Homework 2 *Quantitative Macroeconomics*

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Question 1

Consider the following closed optimal growth economy populated by a large number of identical infinitely lived households that maximize:

$$E_0\{\sum_{t=0}^{\infty}\beta^t u(c_t)\} \tag{1}$$

over consumption and leisure $u(c_t) = ln(c_t)$), subject to:

$$c_t + i_t = y_t \tag{2}$$

$$y_t = (k_t)^{1-\theta}(zh_t)^{\theta} \tag{3}$$

$$i_t = k_{t+1} - (1-\delta)k_t \tag{4}$$

Set labor share (θ)=0.67.Also, to start with, set h_t=0.31 for all t.Population does not grow.

a)Compute the steady state.Choose z to match an annual capital-output ratio of 4 and an investment-output ratio of 0.25

Combining (2),(3) and (4) in a single constraint, the lagrangian corresponding to previous problem can be written as:

$$\mathcal{L} = \sum_{t=0}^{\infty}\beta^t u(c_t) - \sum_{t=0}^{\infty}\lambda_t[c_t + k_{t+1} - (1-\delta)k_t - k_t^{1-\theta}(zht)^{\theta}]$$

Taking FOC, we obtain:

$$\frac{\partial\mathcal{L}}{\partial c_t} = 0 \Rightarrow \beta^t u'(c_t) = \lambda_t \tag{5}$$

$$\frac{\partial\mathcal{L}}{\partial c_{t+1}} = 0 \Rightarrow \beta^{t+1} u'(c_{t+1}) = \lambda_{t+1} \tag{6}$$

$$\frac{\partial\mathcal{L}}{\partial k_{t+1}} = 0 \Rightarrow \lambda_{t+1}[(1-\delta) + (1-\theta)(k_{t+1})^{-\theta}(zh_t)^{\theta}] = \lambda_t \tag{7}$$

Next, if we combine (5),(6),(7), we get Euler equation:

$$u'(c_t) = \beta u'(c_{t+1})[(1-\delta) + (1-\theta)(k_{t+1})^{-\theta}(zh)^{\theta}] \tag{8}$$

Where I don't sub-index h by t because for the moment we've inelastic and exogenous labor supply.At the setady state $k_t = k_{t+1} = k^*$ and $c_t = c_{t+1} = c^*$. Hence at steady state (8) can be written as:

$$1 = \beta[(1-\delta) + (1-\theta)(k^*)^{-\theta}(zh)^{\theta}] \tag{9}$$

From here we can solve for an explicit form of k^* as a function of z and δ (remember that θ and h are known parameters).

$$k^* = \left(\frac{\beta(1-\theta)(zh)^{\theta}}{1-\beta(1-\delta)}\right)^{\frac{1}{\theta}} \tag{10}$$

Now, to obtain z and the rest of relevant variables of the model, what I do is to normalize $y^* = 1$.This makes that at steady state $\frac{k^*}{y^*} = 4 \Rightarrow k^* = 4$ and by the same reasoning $\frac{i^*}{y^*} = 0.25 \Rightarrow i^* = 0.25$. Now using this values in feasibility constraint (2) at steady state I get:

$$\begin{aligned} c^* &= y^* - i^* \\ c^* &= 1 - 0.25 \Rightarrow c^* = 0.75 \end{aligned} \tag{11}$$

Similarly for (3), since we know $\theta = 0.67$ and $h = 0.31$ we've:

$$\begin{aligned} y^* &= (k^*)^{1-\theta}(zh)^{\theta} \\ z &= \left(\frac{y^*}{(k^*)^{1-\theta}(h)^{\theta}}\right)^{\frac{1}{\theta}} \Rightarrow z = 1.63 \end{aligned}$$

And from (4):

$$\begin{aligned} i^* &= k^* - k^* + \delta k^* \\ 0.25 &= \delta * 4 \Rightarrow \delta = 0.0625 \end{aligned} \tag{13}$$

Finally, using all this values in Euler equation at steady state (9) we get:

$$1 = \beta[0.9375 + 0.33 * 4^{-0.67} * (0.5053)^{0.67}] \Rightarrow \beta = 0.98 \tag{14}$$

In my Python code, you will find the solution for this steady state using this z that I found analytically, just to check the results and practice a bit with Python's no linear solver. What I obtain in Python is:
$k^* = 4.000795013134468$ $c^* = 0.7501490649364168$
$i^* = 0.25004968851203235$ $y^* = 1.0001987533115262$
$\beta = 0.9803921568991006$ $\delta = 0.06250000004777254$
So it is very similar to the one obtained analytically.

b)Double permanently the productivity parameter z and solve for the new steady state. Similarly to in case a), applying this modification, Python gives me:
$k_2^* = 8.001590026552888$ $c_2^* = 1.5002981299557547$
$i_2^* = 0.5000993766298872$ $y_2^* = 2.000397506636611$
$\beta_2 = 0.9803921568346184$ $\delta_2 = 0.06249999999629221$

Where the sub index 2 just refers to the "second steady state".
We can see how doubling the productivity parameter z, capital stock, consumption, investment (or savings), and output, are doubled at the new steady state in comparison with the original steady state.

c)Compute the transition from the first to the second steady state and report the time-path for savings, consumption, labor and output. What I did to solve for the transition is the following: Firstly, I combine (2), (3), and (4). This gives me:

$$c_t = k_t^{1-\theta}(zh)^\theta + (1-\delta)k_t - k_{t+1} \tag{15}$$

Which allows me to rewrite Euler equation in (8) as function of capital:

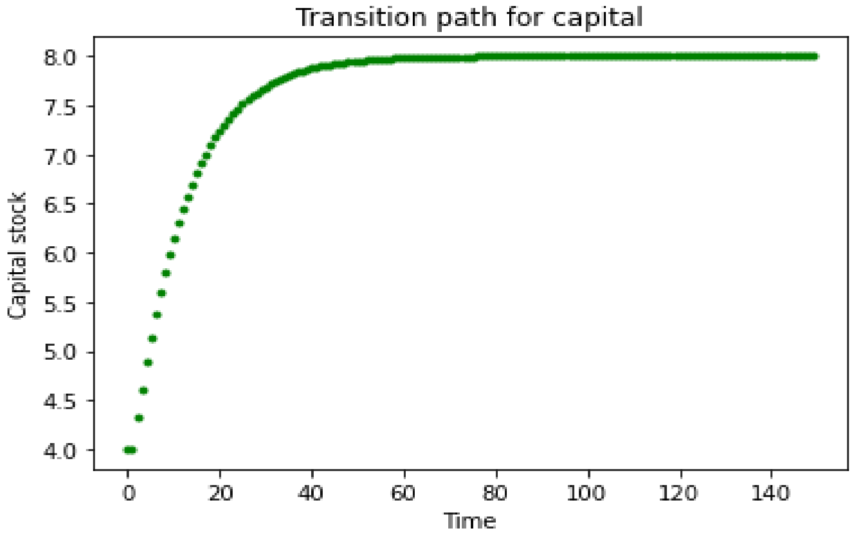
$$u'(k_t^{1-\theta}(zh)^\theta + (1-\delta)k_t - k_{t+1}) = \beta u'(k_{t+1}^{1-\theta}(zh)^\theta + (1-\delta)k_{t+1} - k_{t+2})[(1-\delta) + (1-\theta)(k_{t+1})^{-\theta}(zh)^\theta] \tag{16}$$

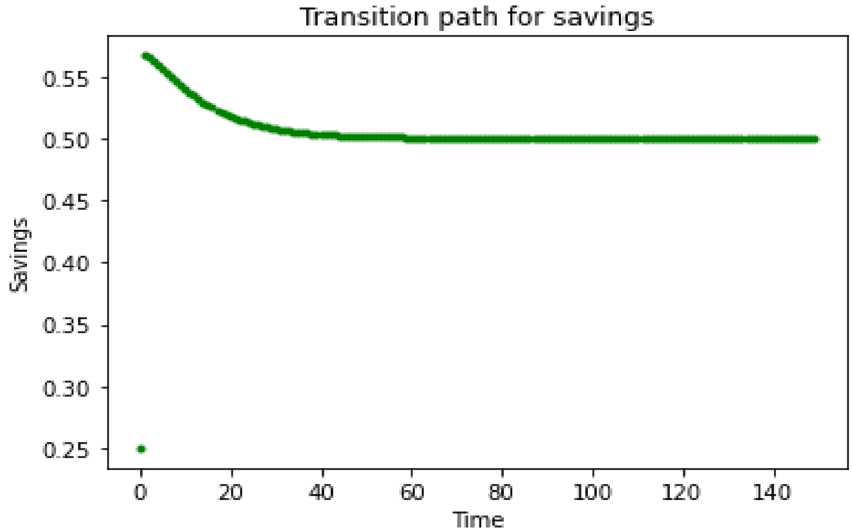
Notice that when we double permanently productivity parameter from z to $z_2 = 2z$, and the transition begins, we have that this Euler equation rewrites as:

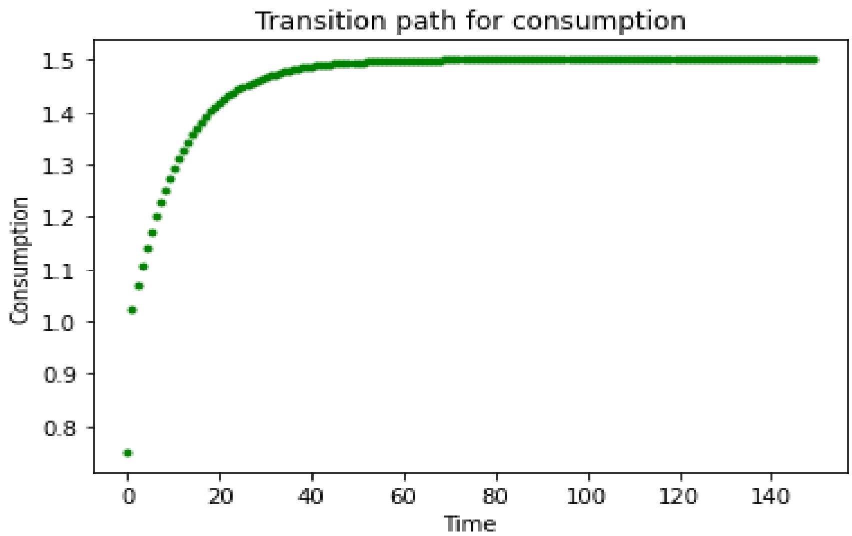
$$u'(k_t^{1-\theta}(z_2h)^\theta + (1-\delta)k_t - k_{t+1}) = \beta u'(k_{t+1}^{1-\theta}(z_2h)^\theta + (1-\delta)k_{t+1} - k_{t+2})[(1-\delta) + (1-\theta)(k_{t+1})^{-\theta}(z_2h)^\theta] \tag{17}$$

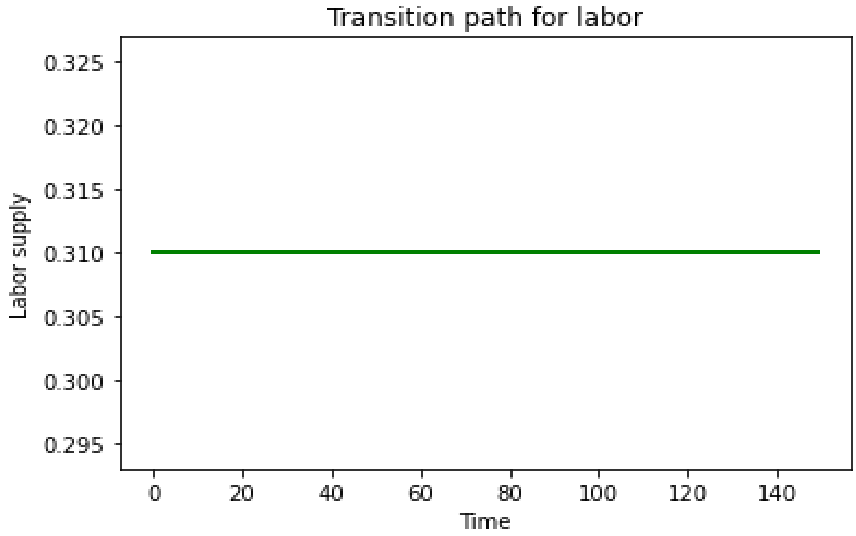
This Euler equation must hold for every period. Hence, if I begin with $k_t = k^*$, and I set up this Euler equation for a sufficiently large n periods with the condition $k_n = k_2^*$, then I have a non-linear system of n equations and n unknowns (the unknowns are a sequence of capitals). Following this procedure and using a no-linear solver, I solve for the transition. More details are defined in the Python code.

