ECON408: Computational Methods in Macroeconomics

Search Models of Unemployment and Dynamic Programming

Jesse Perla

jesse.perla@ubc.ca

University of British Columbia

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Overview

Motivation

- In the previous lecture we described a model with employment and unemployment as a Markov Chain
- Central to that were arrival rates of transitions between the U and E states at some λ probability each period.
- But the worker didn't have a choice whether to accept the job or not. In this lecture we will investigate a simple model where workers search for jobs, and the λ becomes an endogenous choice
- As with the previous lecture on the Permanent Income model, the benefit is that we can consider policy counterfactuals which may affect the workers choices
- Finally, we will review fixed points and connect it to Bellman Equations more formally

Materials

- Adapted from QuantEcon lectures coauthored with John Stachurski and Thomas J. Sargent
  - → Job Search I: The McCall Search Model
  - → Job Search II: Search and Separation
  - → A Lake Model of Employment and Unemployment

```julia
using LinearAlgebra, Statistics
using Distributions, LaTeXStrings
using Plots.PlotMeasures, NLsolve, Roots, Random, Plots
default(;legendfontsize=16, linewidth=2, tickfontsize=12,
         bottom_margin=15mm)
```

The McCall Model

Summary

- See here for a more minimal verison
- The McCall model is a model of “search” in the labor market
- A worker can be in a state of unemployment or employment. at wage W_t
- The key decision: if they are unemployed and receive a job offer at wage W_t, should they accept it or keep searching?
- Assume that wages come from a fixed, known distribution with discrete values $w' \in \{w_1, \ldots, w_N\}$ and probabilities $\{p_1, \ldots, p_N\}$

Preferences

- Let Y_t be the stochastic payoffs of the consumer
  - → $Y_t = W_t$ if employed at wage W_t
  - → $Y_t = c$, unemployment insurance, while unemployed
- Let $u(\cdot)$ be a standard utility function with $u'(\cdot) > 0$ and $u''(\cdot) \leq 0$
- Preferences over stochastic incomes $\{Y_{t+j}\}_{j=0}^{\infty}$ given time t information are

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j u(Y_{t+j})$$

- We will try to rewrite this recursively just as we did when calculating PDVs

Timeline and Decisions

- If they are employed at wage w they
  - → get the wage w and enter the next period.
  - → have some probability α the job ends and they become unemployed before next period starts, otherwise the w does not change
- If they are unemployed they
  - → get unemployment insurance, c
  - → have some probability, γ of getting a wage offer, w' for the next period.
  - → Given some wage offer, w', they can choose to accept the job and enter employment, or to reject the offer and remain unemployed
  - → Cannot recall previously rejected wages (but wouldn't, in equilibrium)

A Trade Off

- The worker faces a trade-off:
  - → Waiting too long for a good offer is costly, since the future is discounted.
  - → Accepting too early is costly, since better offers might arrive in the future.
- To decide optimally in the face of this trade off, we use **dynamic programming**
- The key is to start with the state:
  - → employment status
  - → the current wage, w, if employed
- Then determine the feasible set of actions, and how the state evolves under each action

Value Functions

- All unemployment states are the same since nothing is changing over time and the previous wages are irrelevant
  - → Hence, let U be the value of being unemployed
- The only thing that matters for the employed worker is the current wage, w
  - → Hence, let $V(w)$ be the value of being employed at wage w
- We will write recursive equations for these value functions
- Recursive equations defining the value of being in a state today in terms of the value of different states tomorrow are Bellman Equations

Actions and Transitions if Employed

- The employed agent is passive
- While employed, at the end of the period
  - → With some probability α they become unemployed with value U
  - → Otherwise, they remain employed with value $V(w)$
- In fancier models, they could engage in on the job search, etc.

Actions and Transitions if Unemployed

- While unemployed, at the end of the period
  - → With some probably γ they get a wage offer w'
  - → If they **accept** they enter employment at wage w' next period (i.e. $V(w')$)
  - → If they didn't get an offer, or **rejected** offer w', they remain unemployed with values U

Summarizing Value Functions

- The value function for the unemployed worker is

$$
\begin{aligned}
U &= u(c) + \beta \left[(1-\gamma)U + \gamma \mathbb{E}[\max\{U, V(w')\}]\right] \\
&= u(c) + \beta \left[(1-\gamma)U + \gamma \sum_{i=1}^{N} \max\{U, V(w_i)\} p_i\right]
\end{aligned}
$$

- The value function for the employed worker is

$$
V(w) = u(w) + \beta \left[(1-\alpha)V(w) + \alpha U\right]
$$

- These are the **Bellman Equations** for the McCall model

Reorganize as a Fixed Point

- Since there are only N values of w_i, we can define $V(w_i) \equiv V_i$ and solve for $N+1$ values (i.e., $V_1, \ldots, V_N, U$)
- Let $X \equiv \begin{bmatrix} V_1 & \ldots & V_N & U \end{bmatrix}^\top$
- Define the Bellman Operator $T : \mathbb{R}^{N+1} \to \mathbb{R}^{N+1}$ stacking Bellman Equations

$$T(X) \equiv \begin{bmatrix} u(w_1) + \beta\left[(1-\alpha)V_1 + \alpha U\right] \\ \vdots \\ u(w_N) + \beta\left[(1-\alpha)V_N + \alpha U\right] \\ u(c) + \beta\left[(1-\gamma)U + \gamma \sum_{i=1}^{N} \max\{U, V_i\} p_i\right] \end{bmatrix}$$

