SocModelAnalysis

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Function:

$\frac{dF_1}{dt} = r_1 F_1(1 - F_1) - \frac{h_1 * F_1(1-X_1)}{F_1+s_1} - i_2 F_1 + i_1 F_2$

$\frac{dF_2}{dt} = r_2 F_2(1 - F_2) - \frac{h_2 * F_2(1-X_2)}{F_2+s_2} - i_1 F_2 + i_2 F_1$

$\frac{dX_1}{dt} = k_1 X_1(1 - X_1)[\frac{1}{F_1+c_1} - \omega_1 + d_1(2X_1 - 1) + \rho_1(2X_2 - 1)]$

$\frac{dX_2}{dt} = k_2 X_2(1 - X_2)[\frac{1}{F_2+c_2} - \omega_2 + d_2(2X_2 - 1) + \rho_2(2X_1 - 1)]$

Table 1: Default parameter values used in this analysis

Parameter	Population_1	Population_2	Def
r	0.35	0.35	Fish net growth
s	0.8	0.8	Supply and demand
h	0.5	0.5	Harvesting efficiency
k	1.014	1.014	Social learning rate
ω	0.35	0.35	Conservation cost
c	1.5	1.5	Rarity valuation
d	0.5	0.5	Social norm strength (within pop)
i	0.2	0.2	Fish immigration (from patch)
ρ	0.5	0.5	Social norm strength (opposite pop)