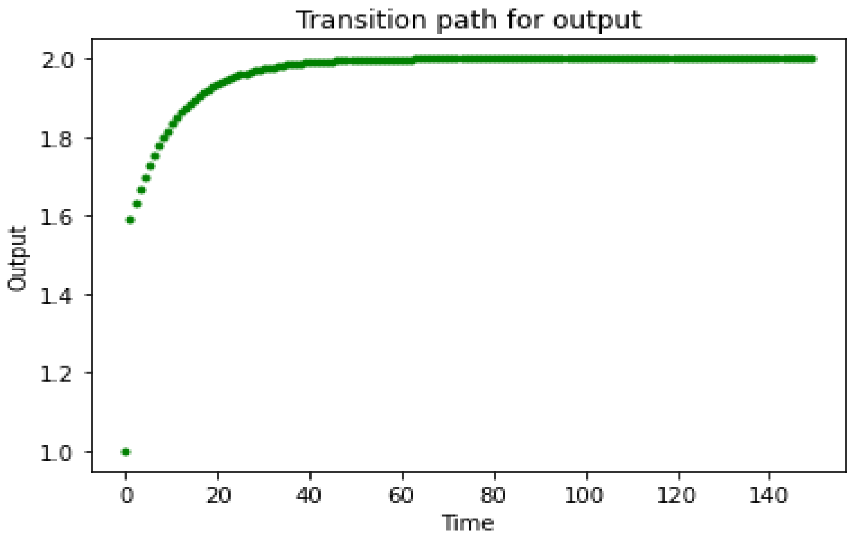
The main results are the following ones:


Transition path for capital
Capital stock
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
0
20
40
60
80
100
120
140
Time


Transition path for savings
Savings
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0
20
40
60
80
100
120
140
Time


Transition path for consumption
Consumption
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0
20
40
60
80
100
120
140
Time



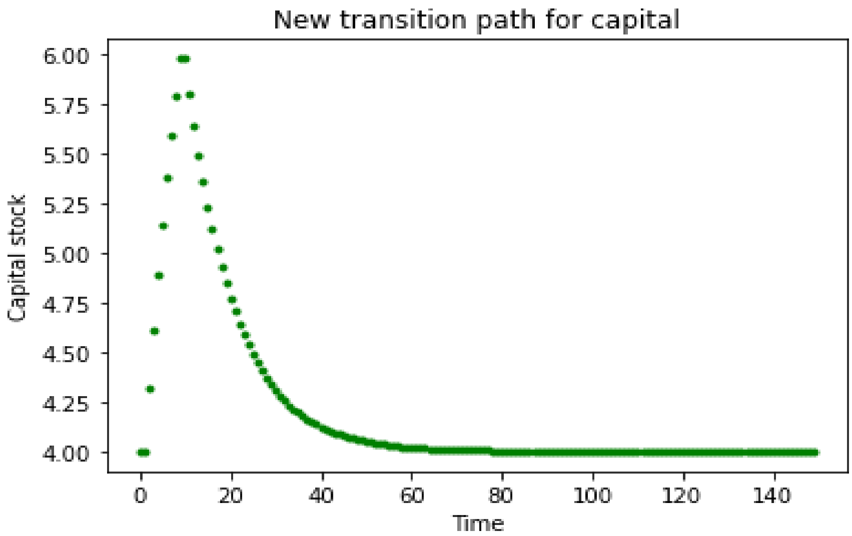


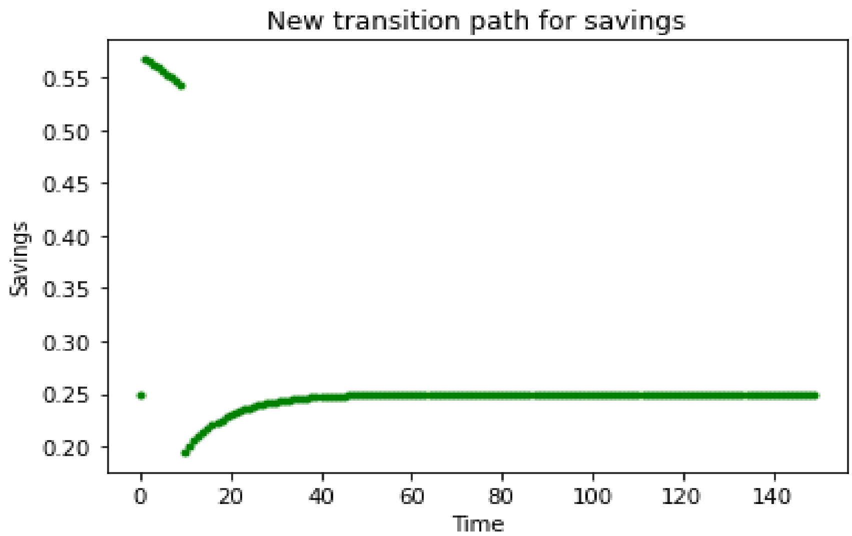
I designed this graphs in a way such that in period 0 the economy is at the original steady state, and at period 1, the productivity shock $z_2 = 2z$ takes place.
We can see that once the shock is introduced the capital stock starts to increase fast, and near period 60 it is already very close tot the new steady state level k_2^*. A similar path is followed by consumption and output. However, regarding to savings (investment), they have a great increase, and then decrease progressively towards the new steady state level (which is still higher than the original one). This evolution for savings is due to the fact that initially consumption grows (relatively) slowly than output, ans hence, by feasibility constraint (2) savings must acquire initially higher weight on output. When transition approaches to the new steady state, this process is reverted.
Finally,obviously, labor supply h keeps constant along the transition because we have not assumed (yet) endogenous labor supply.

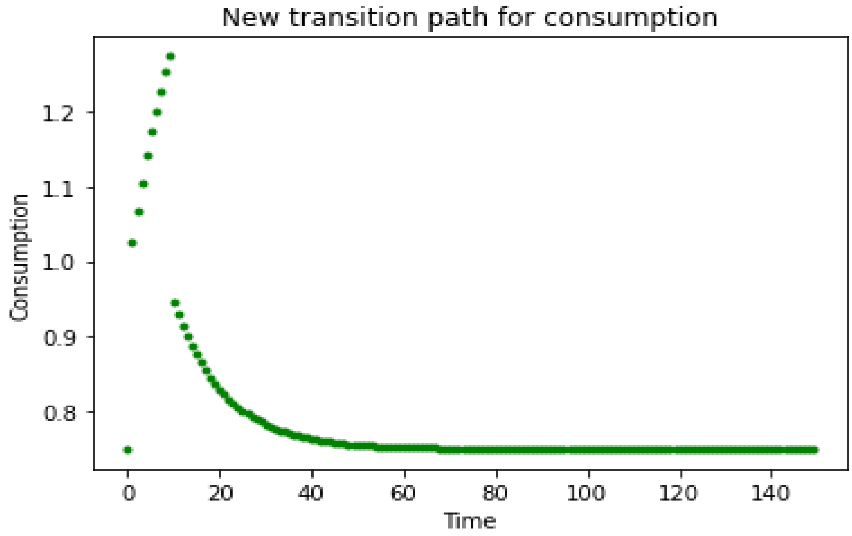
d)Unexpected shocks. Let the agents believe productivity z doubles once and for all periods. However, after 10 periods, surprise the economy by cutting the productivity z back to its original value. Compute the transition for savings, consumption, labor and output.

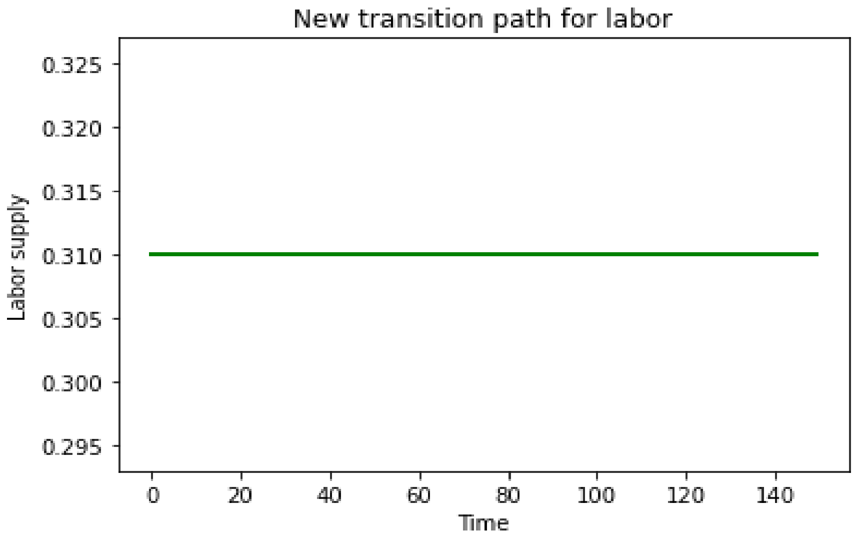
I solved this exercise using similar methods to those I used in part c). More details are defined in Python code.

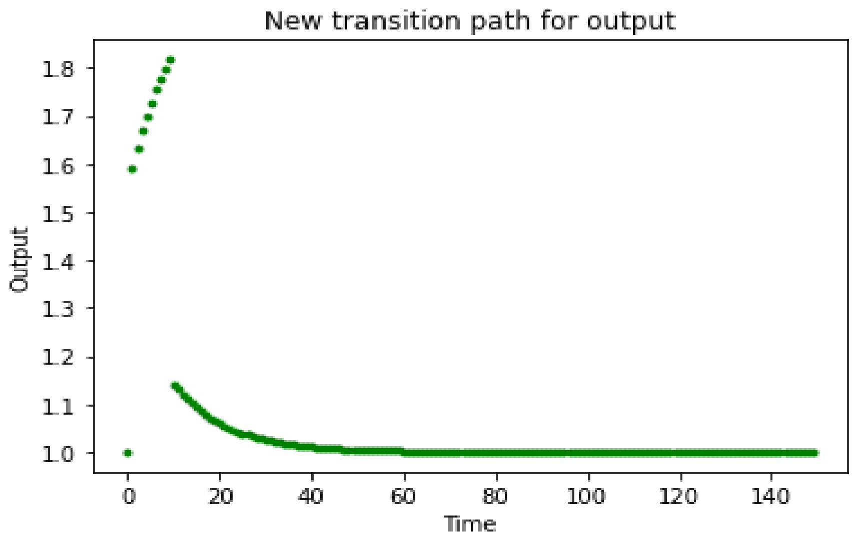
The main results are:






New transition path for consumption
Consumption
Time
1.2
1.1
1.0
0.9
0.8
0
20
40
60
80
100
120
140


New transition path for labor
Labor supply
Time
0.325
0.320
0.315
0.310
0.305
0.300
0.295
0
20
40
60
80
100
120
140


New transition path for output
Output
Time
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
20
40
60
80
100
120
140

The way the graphs is defined is similar than in previous case. At period 0, economy is at the original steady state. Then at period one, the productivity parameter z is doubled, and it keeps in this way until period 10, where z is returned to its original value. What are the effects of this phenomenon on the transition?
According to the graphs we can see how capital stock, consumption and output,start to increase fast towards the second steady state when the economy receive the "positive" productivity shock at period 1, and they do so until period 10, when the "negative" shock that returns z to its original value takes place (and remains forever).When this happens, capital, consumption and output start a fast decreasing convergence towards the original steady state.
In the case of savings (investment), they also follow the same path as in part c) until period 10. When negative shock takes place, savings sink, and then start to increase towards the original steady state.

