

Advanced Macro

Assignment 1

Hans Martinez

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Competitive equilibrium for this economy

Definition: A sequential markets equilibrium is a sequence of prices $\{w_t, r_t\}_{t=0}^{\infty}$, allocations for the representative agent $\{c_t, k_{t+1}^s\}_{t=0}^{\infty}$ and allocations for the representative firm $\{l_t^d, k_t^d\}_{t=0}^{\infty}$ such that:

1. Given k_0 and $\{w_t, r_t\}_{t=0}^{\infty}$, allocations for the representative agent $\{c_t, k_{t+1}^s\}_{t=0}^{\infty}$ solves the agent's maximization problem:

$$\begin{aligned} \max_{\{c_t, k_{t+1}^s\}_{t=0}^{\infty}} \quad & \sum_{t=0}^{\infty} \beta^t U(c_t) \\ \text{s.t.} \quad & c_t + k_{t+1}^s = r_t k_t^s + w_t \\ & c_t, k_{t+1}^s \geq 0 \quad \forall t = 0, 1, \dots \\ & k_0 \text{ given} \end{aligned}$$

2. For each $t \geq 0$, given (w_t, r_t) the firm allocation (l_t^d, k_t^d) solves the firms' maximization problem:

$$\max_{k_t, l_t \geq 0} F(k_t^d, l_t^d) - r_t k_t^d - w_t l_t^d$$

3. Markets clear, for all $t \geq 0$

$$\begin{aligned} l_t^d &= 1 \\ k_t^s &= k_t^d \\ c_t + k_{t+1}^s &= F(k_t^d, l_t^d) \end{aligned}$$

Social Planner's Problem

$$\begin{aligned} w^T(\bar{k}_0) &= \max_{\{k_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(f(k_t) - k_{t+1}) \\ \text{s.t.} \quad & 0 \leq k_{t+1} \leq f(k_t) \\ & k_0 = \bar{k}_0 > 0 \text{ given} \end{aligned}$$

Where $f(k_t) = F(k_t, 1)$.

Show that the equilibrium allocation of consumption, capital, and labor coincides with those of the planner's.

- CE FOC

$$\begin{aligned} -u'(c_t) + \beta u'(c_{t+1})r_t &= 0 \\ -u'(c_t) + \beta u'(c_{t+1})f'(k_{t+1}) &= 0 \text{ from firm's static optimization problem} \\ -u'(f(k_t) - k_{t+1}) + \beta u'(f(k_{t+1}) - k_{t+2})f'(k_{t+1}) &= 0 \text{ from market clearing} \end{aligned}$$

- SPP FOC

$$-u'(f(k_t) - k_{t+1}) + \beta u'(f(k_{t+1}) - k_{t+2})f'(k_{t+1}) = 0$$

Therefore, as long as the transversality condition holds, both solutions are equivalent.

$$\lim_{t \rightarrow \infty} \beta^t u'(f(k_t) - k_{t+1})f'(k_{t+1})k_t = 0$$

Planner's dynamic problem and the Bellman equation

$$v(k') = \max_{0 \leq k' \leq f(k)} \{U(f(k) - k') + \beta v(k')\}$$

Solve planner's problem.

Assume $u(c) = \log(c)$, $f(k, l) = zk^\alpha l^{1-\alpha}$.

Using the guess and verify method, let $v(k) = A + B \ln(k)$.

$$\text{FOC: } k' = \frac{B\beta z k^\alpha}{1+B\beta}$$

Plugging into original problem and solving for coefficients, we get:

$$\begin{aligned} A &= \frac{1}{1-\beta} \left[\frac{\alpha\beta}{1-\alpha\beta} \ln(\alpha\beta) + \ln(1-\alpha\beta) \right] \\ B &= \frac{\alpha}{1-\alpha\beta} \end{aligned}$$

Then, our value function and our policy function would be:

$$\begin{aligned} v^* &= A + B \ln(k) \text{ with A and B as defined above} \\ g^*(k) &= \alpha\beta z k^\alpha \end{aligned}$$

Obtain {c,k,r,w,y} at the steady state

$$\begin{aligned} k^* &= (\alpha\beta z)^{\frac{1}{1-\alpha}} \\ r^* &= \beta^{-1} \\ w^* &= z(1-\alpha)(\alpha\beta z)^{\frac{\alpha}{1-\alpha}} \\ y^* &= z(\alpha\beta z)^{\frac{\alpha}{1-\alpha}} \\ c^* &= z(\alpha\beta z)^{\frac{\alpha}{1-\alpha}} - (\alpha\beta z)^{\frac{1}{1-\alpha}} \end{aligned}$$

