Tópicos en Macroeconomía Internacional con Aplicaciones Cuantitativas

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IMF

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Importa la demanda agregada?

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- Sí

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- Rigideces de precio transmiten gasto a cantidades
- Receta sencilla

  Rigideces de salario *nominal*

  \+ Tipo de cambio *nominal* fijo

  = Rigidez real

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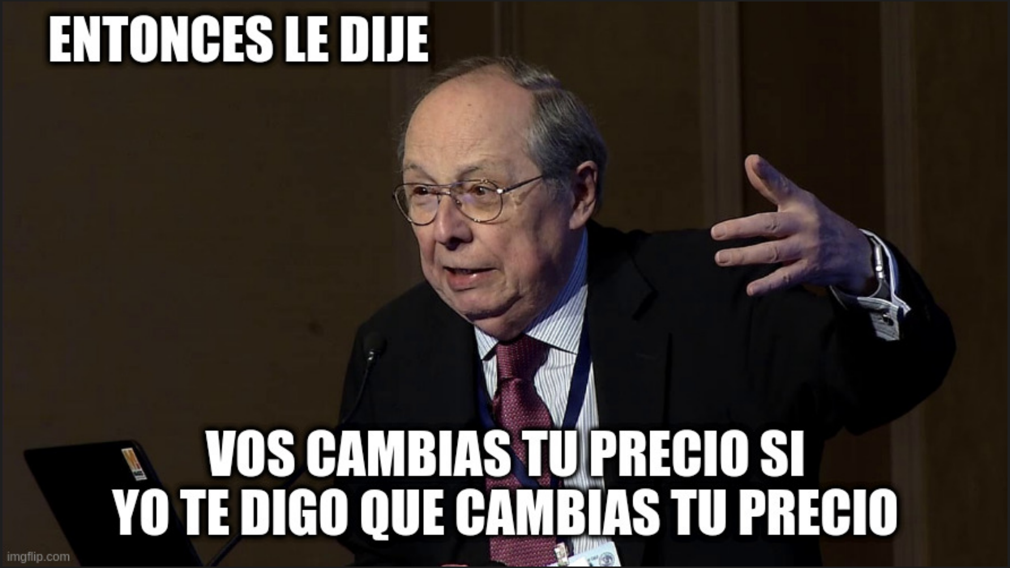
Schmitt-Grohé, S. and M. Uribe (2016): "Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment," *Journal of Political Economy*, 124, 1466–1514

Modern New Keynesian Theory



Curvas de Phillips

- Rigidez a la Calvo/Rotemberg

$$\pi_t = \kappa y_t + \beta \mathbb{E}\left[\pi_{t+1}\right]$$

Versión SOE: Galí y Monacelli (2005, Rev Econ Studies)

- Otra rigidez:
  - Dos sectores: transable y no transable
  - Tipo de cambio fijo: p_T exógeno medido en 'pesos'
  - Salario fijo en 'pesos' = Salario fijo medido en transables

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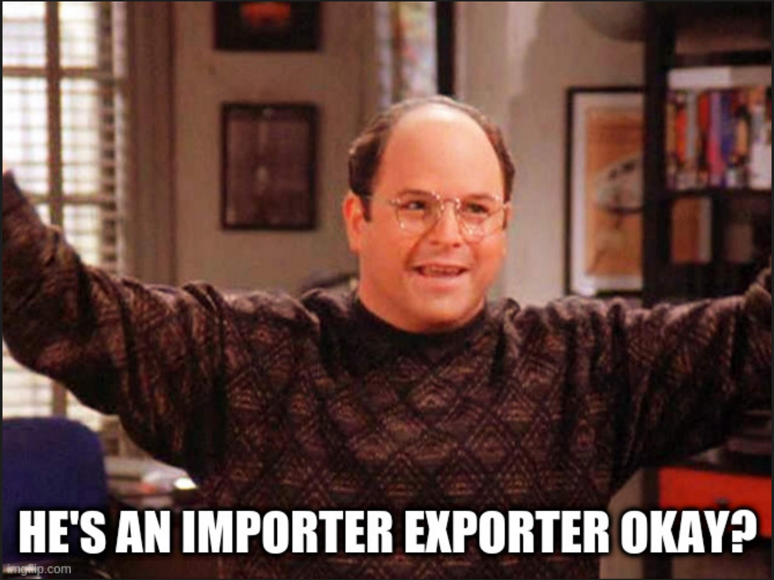
Un solo bien transable?