We can see again that, in general, variables get very close to the steady state at period 60 aprox.

Finally, and as I said before, labor supply h keeps constant along the transition because we have not assumed (yet) endogenous labor supply.

e)Bonus Question: Labor Choice Allow for elastic labor supply and recompute the transition as posed in Question 1.
I was not able to do it.

Question 2

Solve the optimal COVID-19 lockdown model posted in the slides.

a)Show your results for a continuum of combinations of the $\beta(HC) \in [0,1]$ parameter(vertical axis) and the $c(TW) \in [0,1]$ parameter (hztal axis).That is, plot for each pair of β and $c(TW)$ the optimal allocations of $H, H_f, H_{nf}, H_f/H$, output, welfare, amount of infections and deaths. Note that if $H = N$ there is no lockdown, so pay attention to the potential no binding constraint $H < N$.Discuss your results.

You may want to use the following parameters: $A_f = A_{nf} = 1; \rho = 1.1; \kappa_f = \kappa_{nf} = 0.2; \omega = 20; \gamma = 0.9; i_0 = 0.2$ **and** $N = 1$

The model posted in the slides is the following:

It is an economy with only one sector in which production can be done teleworking or working at workplace. The economy is populated by a continuum of ex-ante identical individuals normalized to $N = 1$. If they are employed, then individuals must supply hours inelastically, i.e. $h_i = h^i_f + h^i_{nf} = 1$ where h^i_f is the ammount of hours that individual i works at workplace and h^i_{nf} the ammount of hours that individual i teleworks. Hence, turning to the aggregates, $H_f = \sum_i h^i_f$ are the aggregate hours worked at workplace and $H_{nf} = \sum_i h^i_{nf}$ the aggregate teleworked hours. Notice that because of the continuum $[0,1]$ of exante identical agents assumption, the aggregate hours are identical to the size of employment:

$$H_f + H_{nf} = H = h_i E \leq N \tag{18}$$

Aggregate production in this economy is given by:

$$Y(H_f, H_{nf}) = \left(A_f H_f^{\frac{\rho-1}{\rho}} + c(TW) A_{nf} H_{nf}^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \tag{19}$$

where $c(TW) \in [0,1]$ captures productivity losses associated to teleworking.A_f and A_{nf} indicate respectively a kind of total factor productivity for both modalities of working.

In this economy contagion of COVID-19 can only occur at workplace, i.e., there is contagion risk only at workplace. Teleworking there is not risk. Specifically, the number of infections that occur depends on the conditional infection rate (conditional to the fact that there is meeting) $\beta(HC) \in [0,1]$ in the following manner:

$$i = \beta(HC)m(H_f) \tag{20}$$

$$m(H_f) = \frac{i_0 H_f}{N} \tag{21}$$

where $m(H_f)$ is the meeting probability, i.e the probability that an employed individual meets with a contagious individual at work.In (20) i is, hence the unconditional infection rate. Hence, knowing that, is straightforward to denote the total number of infections as:

$$I = iH_f \tag{22}$$

In (21)i_0 denotes the initial share of contiguous individuals at workplace.
Some of the infected individuals die according to the rate $(1-\gamma)$. Hence the total amount of deads is given by:

$$D = (1-\gamma)I \tag{23}$$

In this economy a Social Planner chooses consumption c, h_f and h_{nf} to maximize total welfare. So the problem is:

$$\max_{c_i, h^i_f, h^i_{nf}} \sum_i (c_i - \kappa_f h^i_f - \kappa_{nf} h^i_{nf}) - \omega D \tag{24}$$

where ω indicates how much planner cares about the total number of deads $D = D_f + D_{nf}$ and where κ_f and κ_{nf} are just an expression to define individuals preferences for the different ways of working.
Now, using in (24) the resource constraint:

$$Y(H_f, H_{nf}) = C = \sum_i c_i \tag{25}$$

and the labor market clearing conditions:

$\sum_{i\in j} h^i = H_j$ for $j = f, nf$ (26)
We can reformulate social planner problem as:

$$\max_{H_j \in [0,N]_{j=f,nf}} Y(H_f, H_{nf}) - \kappa_f H_f - \kappa_{nf} H_{nf} - \omega D \tag{27}$$

subject to:

$$H = H_f + H_{nf} \leq N \tag{28}$$

And now I'm going to use a batch of substitutions on (27) to set the definitive form of the problem:
First substitution: Plug (19) in (27).
Second substitution: Then, plug (21) in (20) using $m(H_f)$ argument, and after that, use the obtained equation in (22) substituting for i, and use the resulting expression to substitute for I in (23), to obtain: $D = (1-\gamma)\beta(HC)\frac{i_0 H_f^2}{N}$. Finally substitute this expression for D in (27).

Therefore the new form of the social planner problem is:

$$\max_{H_j \in [0,N]_{j=f,nf}} \left(A_f H_f^{\frac{\rho-1}{\rho}} + c(TW) A_{nf} H_{nf}^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}} - \kappa_f H_f - \kappa_{nf} H_{nf} - \omega\left((1-\gamma)\beta(HC)\frac{i_0 H_f^2}{N}\right) \tag{29}$$

subject to:

$$H = H_f + H_{nf} \leq N \tag{30}$$

The corresponding Lagrangian is:

$$\mathcal{L} = \left(A_f H_f^{\frac{\rho-1}{\rho}} + c(TW) A_{nf} H_{nf}^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}} - \kappa_f H_f - \kappa_{nf} H_{nf} - \omega\left((1-\gamma)\beta(HC)\frac{i_0 H_f^2}{N}\right) - \mu[H_f + H_{nf} - N] \tag{31}$$

Taking FOC gives:

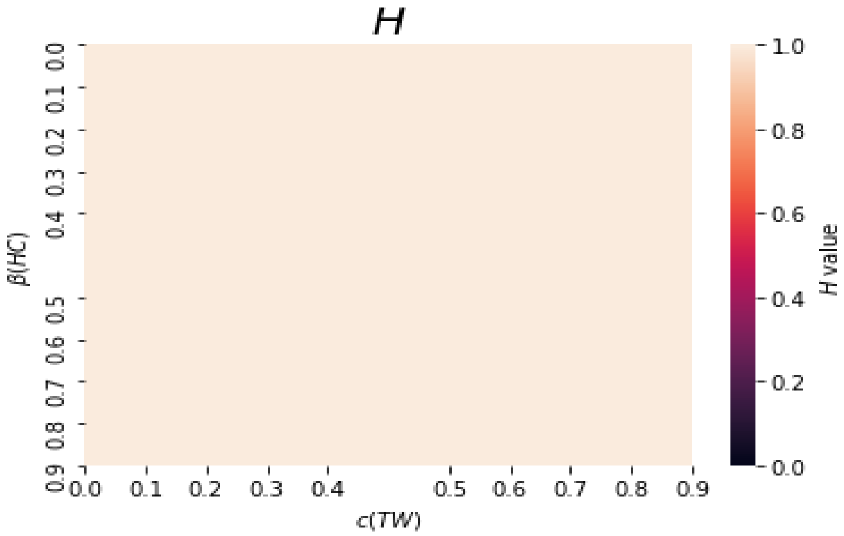
$$\frac{\partial \mathcal{L}}{\partial H_f} = 0 \Rightarrow \left(A_f H_f^{\frac{\rho-1}{\rho}} + c(TW) A_{nf} H_{nf}^{\frac{\rho-1}{\rho}}\right)^{\frac{-1}{\rho-1}} A_f H_f^{\frac{-1}{\rho}} - \kappa_f - 2\omega\left((1-\gamma)\beta(HC)\frac{i_0 H_f}{N}\right) = \mu$$

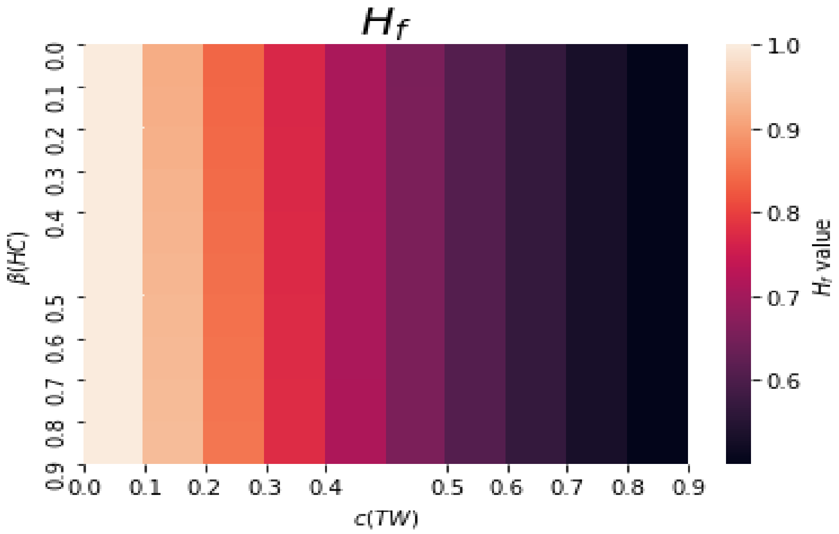
$$\frac{\partial \mathcal{L}}{\partial H_{nf}} = 0 \Rightarrow \left(A_f H_f^{\frac{\rho-1}{\rho}} + c(TW) A_{nf} H_{nf}^{\frac{\rho-1}{\rho}}\right)^{\frac{-1}{\rho-1}} c(TW) A_{nf} H_{nf}^{\frac{-1}{\rho}} - \kappa_{nf} = \mu$$

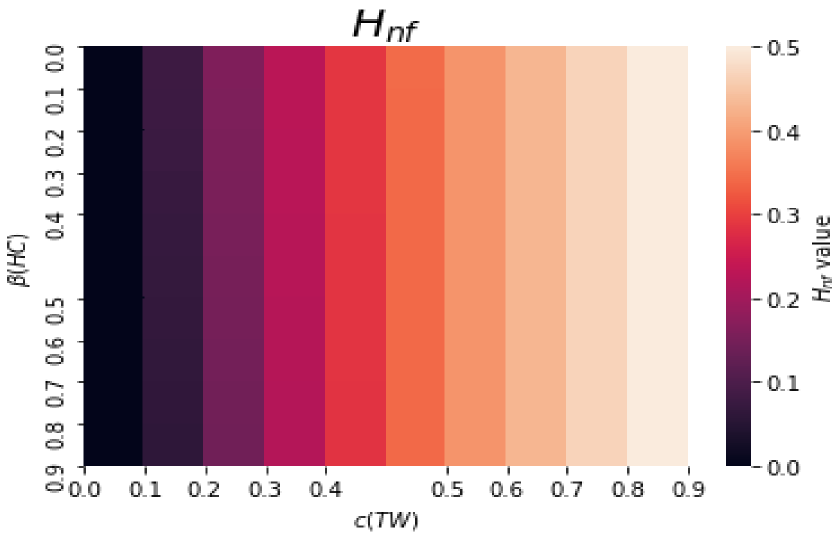
Combining both FOC's gives:

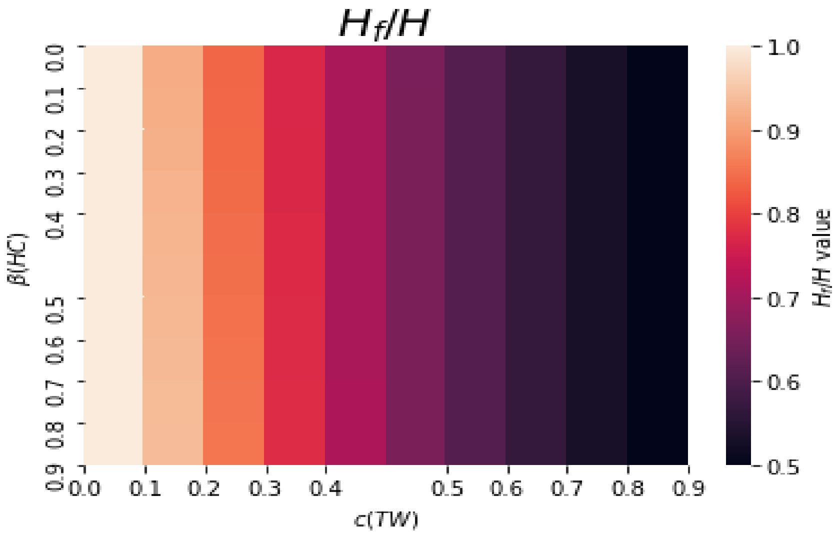
$$A_f H_f^{\frac{-1}{\rho}} - \kappa_f - 2\omega\left((1-\gamma)\beta(HC)\frac{i_0 H_f}{N}\right) = c(TW) A_{nf} H_{nf}^{\frac{-1}{\rho}} - \kappa_{nf} \tag{32}$$