- Then the fixed point of $T(\cdot)$ (i.e., $T(X) = X$) is the solution to the problem

Alternative Formulation

- As practice with Bellman Equations, consider an alternative formulation which is qualitatively identical
- Instead of writing the choice while in the U state between periods, you can write it with a single Value Function $V(w)$
  - → In that case, a state of unemployment must be mapped into the framework.
  - → For example, you could have a wage offer of 0 (although c would also work)

Alternative Formulation Bellman Equation

- The $V(w)$ is now the value of having a wage offer, not of choosing to work at that offer

$$\begin{aligned} V(w) = \max\{&u(w) + \beta\left[(1-\alpha)V(w) + \alpha V(0)\right], \\ &u(c) + \beta\left[(1-\gamma)V(0) + \gamma\mathbb{E}(V(w'))\right]\} \end{aligned}$$

- Let $\bar{w}$ the minimum w_i such that

$$u(w_i) + \beta\left[(1-\alpha)V(w_i) + \alpha V(0)\right] > u(c) + \beta\left[(1-\gamma)V(0) + \gamma\mathbb{E}(V(w'))\right]$$

- Then we can interpret this as the **reservation wage**. If the w' were distributed continuously, then it might be an exact wage at equality
- With this, the $\bar{w}$ will be a kink in the $V(w)$ function at $\bar{w}$

Bellman Operators and Fixed Points

Bellman Equations and Fixed Points

- Before we solve the McCall model, we need to review Fixed Points now that we have more tools
- Given a dynamic programming problem written as a Bellman equation, one common approach is to organize it as a fixed point
  - → Write the Bellman equation as $V = T(V)$ for some operator T
  - → Check if T is a contraction mapping
- In general, this is a fixed point in a function space
  - → If the state space is continuous, you will need to discretize V and/or the state space(e.g., the Tauchen Method)
  - → If it is already discrete states, then the functions usually just map indices to values (i.e., can represent as a vector)

Algorithms

- Given a Bellman Equation $V = T(V)$, we can solve for V through a variety of algorithms. For example,
  - → Guess V^0 and iterate $V^{n+1} = T(V^n)$ until convergence, called **Value Function Iteration (VFI)**
  - → Alternatively, solve the fixed point problem using some specialized algorithm
- One advantage of VFI is that the Banach Fixed Point Theorem shows uniqueness of the algorithm, even if it is not always the fastest approach
- In fact, we have already used this for solving simple asset pricing problems

Repeat of Markov Asset Pricing as a Fixed Point

- Lets re-do that exercise as practice with a few additions
- Payoffs are in $y \equiv \begin{bmatrix} y_L & y_H \end{bmatrix}^\top$
  - → $\mathbb{P}(y_{t+1} = y_H | y_t = y_L) = \alpha$
  - → $\mathbb{P}(y_{t+1} = y_L | y_t = y_H) = \gamma$
- Instead of linear utility, assume risk-averse utility $u(y) = \frac{y^{1-\sigma}-1}{1-\sigma}$ for $\sigma \geq 0$
- Because the process is Markov and payoffs do not depend on time, we can write this recursively

$$
p(y) = u(y) + \beta \mathbb{E}\left[p(y')|y\right]
$$

Expanding out as a Fixed point

- But there are only 2 possible states, so $p \equiv \begin{bmatrix} p_L & p_H \end{bmatrix}^\top \in \mathbb{R}^2$
- Rewriting this as a system of equations

$$
\begin{aligned}
p_L &= u(y_L) + \beta \mathbb{E}\left[p(y')|y_L\right] = u(y_L) + \beta\left[(1-\alpha)p_L + \alpha p_H\right] \\
p_H &= u(y_H) + \beta \mathbb{E}\left[p(y')|y_H\right] = u(y_H) + \beta\left[\gamma p_L + (1-\gamma)p_H\right]
\end{aligned}
$$

- Stack $p \equiv \begin{bmatrix} p_L & p_H \end{bmatrix}^\top$ and $u_y \equiv \begin{bmatrix} u(y_L) & u(y_H) \end{bmatrix}^\top$

$$
p = u_y + \beta \begin{bmatrix} 1-\alpha & \alpha \\ \gamma & 1-\gamma \end{bmatrix} p \equiv T(p)
$$

- Then the fixed point of $T(\cdot)$ (i.e., $T(p) = p$) is the solution to the problem