Un modelo con salarios fijos

- Restricción agregada: $w_t \geq f(w_{t-1})$
  - Schmitt-Grohé y Uribe: $f(x) = \gamma x$, con $\gamma \leq 1$
  - Todavía más fácil: $f(x) = \bar{w}$

- Agentes
  - Consumen N y T, oferta de trabajo inelástica

$$u(c) = \left[\varpi_N c_N^{-\eta} + \varpi_T c_T^{-\eta}\right]^{-\frac{1}{\eta}}$$

  - Pueden ahorrar libre de riesgo en transables

$$p_N c_N + c_T + \frac{a'}{1+r} = p_N y_N + y_T + a$$

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Equilibrio con salarios fijos

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$$\max \left[\varpi_N c_N^{-\eta} + \varpi_T c_T^{-\eta}\right]^{-\frac{1}{\eta}} \quad \text{sujeto a } p_N c_N + c_T = y$$

$$\frac{1}{\eta}[\text{choclo}]^{-\frac{1}{\eta}-1}\eta\varpi_i c_i^{-\eta-1} = \lambda p_i \implies p_N = \frac{\varpi_N}{\varpi_T}\left(\frac{c_T}{c_N}\right)^{1+\eta}$$

- Equilibrio: $c_N = h_N^{\alpha}$
- Firmas

$$\begin{cases} y_N & = h_N^{\alpha} \\ y_T & = z h_T^{\alpha} \end{cases} \longrightarrow \begin{cases} \alpha p_N h_N^{\alpha-1} & = w \\ \alpha z h_T^{\alpha-1} & = w \end{cases} \longrightarrow \begin{cases} h_N & = \left(\frac{\alpha}{w}\frac{\varpi_N}{\varpi_T}\right)^{\frac{1}{1+\alpha\eta}} c_T^{1+\eta} \\ h_T & = \left(\frac{z\alpha}{w}\right)^{\frac{1}{1-\alpha}} \end{cases}$$

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$$h \leq \left(\frac{z\alpha}{\bar{w}}\right)^{\frac{1}{1-\alpha}} + \left(\frac{\alpha}{\bar{w}}\frac{\varpi_N}{\varpi_T}\right)^{\frac{1}{1+\alpha\eta}} c_T^{1+\eta} = \left(\frac{z\alpha}{\bar{w}}\right)^{\frac{1}{1-\alpha}} + \mathcal{H}(\bar{w}, c_T)$$

Equilibrio

- Agentes

$$v(a,A,z) = \max_{a'} u(c) + \beta \mathbb{E}\left[v(a',A',z')\right]$$

$$\text{sujeto a } \; p_C(A,z)c + \frac{a'}{1+r} = y(A,z) + a$$

- En equilibrio, $a = A$, $p_N = \frac{\varpi_N}{\varpi_T}\left(\frac{c_T}{c_N}\right)^{1+\eta}$, y

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- Estrategia: dado p_C, encontrar v, c, a', iterar

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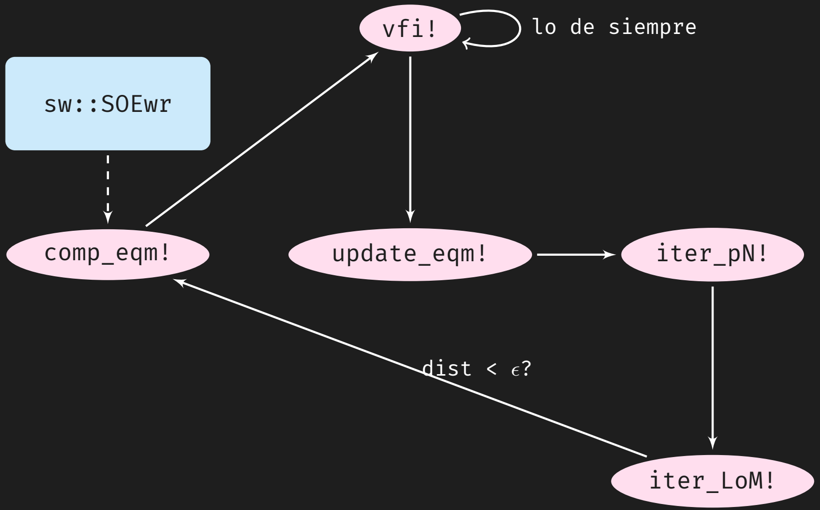
Pseudo-código