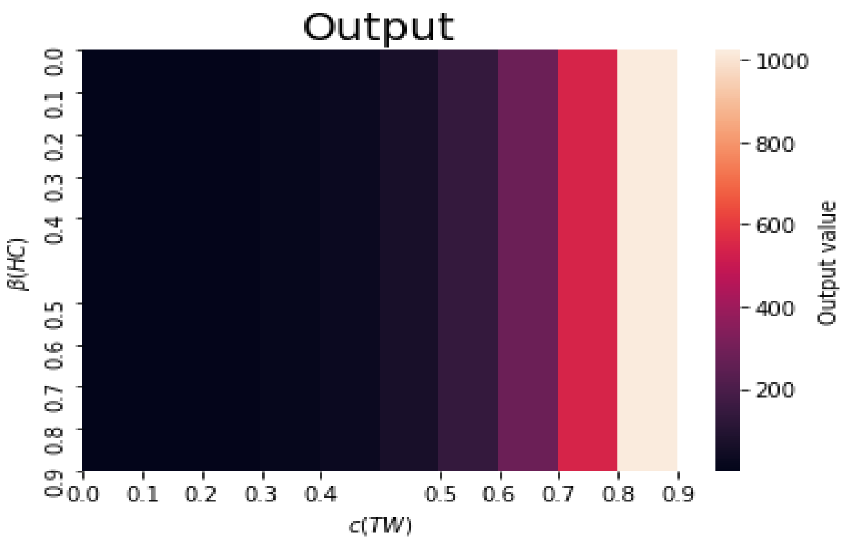
(31) together with the constraint in (29) fully characterize the solution for this model. When I say solution I'm meaning a pair of optimal H_f H_{nf} given the parameters of the model. Given this optimal pair, and all the parameters, all the rest of optimal variables of the model, like output, infections, deaths,etc, are implicitly defined, and hence easy to compute. The problem for us in this exercise is that we have two parameters missing:$\beta(HC)$ and $c(TW)$, and we are asked to compute in some way all the possible solutions for the model for a continuum of combinations of $\beta(HC) \in [0,1]$ and $c(TW) \in [0,1]$. Obviously this cannot be done analytically, so you can find the code in my Python file. Here I will be just showing the main results, which are in the following graphs. I provide also a brief interpretation after the graphs.

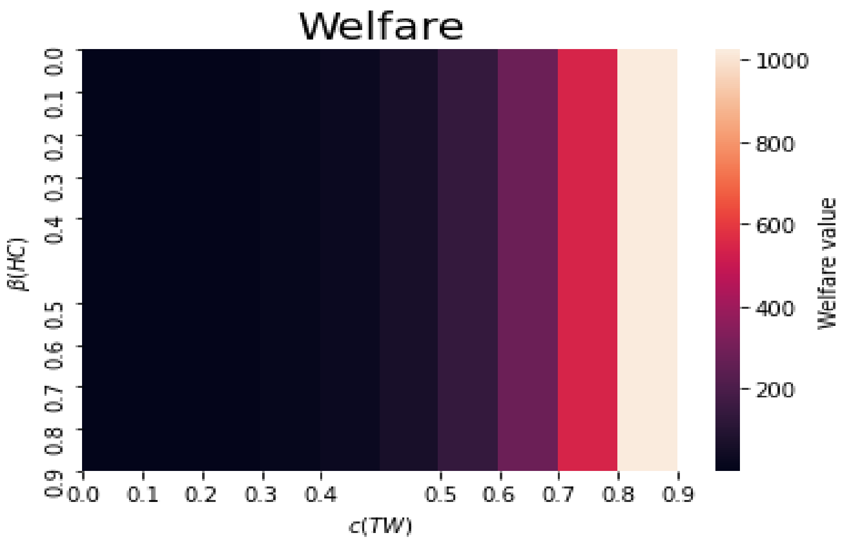

H
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
c(TW)
H value
1.0
0.8
0.6
0.4
0.2
0.0

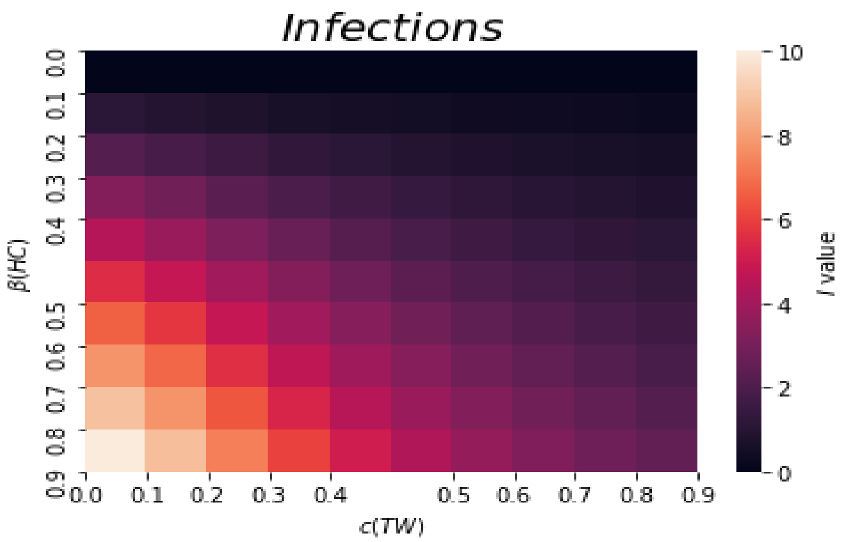

H_f
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
c(TW)
H_f value
1.0
0.9
0.8
0.7
0.6

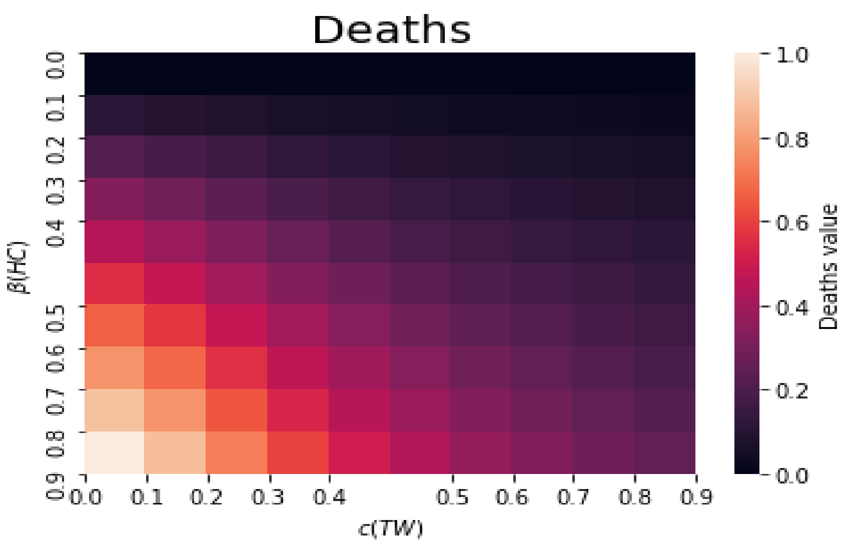

H_{nf}
$\beta(HC)$
$c(TW)$
H_{nf} value
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9


H_f/H
$\beta(HC)$
$c(TW)$
H_f/H value
0.5
0.6
0.7
0.8
0.9
1.0


Output
$\beta(HC)$
$c(TW)$
Output value
200
400
600
800
1000


Welfare
β(HC)
c(TW)
Welfare value
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
200
400
600
800
1000

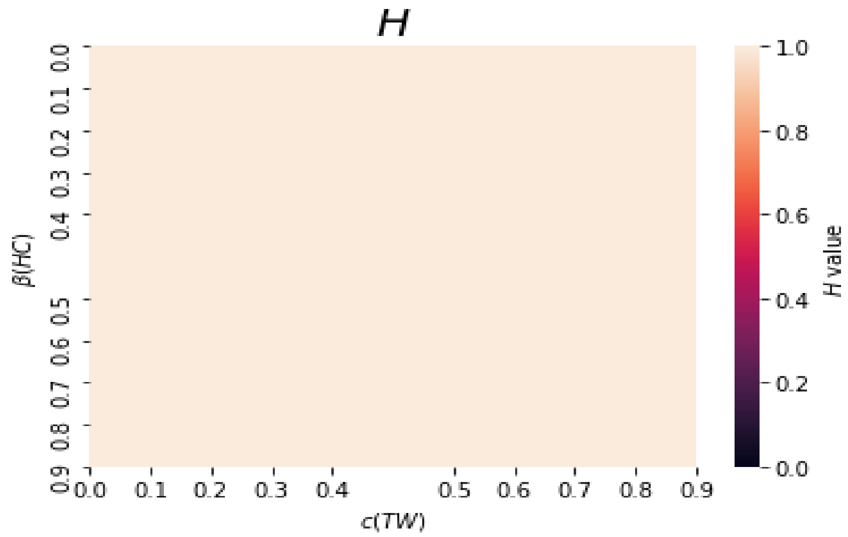

Infections
β(HC)
c(TW)
I value
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10

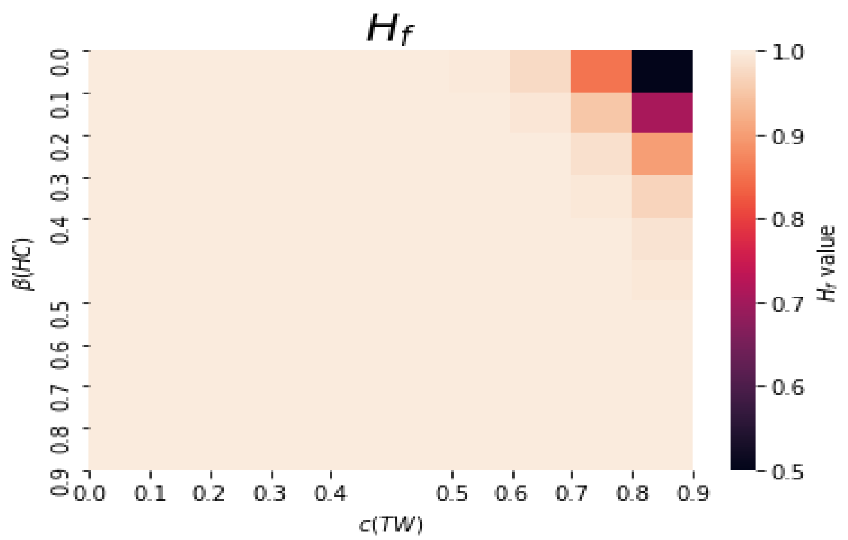

Deaths
β(HC)
c(TW)
Deaths value
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0
0.2
0.4
0.6
0.8
1.0

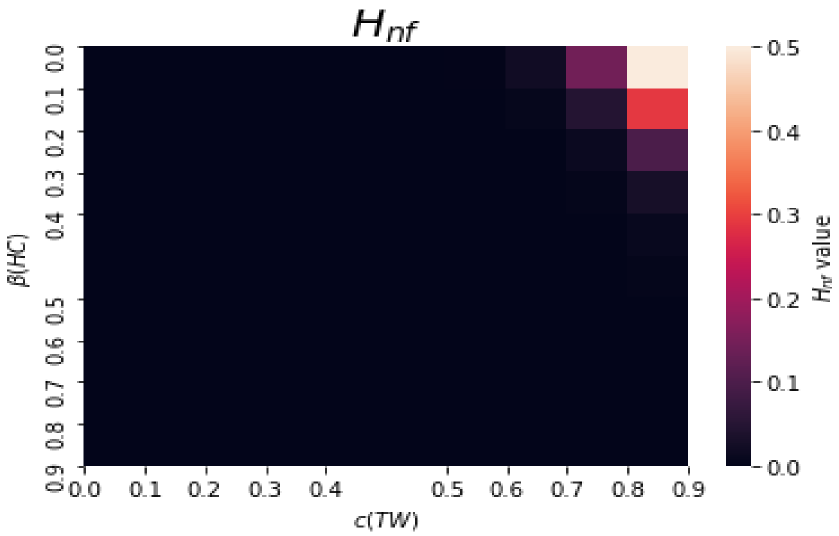
This results don't seem surprising taking into account that $\beta(HC)$ is the conditional infection rate and $c(TW)$ is a factor capturing productivity of teleworking. Obviously optimal total hours H don't change in any case. Optimal hours at workplace obviously decrease as the teleworking becomes more productive, and as infection rate increases. The opposite happens with optimal teleworking hours. However, is true that in general there is always more hours worked at workplace than teleworked. Output is increasing in productivity of teleworking and decreasing in conditional infection rate as well as Welfare. Finally, the dynamics of infections and deaths are not surprising but very interesting. They obviously increase in conditional infection rate, but decrease on productivity of teleworking. Hence one policy implication for fighting against the pandemic could be, according to the model, that investing in improving teleworking productivity saves lives.

b) What happens to your results when you increase (decrease) ρ or ω ?