Obtain the path of $\{c, k, r, w, y\}$ in the following cases

Let $\alpha = \frac{1}{3}, z = 1$. Use planner's solution, starting from steady state:

A. Capital decreases to 80% of its steady state.

```
# Julia code
a = 1/3
b = 0.6
k_star = (a*b)^(1/(1-a))

#Defining vars
a = 1/3
b = 0.6
k_star = (a*b)^(1/(1-a))
r = 1/b

# Initializing array for loop
m, n = 100, 2
K = fill(0.0, (m, n))

#defining policy fn
g = x -> a*b*(x^a)

# loop for capital
k = 0.8*k_star
for i in 1:m
    K[i, 1] = k
    K[i, 2] = g(K[i, 1])
    global k = K[i, 2]
end

# defining fn's for the rest of the variables
w = x -> (1-a)x^a
y = x -> x^a
c = (p, q) -> y(p)-q
r = x -> a*(x^(a-1))
int = r.(K[1:100, 2])
wage = w.(K[1:100, 1])
output = y.(K[1:100, 1])
cons = c.(K[1:100, 1], K[1:100, 2])

# importing packages for plotting
import Pkg; Pkg.add("Plots")
using Plots
gr()

# plotting capital
plot(1:10, fill(k_star, 10), label="capital SS")
plot!(1:10, K[1:10, 1], label="capital path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Capital")
savefig("/Users/Hans/Desktop/capital.pdf")
```

```

# plotting output

plot(1:10,fill(y(k_star),10), label="output SS")
plot!(1:10,output[1:10], label="output path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Output")
savefig("/Users/Hans/Desktop/output.pdf")

# plotting consumption

plot(1:10,fill(c(k_star,k_star),10), label="consumption SS")
plot!(1:10,cons[1:10], label="consumption path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Consumption")
savefig("/Users/Hans/Desktop/consumption.pdf")

# plotting wage

plot(1:10,fill(w(k_star),10), label="wage SS")
plot!(1:10,wage[1:10], label="wage path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Wage")
savefig("/Users/Hans/Desktop/wage.pdf")

# plotting capital rental rate

plot(1:10,fill(r(k_star),10), label="capital rental rate SS")
plot!(1:10,int[1:10], label="rate path", linestyle = :dot, legend = :topright)
xlabel!("t")
title!("Capital rental rate")
savefig("/Users/Hans/Desktop/capitalr.pdf")