Solving Numerically with a Fixed Point

```julia
y = [3.0, 5.0] #y_L, y_H
sigma = 0.5
u_y = (y.^(1-sigma) .- 1) / (1-sigma) # CRRA utility
beta = 0.95
alpha = 0.2
gamma = 0.5
iv = [0.8, 0.8]
A = [1-alpha alpha; gamma 1-gamma]
sol = fixedpoint(p -> u_y .+ beta * A * p, iv) # T(p) := u_y + beta A p
p_L, p_H = sol.zero # can unpack a vector
@show p_L, p_H, sol.iterations
@show (I - beta * A) \ u_y;
```

```
(p_L, p_H, sol.iterations) = (34.63941760551722, 36.04925584308621, 4)
(I - beta * A) \ u_y = [34.63941760551727, 36.04925584308624]
```

Decisions and Valuations

- We have shown the importance of Markovian assumptions to ensure tractability
  - → If decisions only depend on the current state, and not the time itself, and the state is Markovian, then we can write a recursive problem.
- This approach is especially powerful when agent's need to make a **decision** given their state - as in the McCall model
  - → As always, in economics we usually implement decisions as optimization/maximization problems
  - → The key is that the $T(\cdot)$ operator can itself be complicated, and include constrained maximization/etc.

McCall Solution

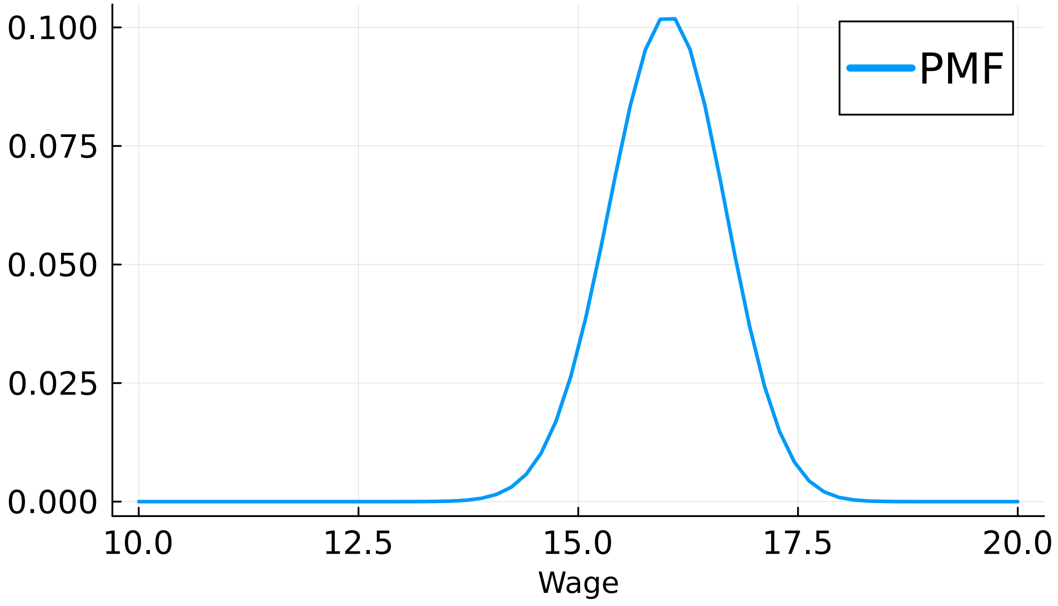
McCall Parameters

- Choose some distribution for wages, such as BetaBinomial
- CRRA Period utility: $u(c) = \frac{c^{1-\sigma}-1}{1-\sigma}$. Nests the $\lim_{\sigma\to 1} \frac{c^{1-\sigma}-1}{1-\sigma} = \log(c)$

```julia
function mccall_model(;
    alpha = 0.2, # prob lose job
    beta = 0.98, # discount rate
    gamma = 0.7, # prob job offer
    c = 6.0, # unemployment compensation
    sigma = 2.0, # CRRA parameters
    w = range(10, 20, length = 60), # wage values
    p = pdf.(BetaBinomial(59, 600, 400), 0:length(w)-1)) # probs for each wage
    # why the c <= 0 case?  Makes it easier when finding equilibrium
    u(c, sigma) = c > 0 ? (c^(1 - sigma) - 1) / (1 - sigma) : -10e-6
    u_c = u(c, sigma)
    u_w = u.(w, sigma)
    return (; alpha, beta, sigma, c, gamma, w, p, u_w, u_c)
end
```

Wage Distribution

```julia
mcm = mccall_model()
plot(mcm.w, mcm.p; xlabel = "Wage",
     label = "PMF", size = (600, 400))
```



Reminder: Value Functions

- The value function for the unemployed worker is

$$\begin{aligned} U &= u(c) + \beta\left[(1-\gamma)U + \gamma\mathbb{E}[\max\{U, V(w')\}]\right] \\ &= u(c) + \beta\left[(1-\gamma)U + \gamma\sum_{i=1}^{N}\max\{U, V(w_i)\}p_i\right] \end{aligned}$$