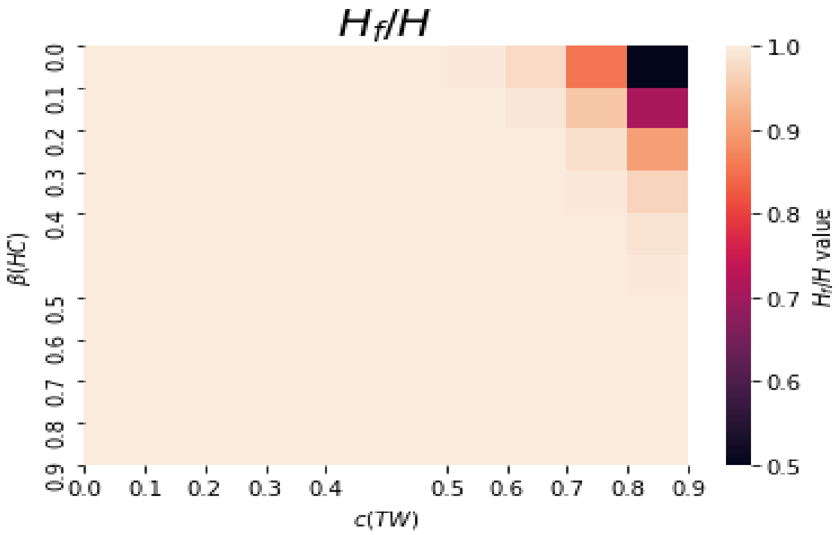
First let me increase ρ. Say $\rho = 15$ and other things equal. Here are the results:



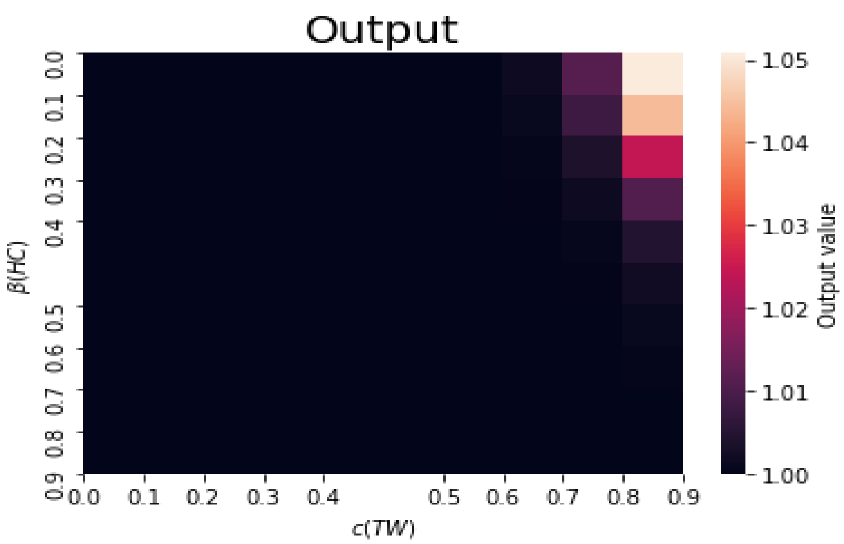




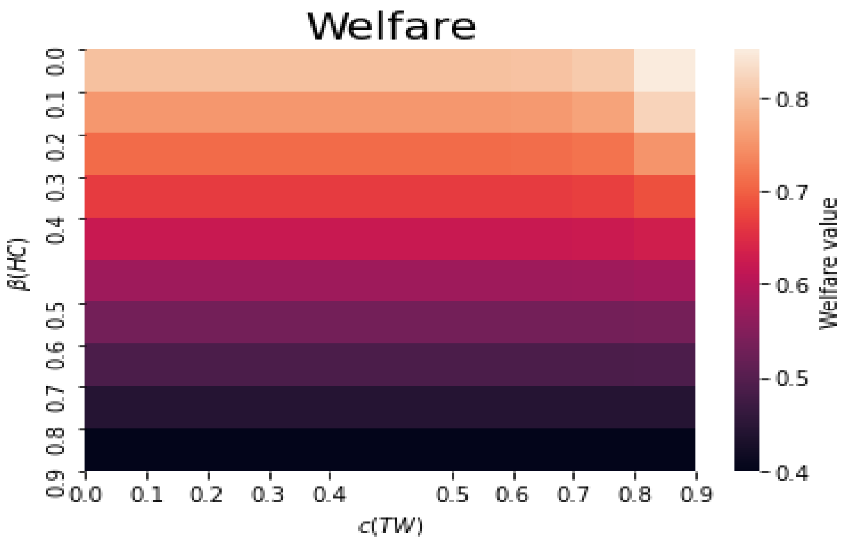
H_{nf}
$\beta(HC)$
$c(TW)$
H_{nf} value
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

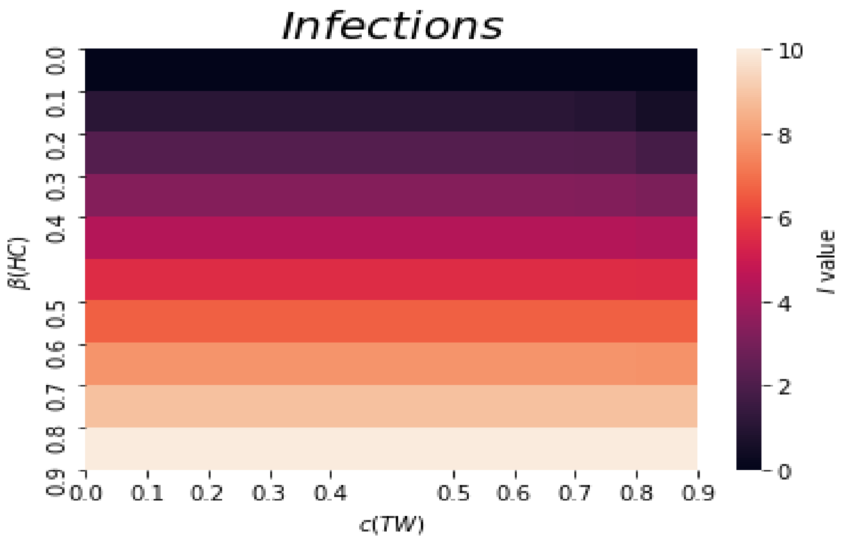


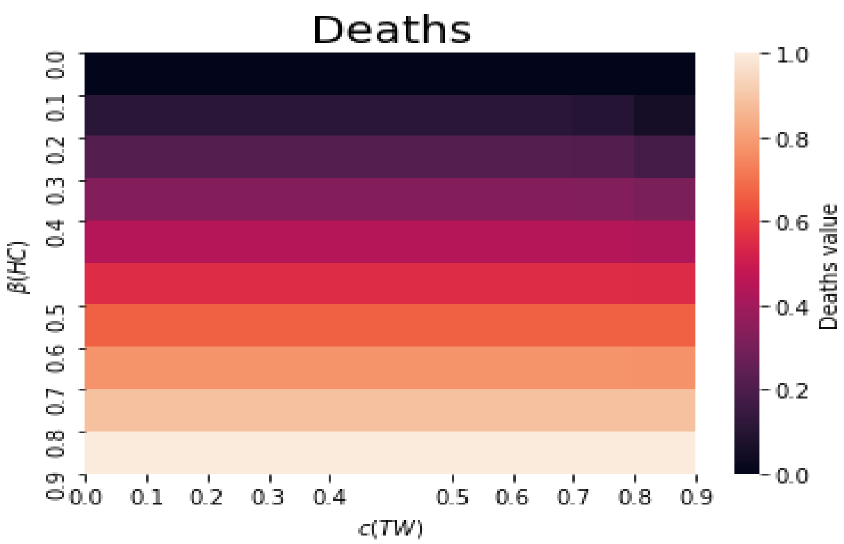
H_f/H
$\beta(HC)$
$c(TW)$
H_f/H value
0.5
0.6
0.7
0.8
0.9
1.0



Output
$\beta(HC)$
$c(TW)$
Output value
1.00
1.01
1.02
1.03
1.04
1.05

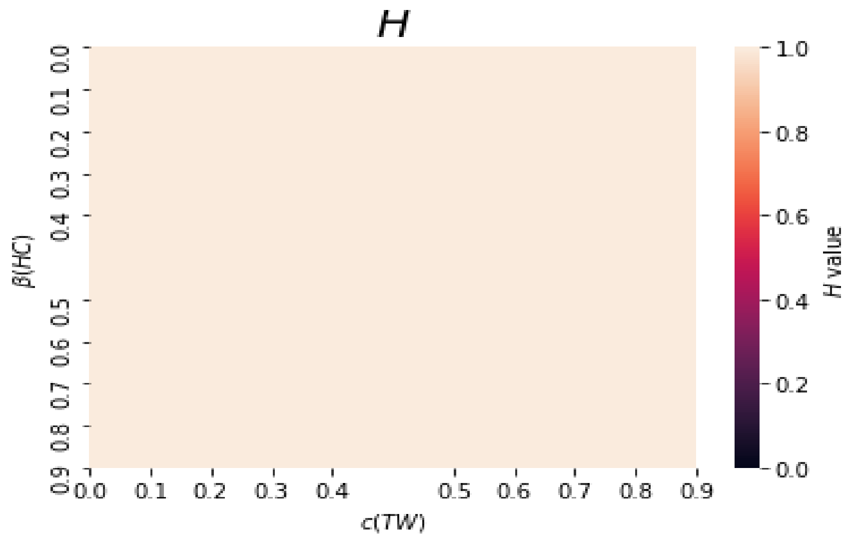

Welfare
β(HC)
c(TW)
Welfare value
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