```

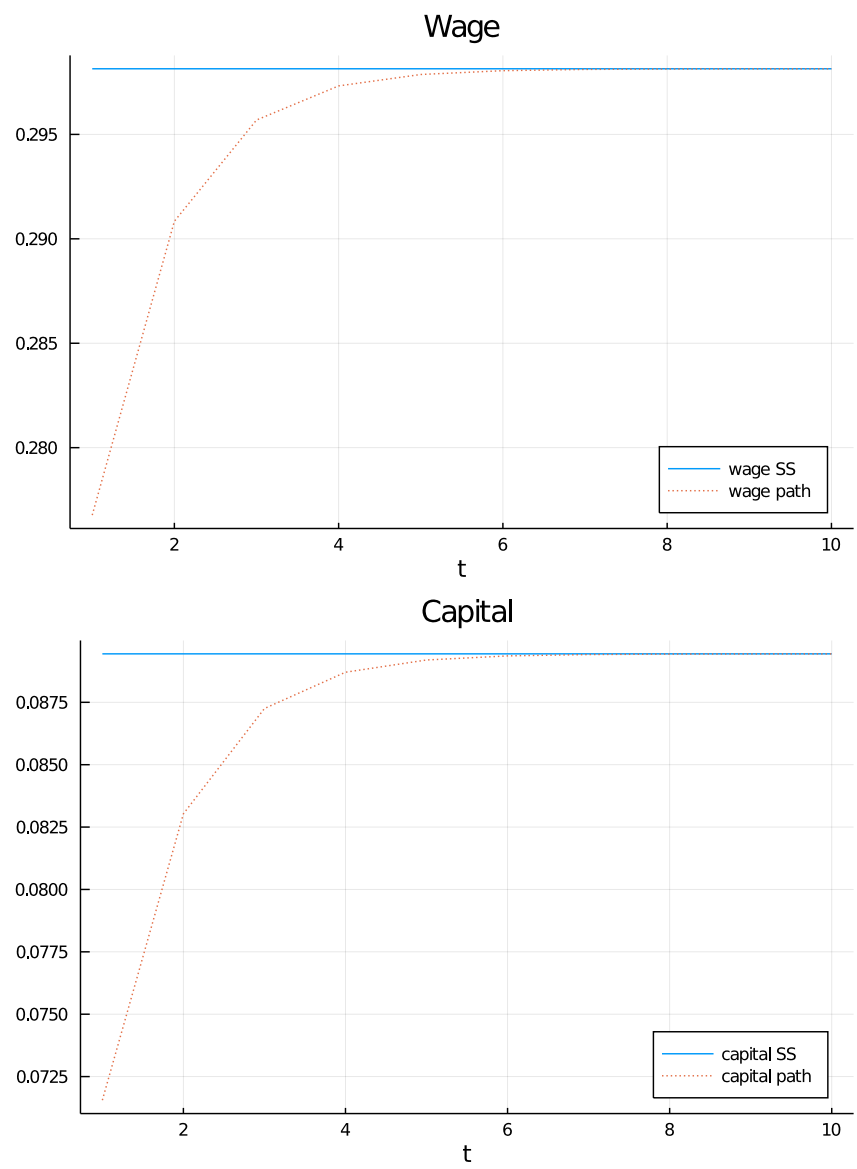


Figure 1: Wage and capital

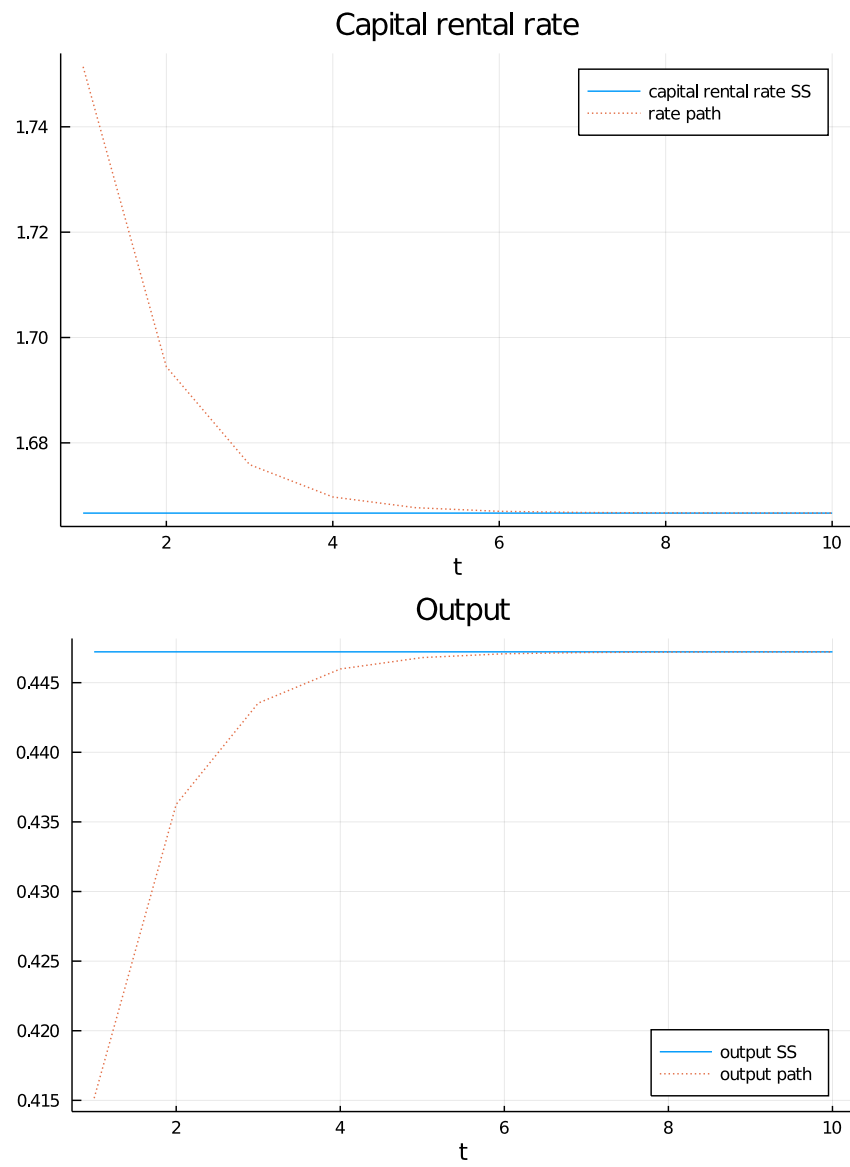


Figure 2: Capital rate and output

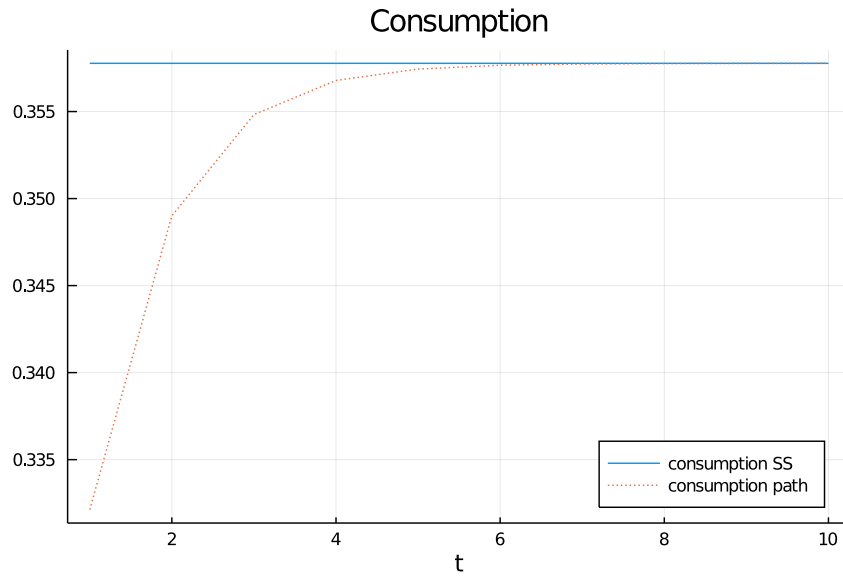


Figure 3: Consumption

B. Productivity increases permanently by 5%

```
# Julia code
# Increase in productivity permanently by 5%

#defining policy fn and ss capital with productivity increases
k_starp = (a*b*1.5)^(1/(1-a))
g1 = x -> a*b*1.05*(x^a)

# Initializing array for loop
K1 = fill(0.0, (m, n))

# loop for capital
k1 = k_starp
for i in 1:m
    K1[i, 1] = k1
    K1[i, 2] = g(K[i,1])
    global k1 = K[i, 2]
end

# defining fn's for the rest of the variables
w1 = x -> (1-a)*(x^a) #does not change
y1 = x -> 1.5*(x^a)
c1 = (p,q) -> y(p)-q #does not change
r1 = x -> a*(1.5*x^(a-1))
int_p = r1.(K1[1:100,2])
wage_p = w1.(K1[1:100,1])
output_p = y1.(K1[1:100,1])
cons_p = c1.(K1[1:100,1],K1[1:100,2])

# plotting capital
plot(1:10,fill(k_star,10), label="capital SS")
```

```

plot!(1:10,K1[1:10,1], label="capital path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Capital (productivity increase)")
savefig("/Users/Hans/Desktop/capitalp.pdf")

# plotting output

plot(1:10,fill(y1(k_star),10), label="output SS")
plot!(1:10,output_p[1:10], label="output path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Output (productivity increase)")
savefig("/Users/Hans/Desktop/outputp.pdf")

# plotting consumption

plot(1:10,fill(c1(k_star,k_star),10), label="consumption SS")
plot!(1:10,cons_p[1:10], label="consumption path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Consumption (productivity increase)")
savefig("/Users/Hans/Desktop/consumptionp.pdf")

# plotting wage

plot(1:10,fill(w1(k_star),10), label="wage SS")
plot!(1:10,wage_p[1:10], label="wage path", linestyle = :dot, legend = :bottomright)
xlabel!("t")
title!("Wage (productivity increase)")
savefig("/Users/Hans/Desktop/wagep.pdf")

# plotting capital rental rate

plot(1:10,fill(r1(k_star),10), label="capital rental rate SS")
plot!(1:10,int_p[1:10], label="rate path", linestyle = :dot, legend = :topright)
xlabel!("t")
title!("Capital rental rate (productivity increase)")
savefig("/Users/Hans/Desktop/capitalrp.pdf")