- The value function for the employed worker is

$$V(w) = u(w) + \beta\left[(1-\alpha)V(w) + \alpha U\right]$$

- These are the **Bellman Equations** for the McCall model

Bellman Operator

- Given the stacked V and U we can implement the $T : \mathbb{R}^{N+1} \to \mathbb{R}^{N+1}$ operator

```julia
function T(X;mcm)
    (;alpha, beta, gamma, c, w, p, u_w, u_c) = mcm
    V = X[1:end-1]
    U = X[end]
    V_p = u_w + beta * ((1 - alpha) * V .+ alpha * U)
    # Or, expanding out with a comprehension
    # V_p = [ u_w[i] + beta * ((1 - alpha) * V[i] + alpha * U) for i in 1:length(w)]
    U_p = u_c + beta * (1 - gamma) * U + beta * gamma * sum(max(U, V[i]) * p[i] for i in 1:length(w))
    return [V_p; U_p]
end
```

Reservation Wage

- The reservation wage is the wage at which the worker is indifferent between accepting and rejecting the offer
- In the case of a continuous wage distribution, it may be an exact state
- However, with a discrete number of wages it will usually lie between two wages
- Define the reservation wage as the smallest wage such that the worker would accept the offer
  - → In the problem, this is the smallest $\bar{w}$ such that $\mathbf{max}\{U, V(\bar{w})\} > U$
  - → Given a V and U vector we find the index where $V_i - U > 0$

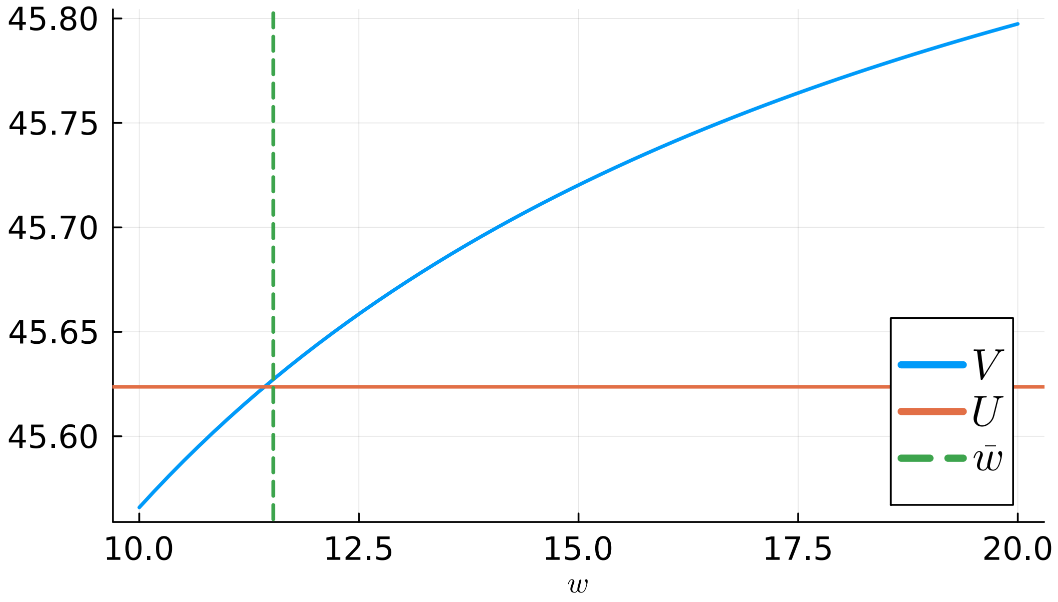
Solution

```julia
function solve_mccall_model(mcm; U_iv = 1.0, V_iv = ones(length(mcm.w)), tol = 1e-5, iter = 2_000)
    (; alpha, beta, sigma, c, gamma, w, sigma, p) = mcm
    x_iv = [V_iv; U_iv] # initial x val
    xstar = fixedpoint(X -> T(X;mcm), x_iv, iterations = iter, xtol = tol, m = 0).zero
    V = xstar[1:end-1]
    U = xstar[end]

    # compute the reservation wage
    wbarindex = searchsortedfirst(V .- U, 0.0)
    if wbarindex >= length(w) # if this is true, you never want to accept
        w_bar = Inf
    else
        w_bar = w[wbarindex] # otherwise, return the number
    end
    return (;V, U, w_bar)
end
```

Results

```julia
mcm = mccall_model()
sol = solve_mccall_model(mcm)
plot(mcm.w, sol.V; label = L"V",
     xlabel=L"w", size=(600, 400))
hline!(mcm.w, [sol.U], label=L"U")
vline!([sol.w_bar]; linestyle = :dash,
         label = L"\bar{w}")
```