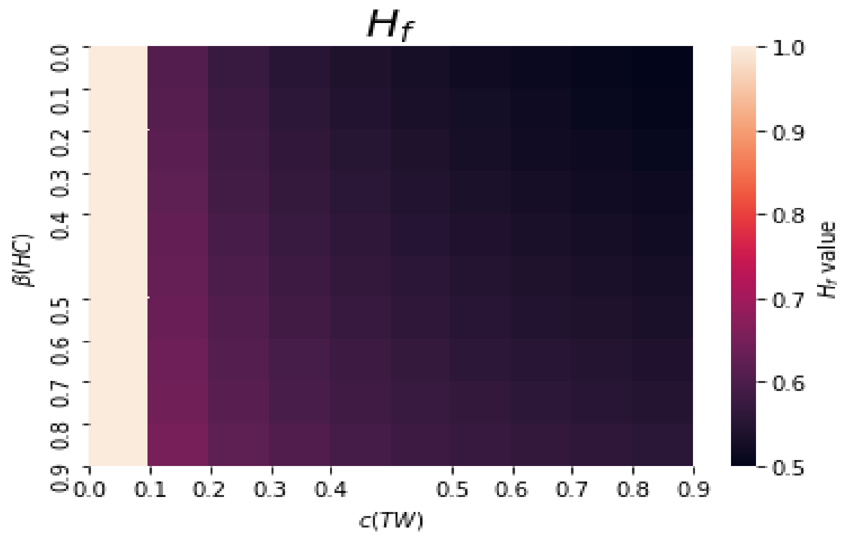

Infections
β(HC)
c(TW)
I value
0
2
4
6
8
10

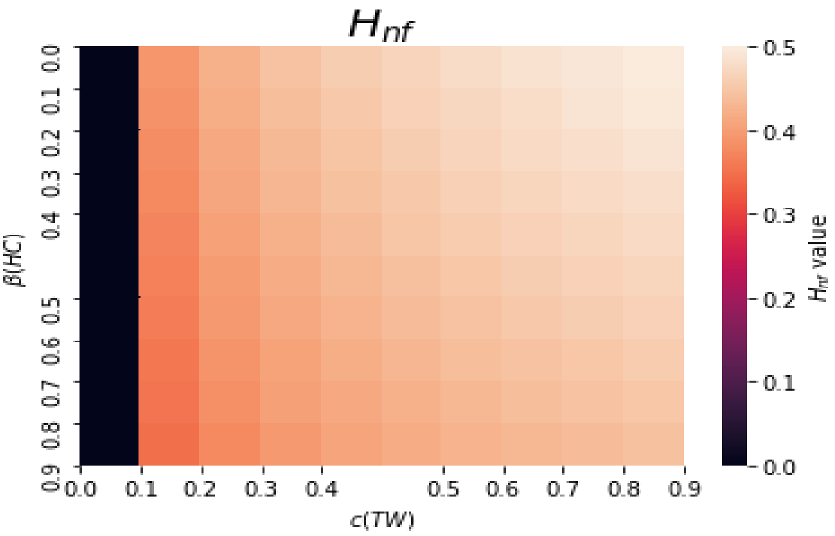

Deaths
β(HC)
c(TW)
Deaths value
0.0
0.2
0.4
0.6
0.8
1.0

It is clear that increasing ρ what increases is the amount of optimal hours worked at workplace, and decrease the teleworking optimal hours.

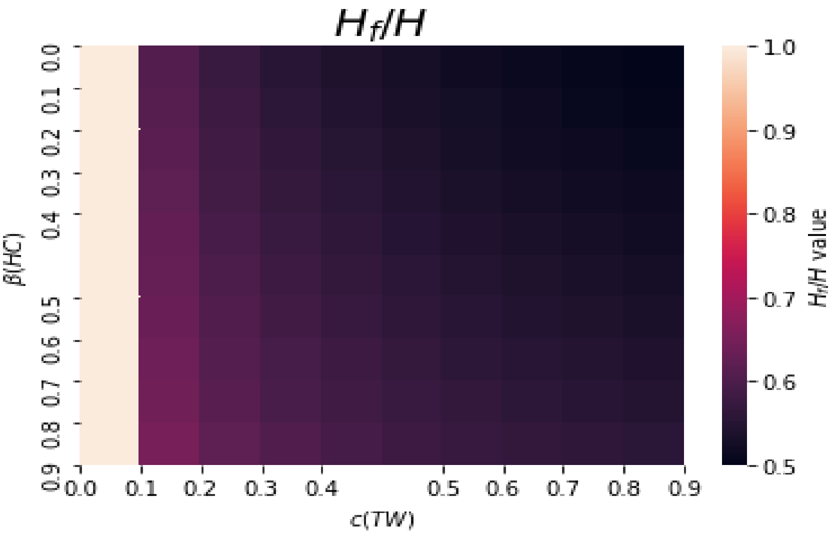
Now let me decrease ρ,say $\rho = 0.2$ other things equal.Results are:



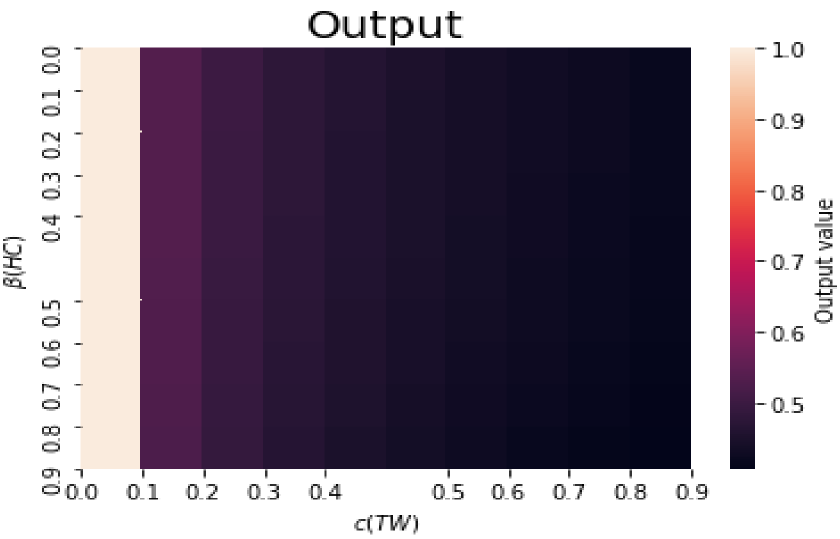




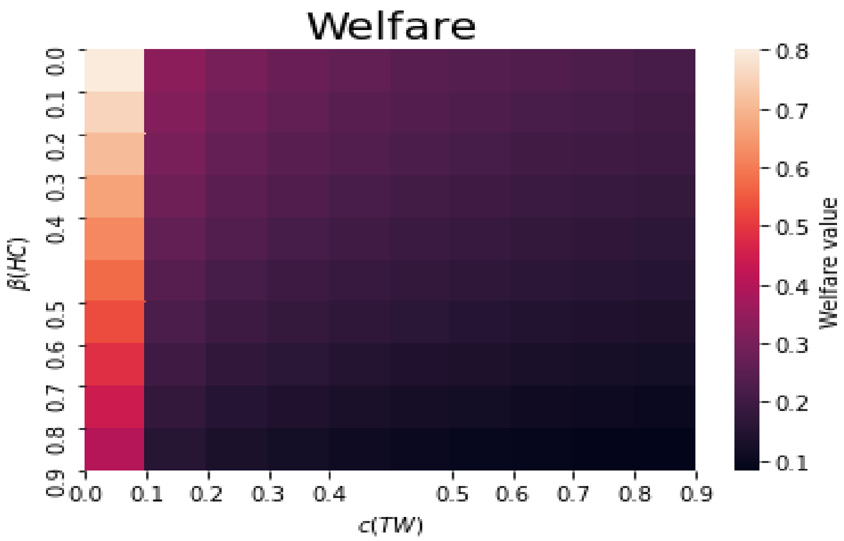
H_{nf}
$\beta(HC)$
$c(TW)$
H_{nf} value

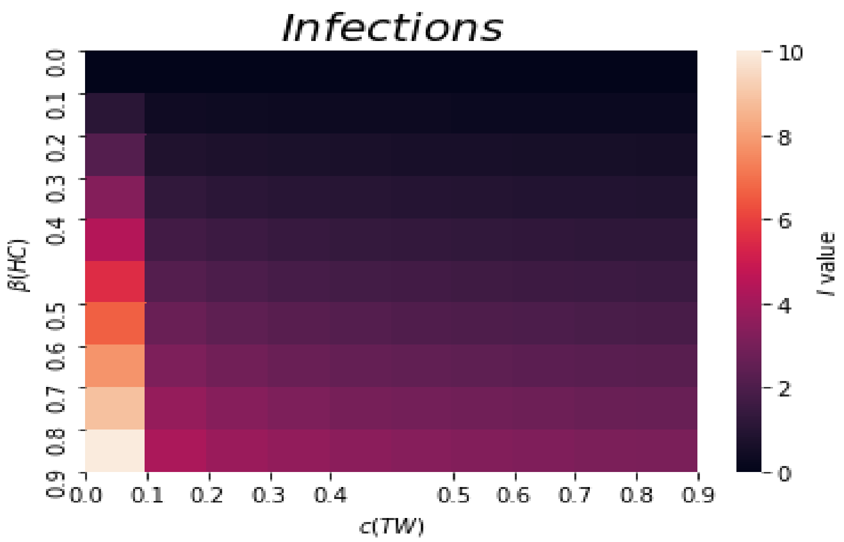


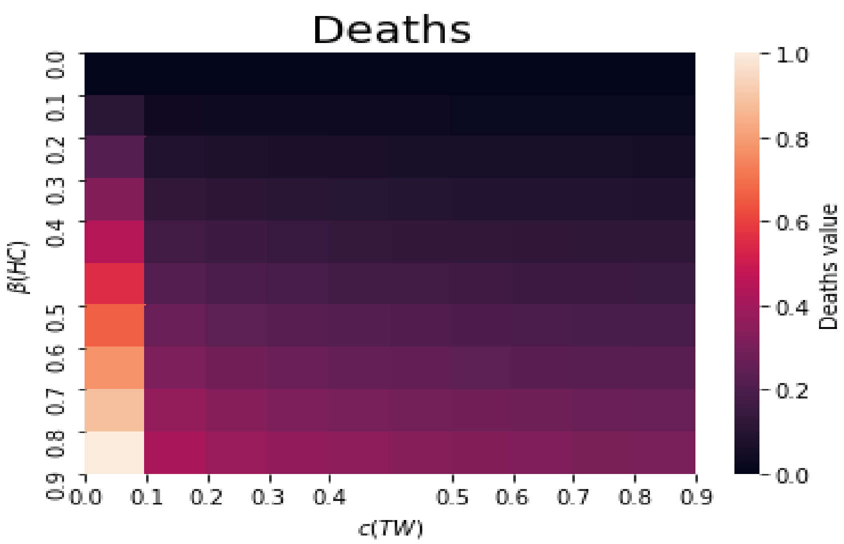
H_f/H
$\beta(HC)$
$c(TW)$
H_f/H value



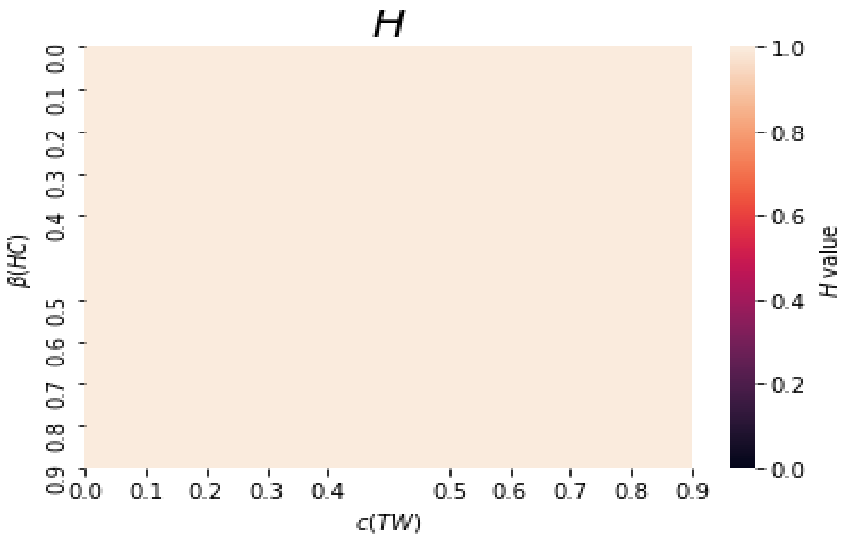
Output
$\beta(HC)$
$c(TW)$
Output value

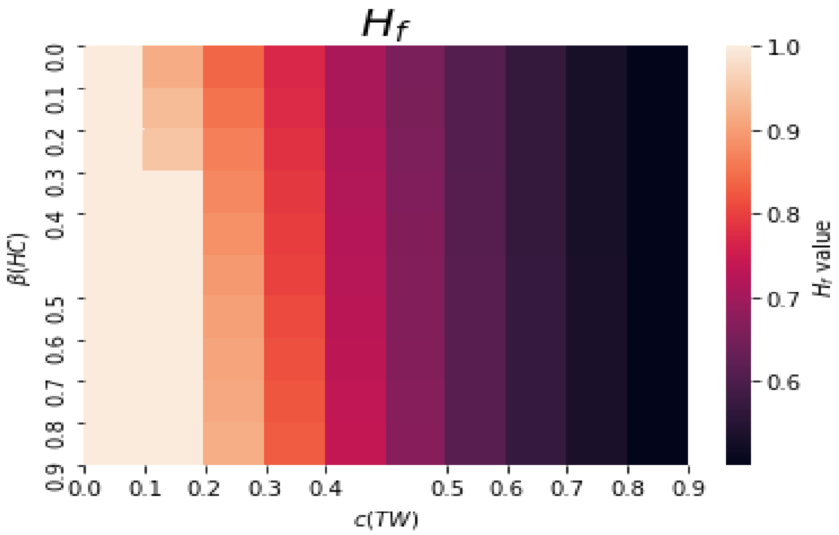

Welfare
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
c(TW)
Welfare value
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