Códigos

Constructor

```julia
mutable struct SOEwr <: SOE
  β::Float64
  γ::Float64
  r::Float64
  ϖN::Float64
  ϖT::Float64
  η::Float64
  α::Float64
  wbar::Float64

  agrid::Vector{Float64}
  zgrid::Vector{Float64}
  Pz::Matrix{Float64}

  v::Dict{Symbol, Array{Float64, 3}}

  pN::Array{Float64, 2}
  w::Array{Float64, 2}
  Ap::Array{Float64, 2}
  Y::Array{Float64, 2}
end
```

- Parámetros, como siempre
  - ... pero podríamos ponerlos en un `Dict`, no?
- Grillas para a, A, z, probabilidades para z
  - ... pero podríamos ponerlas en un `Dict`, no?
- El `Dict` para las funciones de valor, ahorro, consumo
- Variables endógenas agregadas
  - ... pero podríamos ponerlas en un `Dict`, no?

Constructor

```julia
function SOEwr(; β = 0.96, γ = 2, r = 1.02, ϖN = 0.55, η = 1/0.83-1, α = 0.67, wbar = 0.7,
    ρz = 0.945, σz = 0.025, Na = 40, Nz = 21, amin = -0.5, amax = 10)

  ϖT = 1 - ϖN

  agrid = range(amin, amax, length = Na)
  zchain = tauchen(Nz, ρz, σz, 0, 3)
  zgrid, Pz = exp.(zchain.state_values), zchain.p

  v = Dict(key => ones(Na, Na, Nz) for key in [:v, :c, :a])

  pN, w = ones(Na, Nz), ones(Na, Nz)
  Ap = [av for av in agrid, zv in zgrid]
  Y  = [exp(zv) for av in agrid, zv in zgrid]

  return SOEwr(β, γ, r, ϖN, ϖT, η, α, wbar, agrid, zgrid, Pz, v, pN, w, Ap, Y)
end
```

Funciones básicas con trucos

```
function utility(c, sw::SOE)
  γ = sw.γ
  cmin = 1e-3
  if c < cmin
    return utility(cmin,sw) + (c-cmin) * (cmin)^-γ
  else
    γ == 1 && return log(c)
    return c^(1-γ)/(1-γ)
  end
end

function price_index(pN, pT, sw::SOE)
  ϖN, ϖT, η = sw.ϖN, sw.ϖT, sw.η
  return ( ϖN^(1/(1+η))*pN^(η/(1+η)) + ϖT^(1/(1+η))*pT^(η/(1+η)) )^((1+η)/η)
end
price_index(pN, sw::SOE) = price_index(pN, 1, sw)
```

Evaluar la v dado a'

```julia
function expect_v(apv, Apv, pz, itp_v, sw::SOE)
  Ev = 0.0
  for (jzp, zpv) in enumerate(sw.zgrid)
    prob = pz[jzp]
    Ev += prob * itp_v[:v](apv, Apv, zpv)
  end
  return Ev
end

budget_constraint(apv, av, yv, r, pCv) = ( yv + av - apv/(1+r) ) / pCv

function eval_value(apv, av, yv, Apv, pz, pCv, itp_v, sw::SOE)
  c = budget_constraint(apv, av, yv, sw.r, pCv)
  u = utility(c, sw)
  Ev = expect_v(apv, Apv, pz, itp_v, sw)
  return u + sw.β * Ev
end
```

Elegir a'

```julia
function optim_value(av, yv, Apv, pz, pCv, itp_v, sw::SOE)

  obj_f(x) = -eval_value(x, av, yv, Apv, pz, pCv, itp_v, sw)
  amin, amax = extrema(sw.agrid)

  res = Optim.optimize(obj_f, amin, amax)

  apv = res.minimizer
  v  = -res.minimum

  c = budget_constraint(apv, av, yv, sw.r, pCv)

  return v, apv, c
end
```