Interpretation

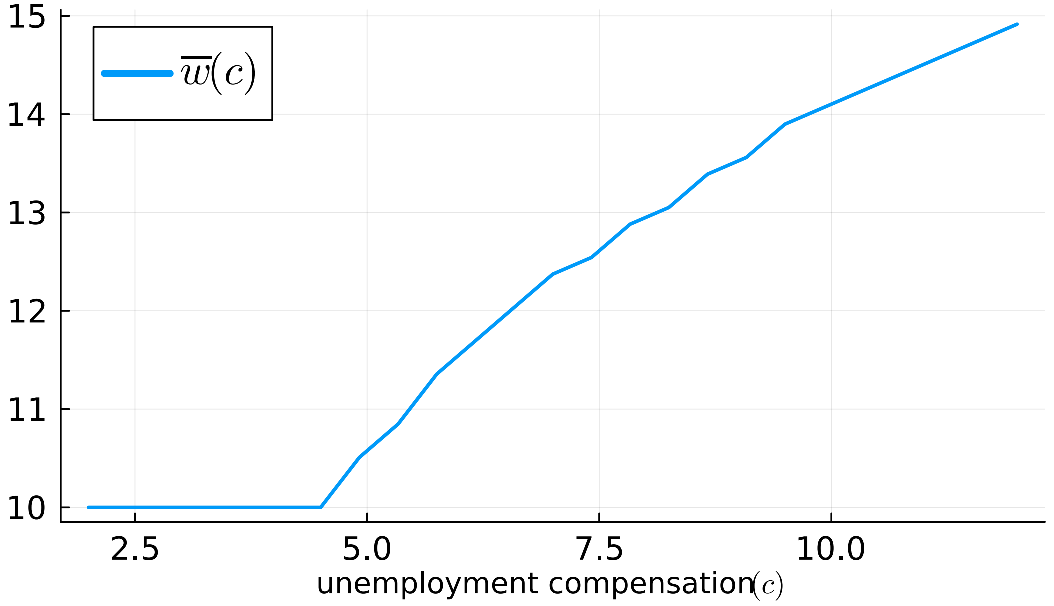
- The value of being employed is increasing in the wage, but has concavity due to the CRRA utility
- The value of unemployment is constant since the
  - → wage distribution is fixed over time
  - → the unemployment insurance is independent of previous wages
- While the agent can calculate the $V(w)$ for $w < \bar{w}$, when thinking through decisions, they will never accept a wage offer below the reservation wage
- Lets do further analysis of the reservation wage through **comparative statics** (i.e., modifying parameters)

Comparative Statics

Changing Unemployment Insurance

- Change in c affect value of searching for new job
- Too high and they will never accept a job, too low and they accept every job

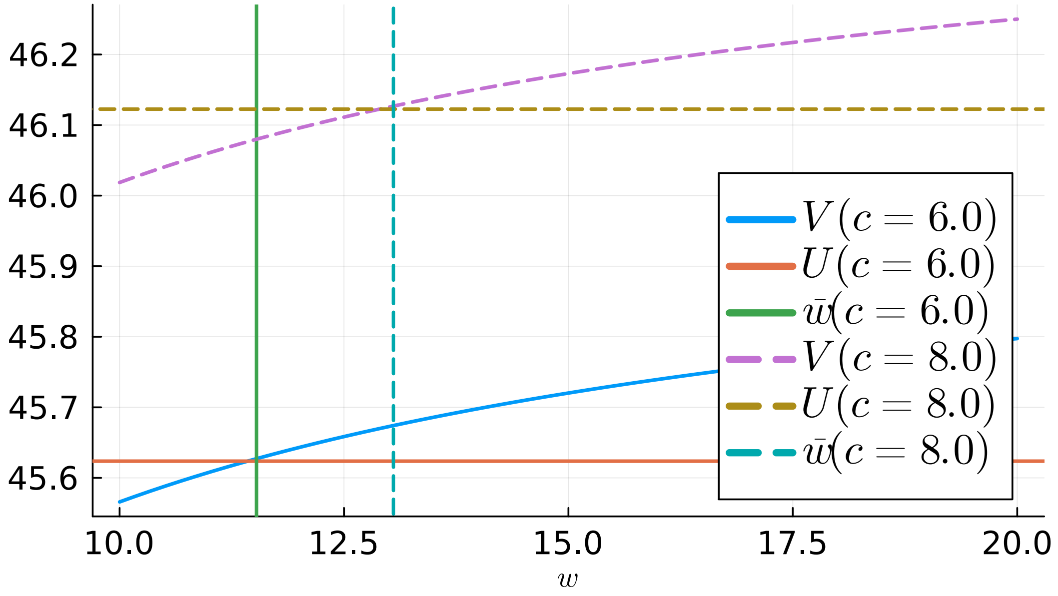
```julia
c_vals = range(2, 12, length = 25)
w_bars = [solve_mccall_model(
          mccall_model(;c)).w_bar
          for c in c_vals]
plot(c_vals, w_bars;
 xlabel = L"unemployment compensation$(c)$",
 label = L"\overline{w}(c)",
 size = (600, 400))
```