```

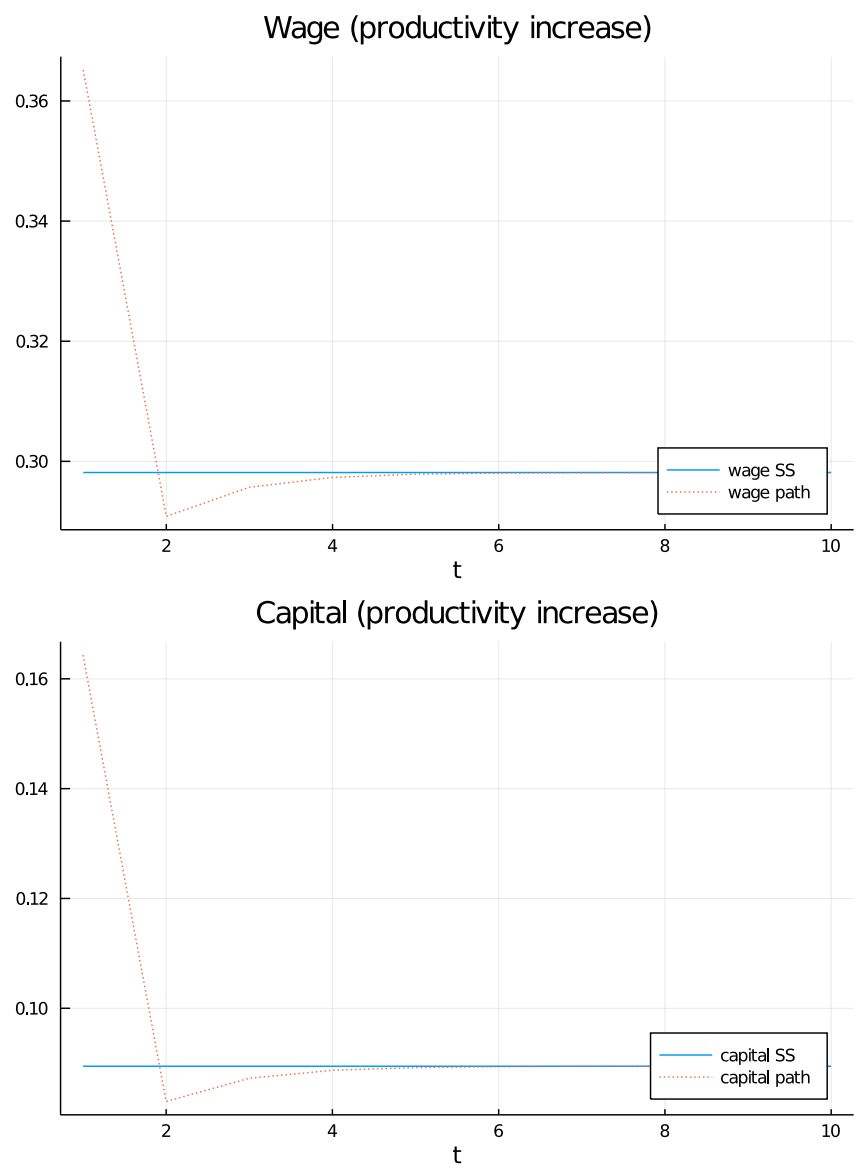



Figure 4: Wage and capital (productivity increase)