Actualizar la v

```
function vf_iter!(new_v, sw::SOE)
  itp_v = Dict(key => interpolate((sw.agrid, sw.agrid, sw.zgrid), sw.v[key],
     Gridded(Linear())) for key in keys(sw.v))

  for (jA, Av) in enumerate(sw.agrid), (jz, zv) in enumerate(sw.zgrid)
    pNv = sw.pN[jA, jz]
    pCv = price_index(pNv, sw)

    Apv, yv, pz = sw.Ap[jA, jz], sw.Y[jA, jz], sw.Pz[jz, :]
    for (ja, av) in enumerate(sw.agrid)
      v, apv, c = optim_value(av, yv, Apv, pz, pCv, itp_v, sw)

      new_v[:v][ja, jA, jz] = v
      new_v[:a][ja, jA, jz] = apv
      new_v[:c][ja, jA, jz] = c
    end
  end
end
```

Value function iteration

```julia
function update_v!(new_v, sw::SOE; upd_η = 1)
  for key in keys(new_v)
    sw.v[key] = sw.v[key] + upd_η * (new_v[key] - sw.v[key])
  end
end

function vfi!(sw::SOE; tol=1e-4, maxiter = 2000)
  iter, dist = 0, 1+tol
  new_v = Dict(key => similar(val) for (key, val) in sw.v)
  while iter < maxiter && dist > tol
    iter += 1
    vf_iter!(new_v, sw)
    dist = maximum([ norm(new_v[key] - sw.v[key]) / (1+norm(sw.v[key])) for key in keys(sw.v) ])
    norm_v = 1+maximum([norm(sw.v[key]) for key in keys(sw.v)])
    print("Iteration $iter: dist = $(@sprintf("%0.3g", dist)) at |v| =
      $(@sprintf("%0.3g", norm_v))\n")
    update_v!(new_v, sw)
  end
  return dist
end
```

Respirar

- Nuestro `vfi!` de siempre encuentra el consumo y el ahorro de un agente dados
    - La ley de movimiento de A
    - El precio relativo p_N, aka el tipo de cambio real
    - Los niveles de producto y_N, y_T

- Nos falta encontrar esas cosas
    - Agregar las decisiones de los agentes
    - Encontrar los precios que igualen demanda y oferta (de qué?)

- Big K, little k
    - El agente representativo piensa que a y A son cosas distintas
    - El consumo agregado en (A, z) es $c(A, A, z)$

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Agregados (de atrás para adelante)

```
function comp_eqm!(sw::SOE; tol = 1e-3, maxiter = 2000)
  iter, dist = 0, 1+tol
  new_p = similar(sw.pN)
  tol_vfi = 1e-2
  while dist > tol && iter < maxiter
    iter += 1
    print("Outer Iteration $iter (tol = $(@sprintf("%0.3g",tol_vfi)))\n")
    dist_v = vfi!(sw, tol = tol_vfi)

    norm_p = norm(sw.pN)
    dist_p = update_eqm!(new_p, sw) / (1+norm_p)

    dist = max(dist_p, 10*dist_v)

    print("After $iter iterations, dist = $(@sprintf("%0.3g",dist_p)) at |pN| =
      $(@sprintf("%0.3g", norm_p))\n\n")

    tol_vfi = max(1e-4, tol_vfi * 0.9)
  end
end
```

Iteración de la ley de movimiento

```julia
function iter_LoM!(sw::SOE; upd_η = 1)
  for jA in eachindex(sw.agrid), jz in eachindex(sw.zgrid)
    sw.Ap[jA, jz] = (1-upd_η) * sw.Ap[jA, jz] + upd_η * sw.v[:a][jA, jA, jz]
  end
end

function update_eqm!(new_p, sw::SOE; upd_η = 1)
  iter_pN!(new_p, sw)
  iter_LoM!(sw)
  dist = norm(new_p - sw.pN)
  sw.pN = sw.pN + upd_η * (new_p - sw.pN)
  return dist
end
```

Iteración sobre los precios

```julia
function iter_pN!(new_p, sw::SOE; upd_η = 1)
  minp = 0.9 * minimum(sw.pN)
  maxp = 1.1 * maximum(sw.pN)
  for (jA, Av) in enumerate(sw.agrid), (jz, zv) in enumerate(sw.zgrid)
    pNg = sw.pN[jA, jz]
    pcC = sw.v[:c][jA, jA, jz] * price_index(pNg, sw)

    obj_f(x) = diff_pN(x, pcC, zv, sw).F

    res = Optim.optimize(obj_f, minp, maxp)

    p = sw.pN[jA, jz] * (1-upd_η) + res.minimizer * upd_η
    new_p[jA, jz] = p

    others = diff_pN(p, pcC, zv, sw)
    sw.Y[jA, jz] = others.y
    sw.w[jA, jz] = others.w
  end
end
```

Encontrar un precio (y un salario!)

