$f(\theta_p) = \mu^{\frac{1}{\eta}} q^{\frac{\eta-1}{\eta}} \quad (8)$$

Optimal Control

Continued

- ▶ Optimal wage at each productivity level is given by the Nash Bargaining:

$$W_p - U_p = \beta(W_p - U_p + J_p) \quad (9)$$

- ▶ Note Bellman Equation of W_p given by 2, U_p given by 1, J_p given by 3
- ▶ Following the algebra given in slide 12, optimal wage for each p is

$$w_p = \beta p + (1 - \beta)z + \beta c \theta_p \quad (10)$$

- ▶ And unemployment rate

$$u_p = \frac{\delta}{\delta + f(\theta_p)} \quad (11)$$

Question a I

Discretization Algorithm

Inspired by Karen A. Kopecky 2006 Lecture Note

1. Choose a relative error tolerance level tol ;
2. Discretize the state space by constructing a grid for productivity

$$p = \exp\{\log p\} \text{ where } \log p = \{\log p_1, \log p_2, \dots, \log p_n\}$$

given by the Tauchen-Hussey (1991) method. The n is chosen at 100;

3. Start with an initial guess of the value function $V^{(0)}(p)$ is a vector of length n , i.e., $V^{(0)}(p) = \{V_i^{(0)}\}_{i=1}^n$, where $V_i^{(0)} = V^{(0)}(p_i)$. V here represents U, W, J . The initial guess is ones.

Question a II

Discretization Algorithm

4. Update the value function using equations 1 to 10, specifically
 - 4.1 Fix the current productivity level at one of the grid points, p_i from $i = 1$
 - 4.2 For each possible choice of productivity next period, calculate optimal control in the following order:

$$q(\theta_{p_i}) = \frac{c}{\delta \sum_{j=1}^n p_{i,j} J^{(0)}(p_j)}$$

$$f(\theta_{p_i}) = \mu^{\frac{1}{\eta}} q^{\frac{\eta-1}{\eta}}$$

$$\theta_{p_i} = \left(\frac{q(\theta_{p_i})}{\mu} \right)^{-\frac{1}{\eta}}$$

$$w_{p_i} = \beta p_i + (1 - \beta)z + \beta c \theta_{p_i}$$

- 4.3 and update the value function system with

Question a III

Descretization Algorithm

$$U_{p_i}^{(1)} = z + \delta \{ f(\theta_{p_i}) \sum_{j=1}^n p_{i,j} W^{(0)}(p_j) + (1 - f(\theta_{p_i})) \sum_{j=1}^n p_{i,j} U^{(0)}(p_j) \}$$

$$W_{p_i}^{(1)} = w_{p_i} + \delta \{ (1 - s) \sum_{j=1}^n p_{i,j} W^{(0)}(p_j) + s \sum_{j=1}^n p_{i,j} U^{(0)}(p_j) \}$$

$$J_{p_i}^{(1)} = p_i - w_{p_i} + \delta (1 - s) \sum_{j=1}^n p_{i,j} J^{(0)}(p_j)$$

- 4.4 Choose a new grid point for productivity, go through 4.1 to 4.3. Once we have done the update for all productivity grid, we have new system of value function $V_p^{(1)}$
- 4.5 Compute distance between the two systems of value functions following the sup norm

$$d = \max_{i \in \{1, \dots, n\}} |V_i^{(0)} - V_i^{(1)}|$$

Question a IV

Discretization Algorithm

4.6 If distance is within the error tolerance level, $d \leq tol * ||V_1^{(1)}||$, the functions have converged and go to step 5, or else go back to step 4.

5. Calculate the optimal control for each productivity level:

$$q(\theta_{p_i}^*) = \frac{c}{\delta \sum_{j=1}^n p_{i,j} J^*(p_j)}$$

$$f(\theta_{p_i}^*) = \mu^{\frac{1}{\eta}} q^{\frac{\eta-1}{\eta}}$$

$$\theta_{p_i}^* = \left(\frac{q(\theta_{p_i}^*)}{\mu} \right)^{-\frac{1}{\eta}}$$

$$w_{p_i}^* = \beta p_i + (1 - \beta)z + \beta c \theta_{p_i}^*$$

$$u_p^* = \frac{\delta}{\delta + f(\theta_p^*)}$$

where J^* is the converged value function.

Calibration

Appendix A

Optimal wage

$$\begin{aligned}W_p - U_p &= \beta(W_p - U_p + J_p) \\ \Leftrightarrow w_p - z + \delta(1 - s - f(\theta_p))(\mathbb{E}_p W_{p'} - \mathbb{E}_p U_{p'}) &= \\ \beta(p - z + \delta(1 - s - f(\theta_p))(\mathbb{E}_p W_{p'} - \mathbb{E}_p U_{p'}) + \delta(1 - s)\mathbb{E}_p J_{p'}) & \\ \Leftrightarrow w_p = \beta p + (1 - \beta)z + (\beta - 1)\delta(1 - s - f(\theta_p))(\mathbb{E}_p W_{p'} - \mathbb{E}_p U_{p'}) & \\ + \frac{\beta c(1 - s)}{q(\theta_p)} & \\ \Leftrightarrow w_p = \beta p + (1 - \beta)z - \frac{\beta c \delta(1 - s - f(\theta_p))}{q(\theta_p)} + \frac{\beta c(1 - s)}{q(\theta_p)} & \\ \Leftrightarrow w_p = \beta p + (1 - \beta)z + \beta c \theta_p &\end{aligned}$$

where we use the fact that $\mathbb{E}_p W_{p'} - \mathbb{E}_p U_{p'} = \frac{\beta}{1-\beta} \mathbb{E}_p J_{p'}$ and $f(\theta_p)/q(\theta_p) = \theta_p$

Reference I

Shimer, R. (2005), 'The cyclical behavior of equilibrium unemployment and vacancies', *American Economic Review* **95**(1), 25–49.

URL: <https://www.aeaweb.org/articles?id=10.1257/0002828053828572>