Analyzing Value Functions

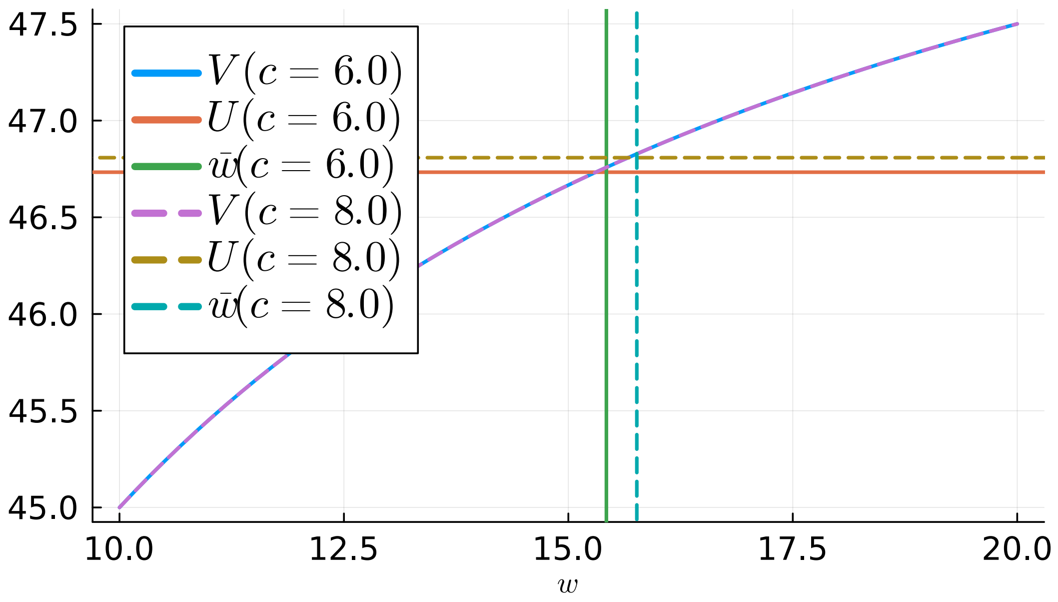
- Why does the $V(w)$ change with c?

```julia
mcm = mccall_model()
sol = solve_mccall_model(mcm)
plot(mcm.w, sol.V; label = L"V(c=6.0)",
     xlabel=L"w", size=(600, 400))
hline!(mcm.w, [sol.U], label=L"U(c=6.0)")
vline!([sol.w_bar];
        label = L"\bar{w}(c=6.0)")
mcm2 = mccall_model(c = 8.0)
sol2 = solve_mccall_model(mcm2)
plot!(mcm2.w, sol2.V; label = L"V(c=8.0)",
     linestyle = :dash)
hline!(mcm2.w, [sol2.U], label=L"U(c=8.0)",
       linestyle = :dash,)
vline!([sol2.w_bar]; linestyle = :dash,
        label = L"\bar{w}(c=8.0)")
```



Analyzing Value Functions ($\alpha = 0$)

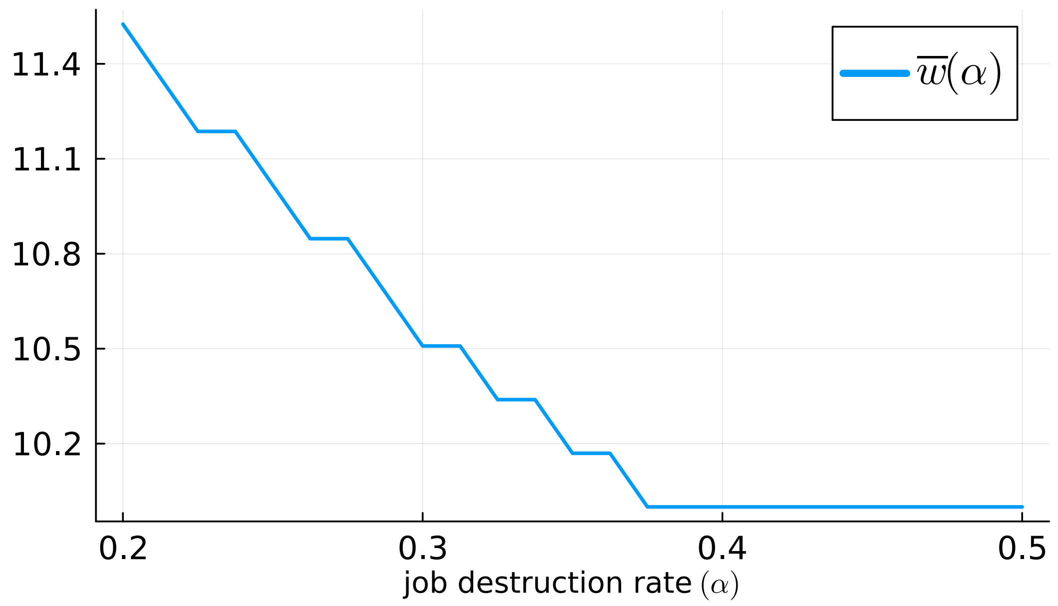
```julia
mcm = mccall_model(;alpha = 0.0)
sol = solve_mccall_model(mcm)
plot(mcm.w, sol.V; label = L"V(c=6.0)",
     xlabel=L"w", size=(600, 400))
hline!(mcm.w, [sol.U], label=L"U(c=6.0)")
vline!([sol.w_bar];
        label = L"\bar{w}(c=6.0)")
mcm2 = mccall_model(;c = 8.0, alpha = 0.0)
sol2 = solve_mccall_model(mcm2)
plot!(mcm2.w, sol2.V; label = L"V(c=8.0)",
     linestyle = :dash)
hline!(mcm2.w, [sol2.U], label=L"U(c=8.0)",
       linestyle = :dash,)
vline!([sol2.w_bar]; linestyle = :dash,
        label = L"\bar{w}(c=8.0)")
```