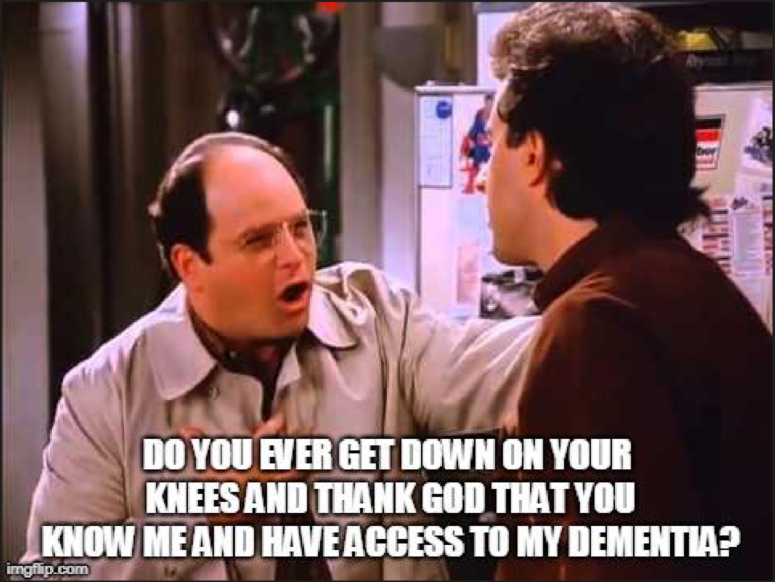
```
function diff_pN(pNv, pcC, zv, sw::SOE)
  α, ϖN, ϖT, η, wbar = sw.α, sw.ϖN, sw.ϖT, sw.η, sw.wbar

  pCv = price_index(pNv, sw)
  C = pcC / pCv

  cT = C * ϖT * pCv^η      # c_i = ϖ_i (p_i/p)^(-η) C

  hN, hT, wopt = find_w(zv, cT, wbar, sw)

  yN = hN^α
  yT = zv * hT^α

  pN_new = ϖN / ϖT * (cT/yN)^(1+η)

  output = pN_new * yN + yT

  return (F = (pN_new-pNv)^2, y = output, w = wopt)
end
```

Encontrar el salario (si hace falta)

```
function labor_demand(zv, cT, w, sw::SOE)
  α, ϖN, ϖT, η = sw.α, sw.ϖN, sw.ϖT, sw.η
  hN = (α/w * ϖN / ϖT)^(1/(1+α*η)) * cT^(1+η)
  hT = (zv*α/w)^(1/(1-α))
  return (h = hN+hT, hN = hN, hT = hT)
end

function find_w(zv, cT, wbar, sw::SOE)
  hN = labor_demand(zv, cT, wbar, sw).hN
  hT = labor_demand(zv, cT, wbar, sw).hT
  H = hN + hT
  if H < 1
    wopt = wbar
  else
    f(w) = (labor_demand(zv, cT, w, sw).h - 1)^2
    res = Optim.optimize(f, wbar, 2*wbar)
    wopt = res.minimizer
    hN = labor_demand(zv, cT, wopt, sw).hN
    hT = labor_demand(zv, cT, wopt, sw).hT
  end
  return hN, hT, wopt
end
```

Graficar (finalmente)