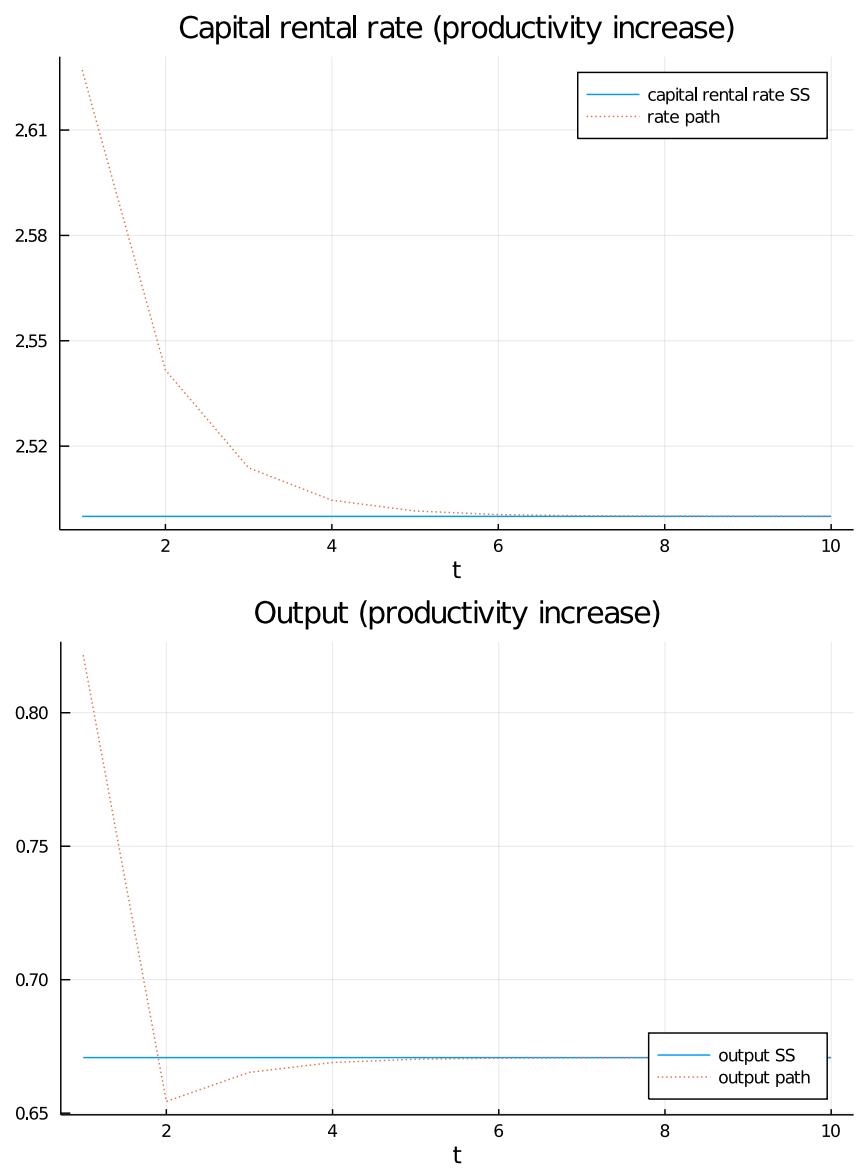


Figure 5: Capital rate and output (productivity increase)

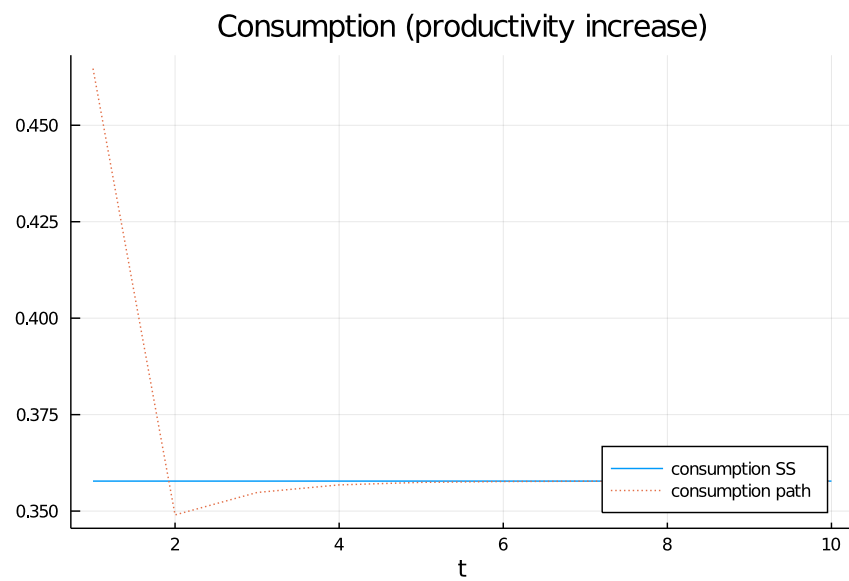


Figure 6: Consumption (productivity increase)