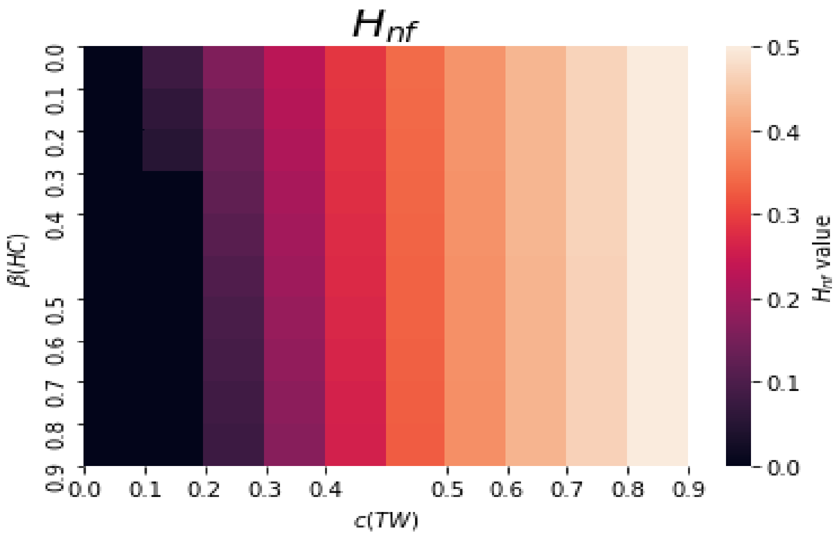

Infections
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
c(TW)
I value
0 2 4 6 8 10

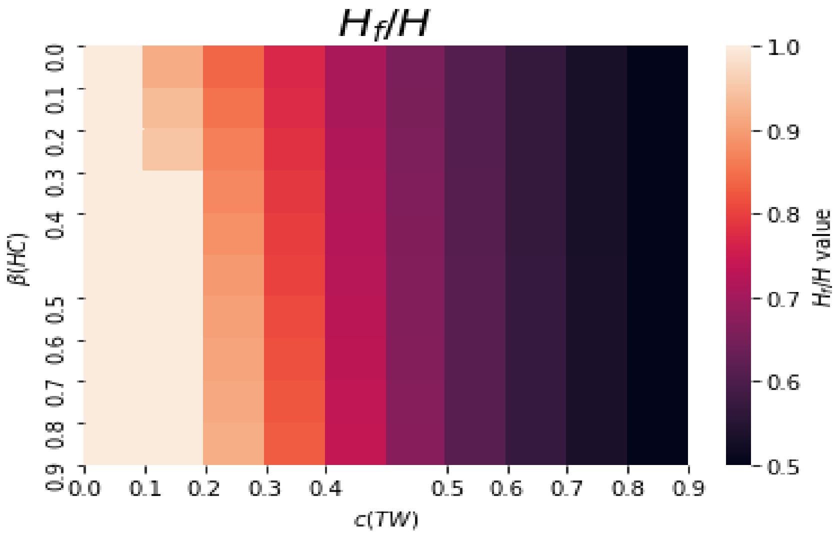

Deaths
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
c(TW)
Deaths value
0.0 0.2 0.4 0.6 0.8 1.0

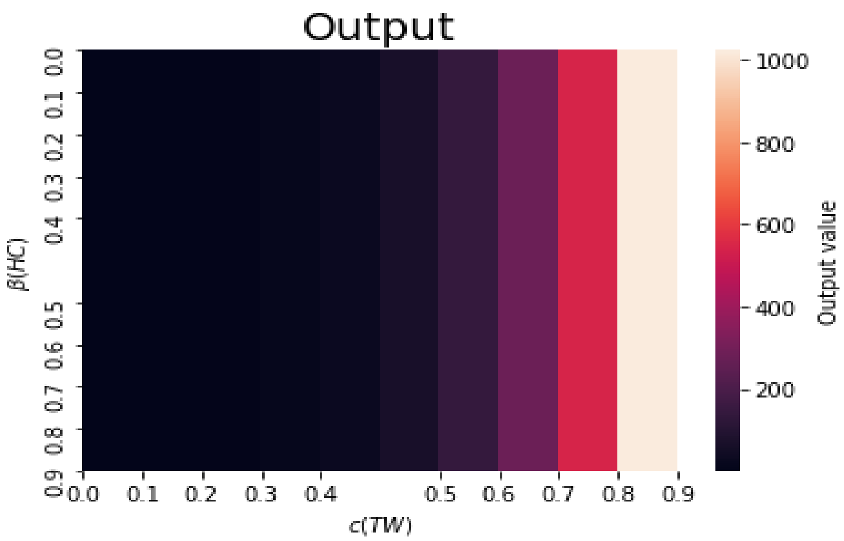
Decreases in ρ lead to generalized increases of optimal hours teleworked and generalized decreases of optimal hours at workplace.
Now let's return ρ to it's original value and increase ω, say for example ω=150, other things equal.