Changing Job Destruction Rate

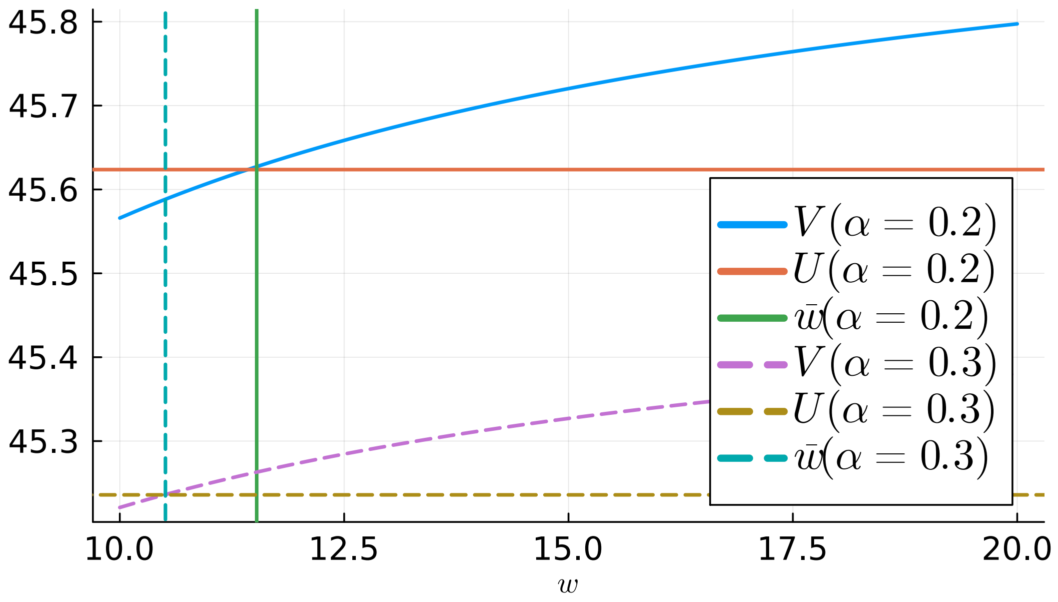
- How would α affect reservation wages? Why?

```julia
alpha_vals = range(0.2, 0.5, length = 25)
w_bars = [solve_mccall_model(
          mccall_model(;alpha)).w_bar
          for alpha in alpha_vals]
plot(alpha_vals, w_bars;
 xlabel = L"job destruction rate $(\alpha)$",
 label = L"\overline{w}(\alpha)",
 size = (600, 400))
```



Job Destruction Rate

```julia
mcm = mccall_model()
sol = solve_mccall_model(mcm)
plot(mcm.w, sol.V; label = L"V(\alpha=0.2)",
     xlabel=L"w", size=(600, 400))
hline!(mcm.w,[sol.U],label=L"U(\alpha=0.2)")
vline!([sol.w_bar];
        label = L"\bar{w}(\alpha=0.2)")
mcm2 = mccall_model(;alpha = 0.3)
sol2 = solve_mccall_model(mcm2)
plot!(mcm2.w,sol2.V; label=L"V(\alpha=0.3)",
     linestyle = :dash)
hline!(mcm2.w,[sol2.U],label=L"U(\alpha=0.3)",
       linestyle = :dash,)
vline!([sol2.w_bar]; linestyle = :dash,
        label = L"\bar{w}(\alpha=0.3)")
```



Connecting $\bar{w}$ to the Unemployment Rate

- Going back to our Lake Model
- Recall that the probability to transition from E to U is λ
- Our model of search leads to an endogenous choice of λ. In particular, while in U,
  - → With probability γ they get a wage offer
  - → Conditional on a wage offer, the probability the accept a wage is the probability that the wage is above the reservation wage

$$\lambda = \gamma \mathbb{P}(w > \bar{w}) = \gamma \sum_{i=1}^{N} \mathbb{1}(w_i > \bar{w}) p_i$$