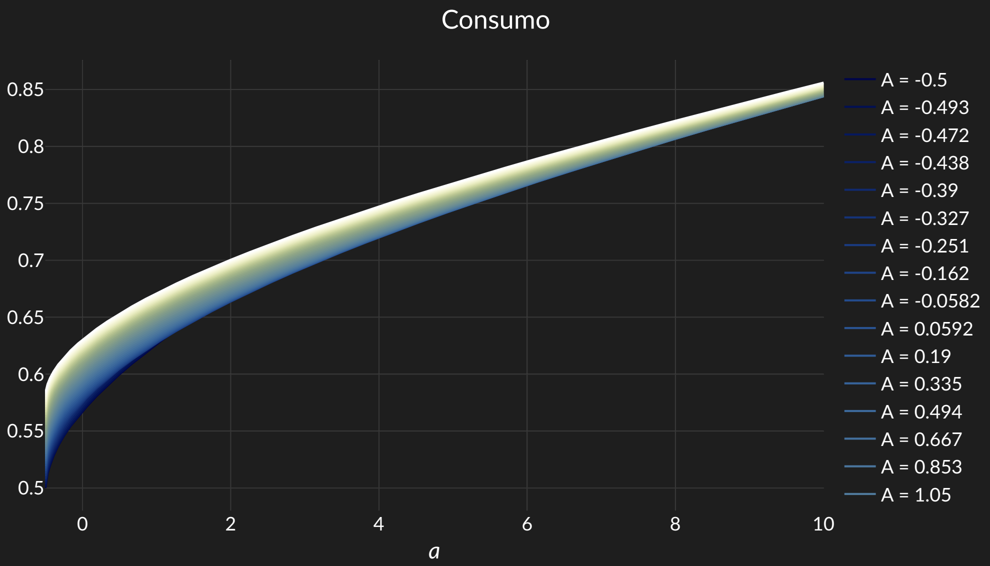
Gráficos y TOC



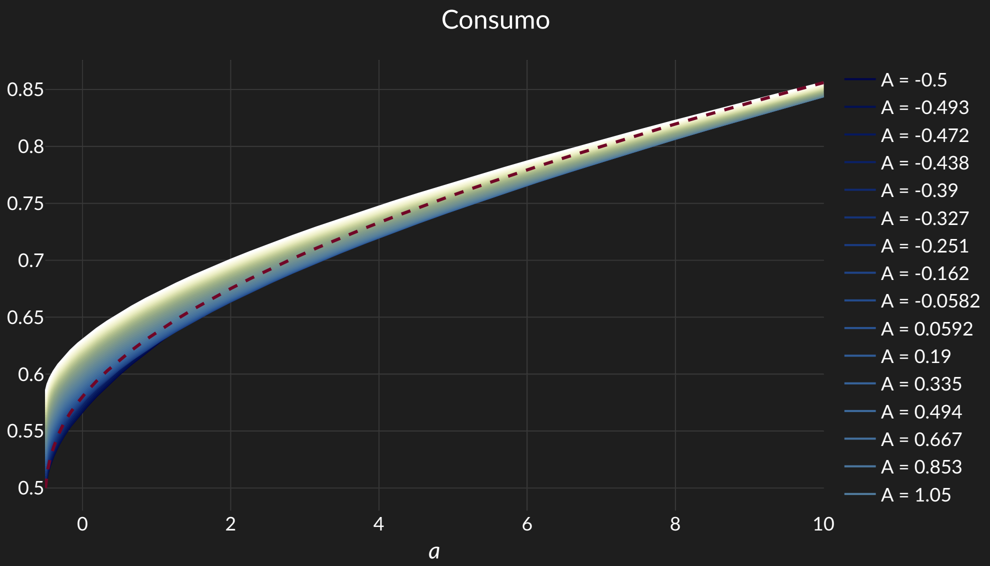
Funciones de valor/comportamiento

```julia
function plot_cons(sw::SOE; indiv=false)
  jA, jz, Na = 5, 5, length(sw.agrid)

  cons_mat = [sw.v[:c][ja, jA, jz] for ja in eachindex(sw.agrid), jA in eachindex(sw.agrid)]
  cons_agg = [sw.v[:c][ja, ja, jz] for ja in eachindex(sw.agrid)]

  colvec = [get(ColorSchemes.davos, (jA-1)/(Na-1)) for jA in eachindex(sw.agrid)]

  scats = [scatter(x=sw.agrid, y=cons_mat[:, jA], marker_color=colvec[jA], name = "A = 
     $(@sprintf("%0.3g",Av))") for (jA, Av) in enumerate(sw.agrid)]

  indiv || push!(scats, scatter(x=sw.agrid, y=cons_agg, line_dash="dash", line_width=3,
     name= "Agregado", line_color="#710627"))

  layout = Layout(title="Consumo",
    font_family = "Lato", font_size = 18, width = 1920*0.5, height=1080*0.5,
    paper_bgcolor="#1e1e1e", plot_bgcolor="#1e1e1e", font_color="white",
    xaxis = attr(zeroline = false, gridcolor="#353535", title="<i>a"),
    yaxis = attr(zeroline = false, gridcolor="#353535"),
    )
  plot(scats, layout)
end
```