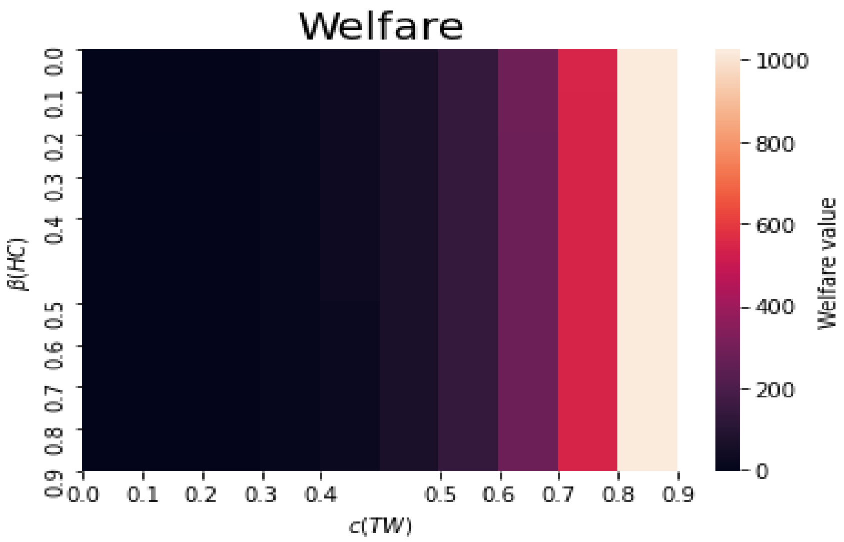


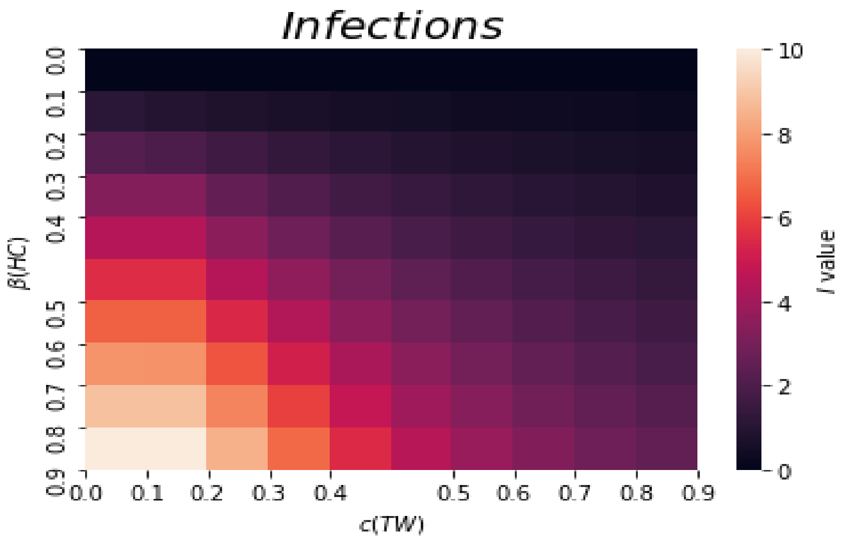


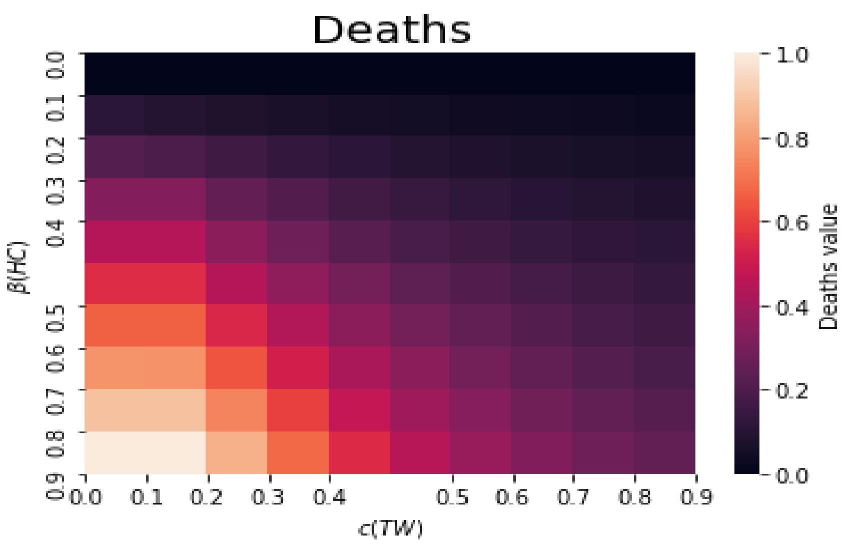

H_{nf}
β(HC)
c(TW)
H_{nf} value


H_f/H
β(HC)
c(TW)
H_f/H value

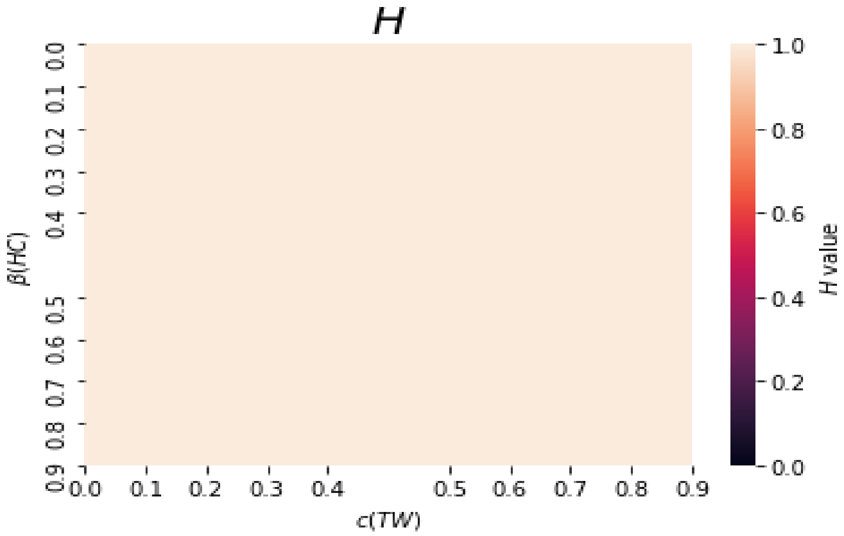

Output
β(HC)
c(TW)
Output value

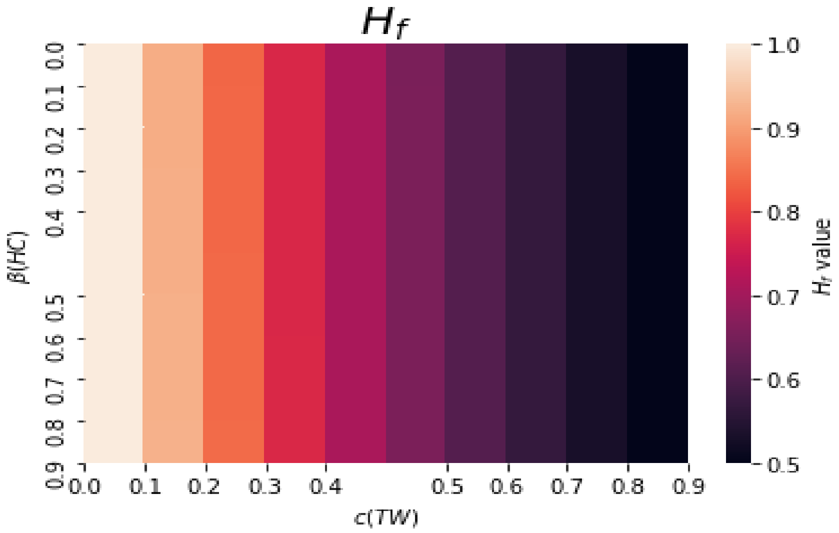

Welfare
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
c(TW)
Welfare value
1000
800
600
400
200
0

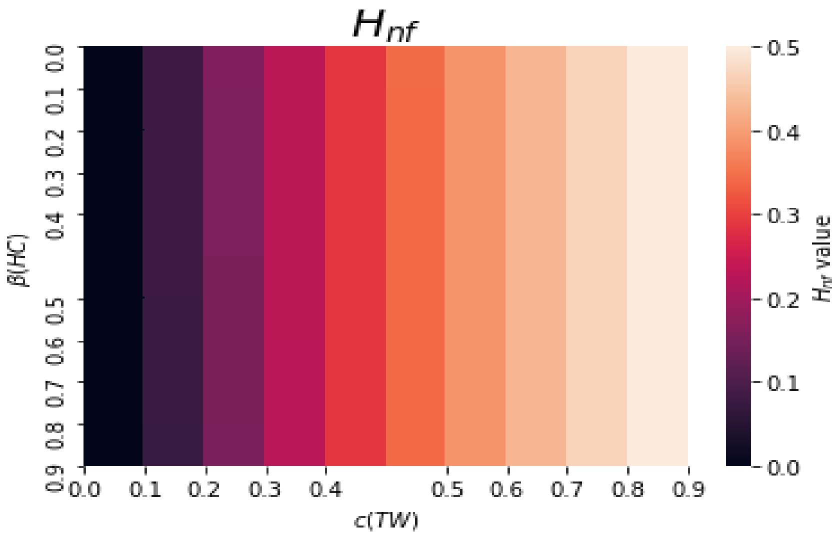

Infections
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
c(TW)
I value
10
8
6
4
2
0

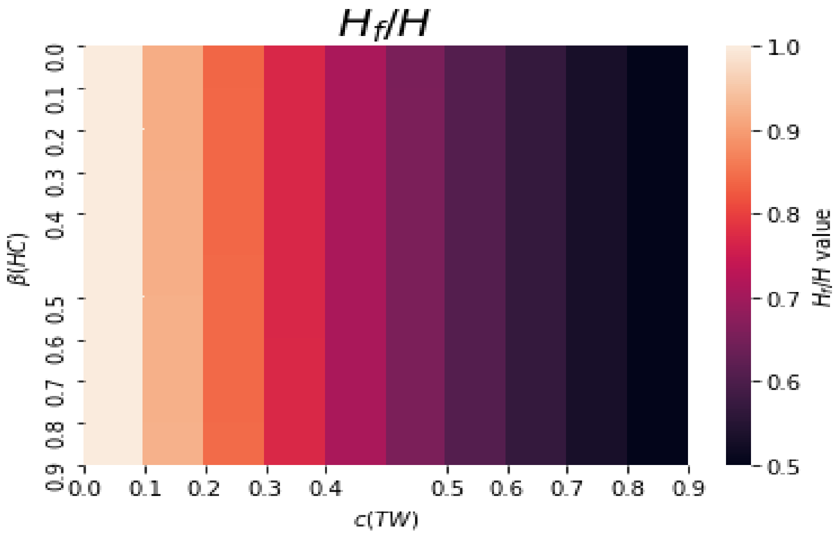

Deaths
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
c(TW)
Deaths value
1.0
0.8
0.6
0.4
0.2
0.0

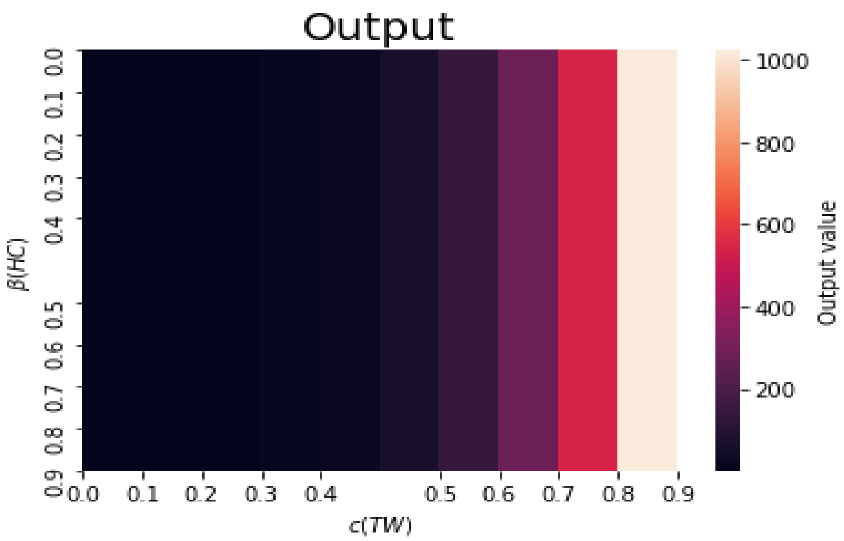
Note that increases in ω, which reflects how planner cares about the ammount of deaths, don't seem to have too much effect on my graphs.
Finally let's try to decrease ω bellow it's original value, say, for example $\omega = 5$, other things equal.

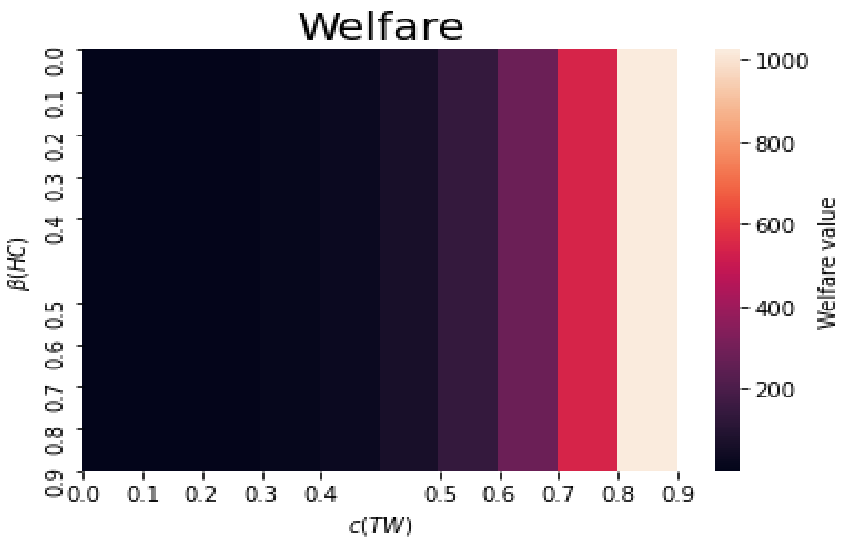


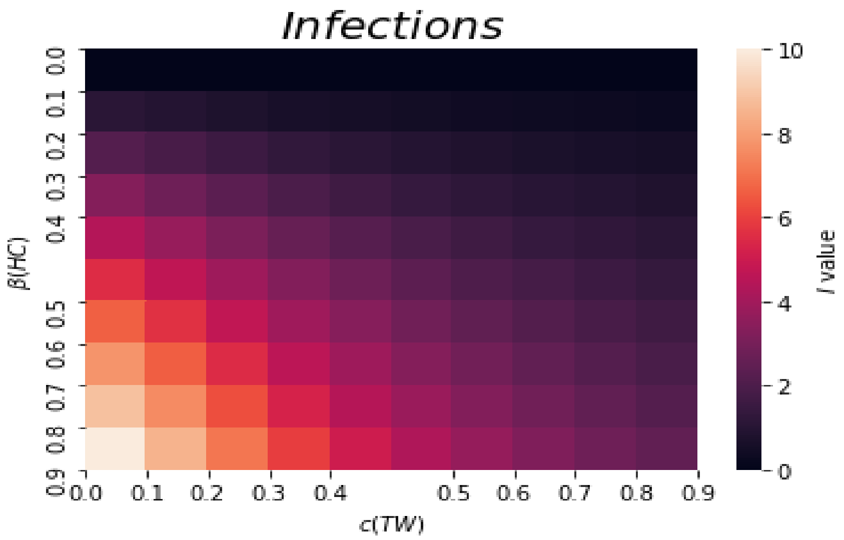


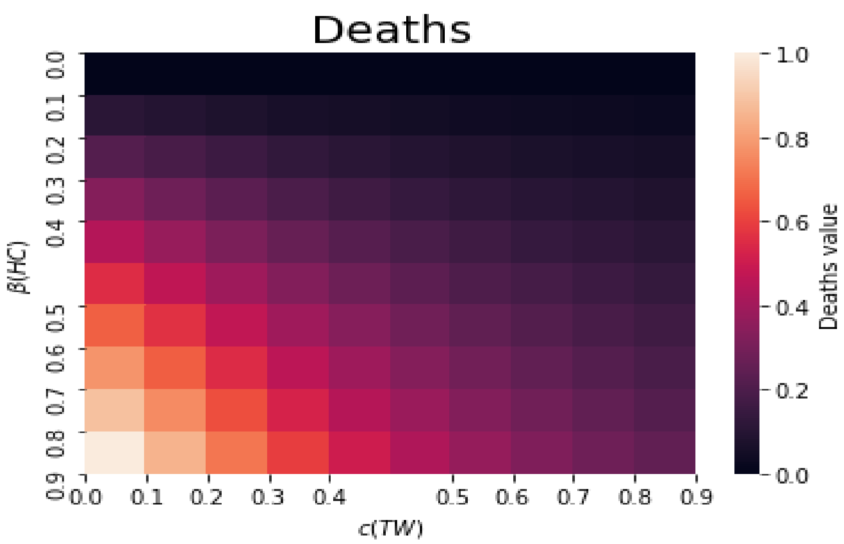

H_{nf}
$\beta(HC)$
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
$c(TW)$
H_{nf} value
0.0
0.1
0.2
0.3
0.4
0.5


H_f/H
$\beta(HC)$
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
$c(TW)$
H_f/H value
0.5
0.6
0.7
0.8
0.9
1.0


Output
$\beta(HC)$
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
$c(TW)$
Output value
200
400
600
800
1000


Welfare
β(HC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
c(TW)
1000
800
600
400
200
Welfare value


Infections
β(HC)
c(TW)
10
8
6
4
2
0
I value


Deaths
β(HC)
c(TW)
1.0
0.8
0.6
0.4
0.2
0.0
Deaths value

Also decreases of ω don't seem to change a lot the dynamics of the problem.