Tax Policy

Government Budget and Fiscal Policy

- Unemployment insurance is a transfer from the government to the unemployed
- We will assume that:
  - → The government finances the unemployment insurance through a lump-sum tax τ on all wages.
  - → We can subtract it from c as well for simplicity
  - → Must balance the budget at the steady-state level
- If there are a normalized measure 1 in the economy, then the government budget constraint is

$$\tau = \bar{u}c$$

Wage Conditional on Employment

- Given that the consumer values their wage or unemployment with $V(w)$ and U, a benevolent planner would use the same criteria
- Let $\bar{e}$ and $\bar{u}$ be the steady state fraction of employed and unemployed individuals
- Since consumers would never accept a $w < \bar{w}$ we know the wage distribution **conditional on being employed** is

$$\mathbb{P}(w_i | w_i > \bar{w}) = \frac{p_i}{\sum_{j=i}^{N} p_j}$$

Aggregate Welfare

- The aggregate welfare, given U and $V(w)$ depends on the steady state fraction of unemployed and employed individuals

$$W \equiv \bar{u}U + \bar{e}\mathbb{E}[V(w)|w > \bar{w}]$$

Reminder: Lake Model

```julia
function lake_model(; lambda = 0.283, alpha = 0.013, b = 0.0124, d = 0.00822)
    g = b - d
    A = [(1 - lambda) * (1 - d)+b (1 - d) * alpha+b
         (1 - d)*lambda (1 - d)*(1 - alpha)]
    A_hat = A ./ (1 + g)
    x_0 = ones(size(A_hat, 1)) / size(A_hat, 1)
    sol = fixedpoint(x -> A_hat * x, x_0)
    converged(sol) || error("Failed to converge in $(sol.iterations) iter")
    x_bar =sol.zero
    return (; lambda, alpha, b, d, A, A_hat, x_bar)
end
```

Computing Steady State Quantities with Possibly Unbalanced Budget

```
function compute_optimal_quantities(c_pretax, tau; p, sigma, gamma, beta, alpha, w_pretax, b, d)
    c = c_pretax - tau
    w = w_pretax .- tau
    mcm = mccall_model(; alpha, beta, gamma, sigma, p, c, w)
    (; V, U, w_bar) = solve_mccall_model(mcm)
    accept_wage = w .> w_bar # indices of accepted wages
    prop_accept = dot(p, accept_wage) # proportion of accepted wages
    lambda = gamma * prop_accept
    lm = lake_model(; lambda, alpha, b, d)
    u_bar, e_bar = lm.x_bar
    V_wealth = (dot(p, V .* accept_wage)) / dot(p, accept_wage)
    welfare = e_bar .* V_wealth + u_bar .* U
    return (;w_bar, lambda, V, U, u_bar, e_bar, welfare)
end
```

Balancing the Budget

- Fixing c, modify τ until $\tau - \bar{u}c \approx 0$

```julia
function find_balanced_budget_tax(c_pretax; p, sigma, gamma, beta, alpha, w_pretax, b, d)
    function steady_state_budget(tau)
        (;u_bar, e_bar) = compute_optimal_quantities(c_pretax, tau; p, sigma, gamma, beta,
                                                     alpha, w_pretax, b, d)
        return tau - u_bar * c_pretax
    end
    # Find root
    tau = find_zero(steady_state_budget, (0.0, 0.9 * c_pretax))
    return tau
end
```

Example Parameters

```julia
alpha = (1 - (1 - 0.013)^3)
b = 0.0124
d = 0.00822
beta = 0.98
gamma = 1.0
sigma = 2.0
# Discretized log normal
log_wage_mean = 20
wage_grid_size = 200
w_pretax = range(1e-3, 170,
                 length = wage_grid_size + 1)
wage_dist = LogNormal(log(log_wage_mean), 1)
p = pdf.(wage_dist, w_pretax)
p = p ./ sum(p)
plot(w_pretax, p; xlabel = "Pretax Wage",
     label = "PMF", size = (600, 400))
```

Solving for various c

```
function calculate_equilibriums(c_pretax; p, sigma, gamma, beta, alpha, w_pretax, b, d)
    tau_vec = similar(c_pretax)
    u_vec = similar(c_pretax)
    e_vec = similar(c_pretax)
    welfare_vec = similar(c_pretax)
    for (i, c_pre) in enumerate(c_pretax)
        tau = find_balanced_budget_tax(c_pre; p, sigma, gamma, beta,alpha, w_pretax, b, d)
        (;u_bar, e_bar, welfare) = compute_optimal_quantities(c_pre, tau; p, sigma, gamma, beta,alpha,
                                                              w_pretax,b, d)
        tau_vec[i] = tau
        u_vec[i] = u_bar
        e_vec[i] = e_bar
        welfare_vec[i] = welfare
    end
    return tau_vec, u_vec, e_vec, welfare_vec
end
```

Results with Various c

```julia
# levels of unemployment insurance we wish to study
c_pretax = range(5, 140, length = 60)
tau_vec, u_vec, e_vec, welfare_vec = calculate_equilibriums(c_pretax; p, sigma, gamma, beta,alpha,
                                                            w_pretax, b, d)

# plots
plt_unemp = plot(title = "Unemployment", c_pretax, u_vec, color = :blue, xlabel = "c", label = "")
plt_tax = plot(title = "Tax", c_pretax, tau_vec, color = :blue, xlabel = "c", label = "")
plt_emp = plot(title = "Employment", c_pretax, e_vec, color = :blue, xlabel = "c", label = "")
plt_welf = plot(title = "Welfare", c_pretax, welfare_vec, color = :blue, xlabel = "c", label = "")

plot(plt_unemp, plt_emp, plt_tax, plt_welf, layout = (2, 2))
```

Results with Various c