Consumo


Consumo
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
2
4
6
8
10
a
A = -0.5
A = -0.493
A = -0.472
A = -0.438
A = -0.39
A = -0.327
A = -0.251
A = -0.162
A = -0.0582
A = 0.0592
A = 0.19
A = 0.335
A = 0.494
A = 0.667
A = 0.853
A = 1.05

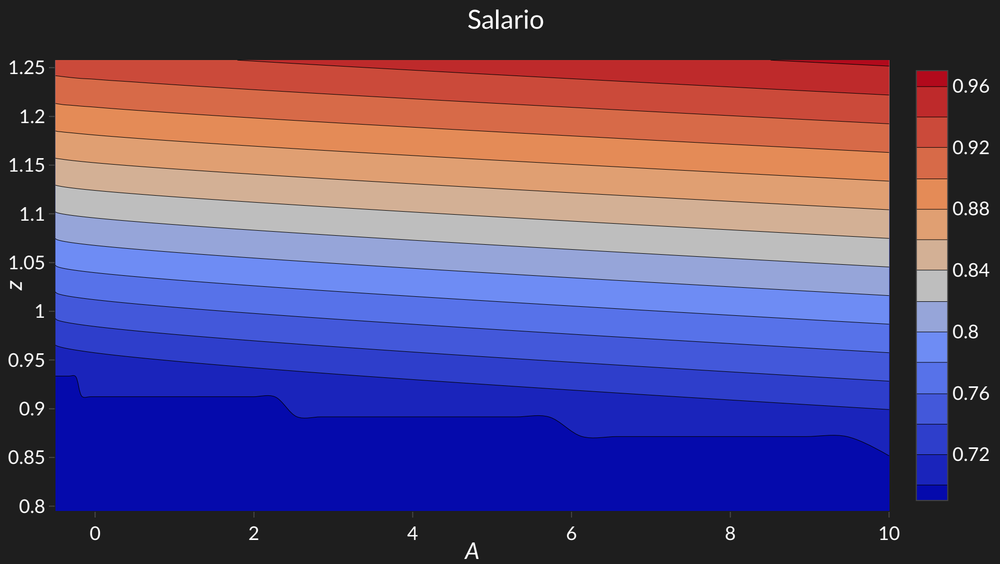
Consumo


Consumo
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
2
4
6
8
10
a
A = -0.5
A = -0.493
A = -0.472
A = -0.438
A = -0.39
A = -0.327
A = -0.251
A = -0.162
A = -0.0582
A = 0.0592
A = 0.19
A = 0.335
A = 0.494
A = 0.667
A = 0.853
A = 1.05

Salarios de equilibrio

```
function plot_wage(sw::SOE)

  con = contour(x=sw.agrid, y=sw.zgrid,
    z = sw.w)

  layout = Layout(title="Salario",
    font_family = "Lato", font_size = 18, width = 1920*0.5, height=1080*0.5,
    paper_bgcolor="#1e1e1e", plot_bgcolor="#1e1e1e", font_color="white",
    xaxis = attr(zeroline = false, gridcolor="#353535", title="<i>A"),
    yaxis = attr(zeroline = false, gridcolor="#353535", title="<i>z"),
    )

  plot(con, layout)
end
```

Salarios



Salario
1.25
1.2
1.15
1.1
1.05
z
1
0.95
0.9
0.85
0.8
0
2
4
6
8
10
A
0.96
0.92
0.88
0.84
0.8
0.76
0.72

Cierre

Conclusión

Para seguir

- Los invito a
  - Resolver con y sin rigidez de salarios
  - Análisis "empírico" con los datos del simulador
    - `DataFrames`!
  - Resolver el problema del planner en esta economía. Ayudas:
    1. El planner entiende que $a = A$ (un solo estado!)
    2. El planner entiende que la restricción es $h \leq \mathcal{H}(c_T, \bar{w})$
  - Combinar Schmitt-Grohé y Uribe (planner) con Arellano.
    - Tesis de doctorado de Anzoategui (2020)
    - Bianchi, Ottonello, y Presno (2020)
- QuantEcon