Table 2: Starting values used in this analysis

Parameter	Population_1	Population_2
F	0.406	0.406
X	0.240	0.240

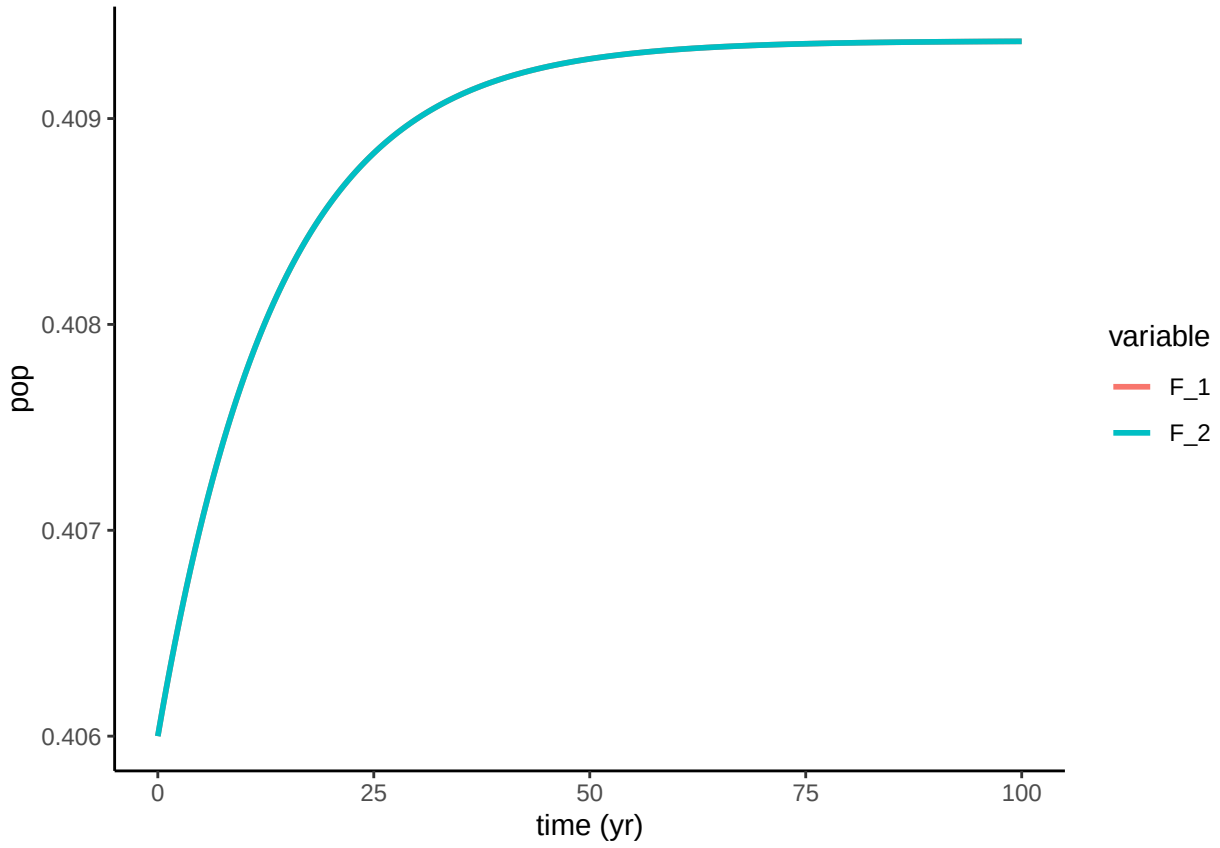


Figure 1: Model without social dynamics

Observations:

- Fishing remains sustainable UNLESS more than 50% of people are fishing

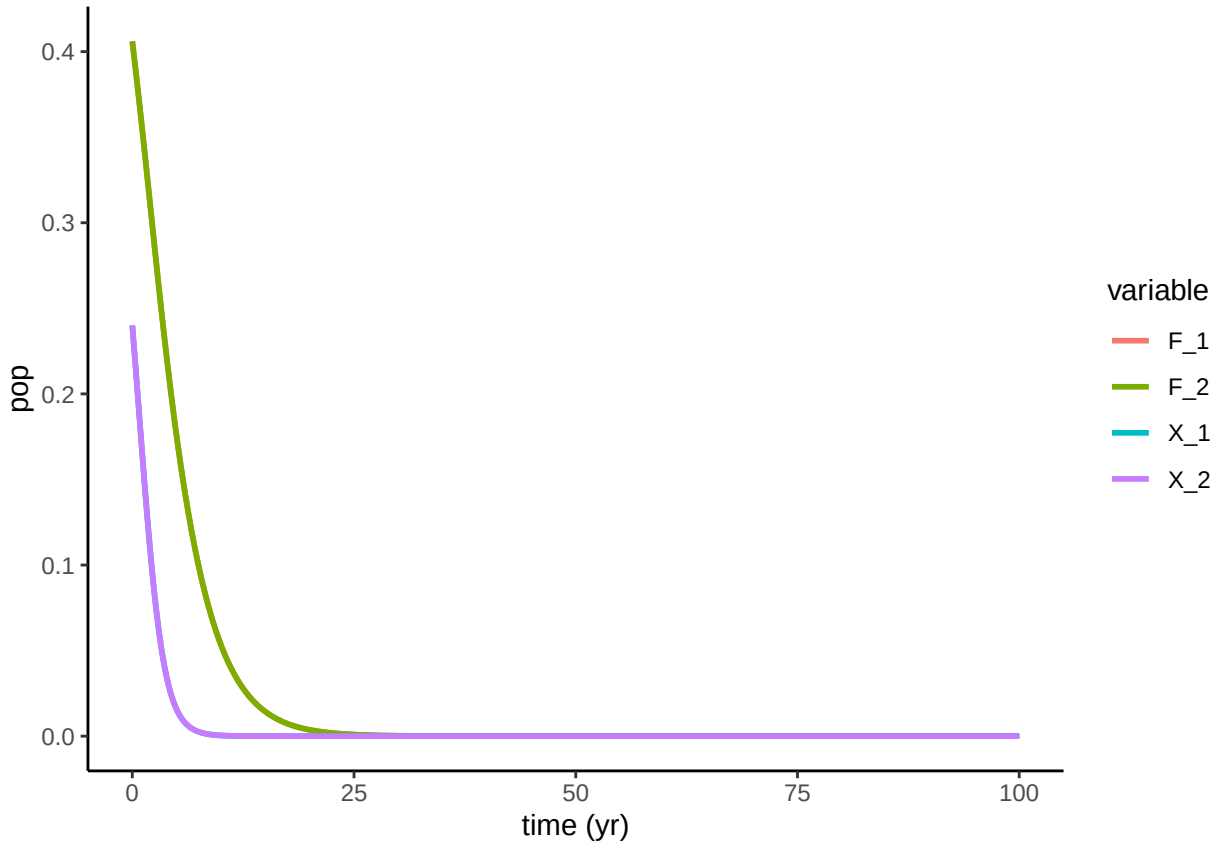


Figure 2: New Model with social dynamics

Observations:

- Still decreasing

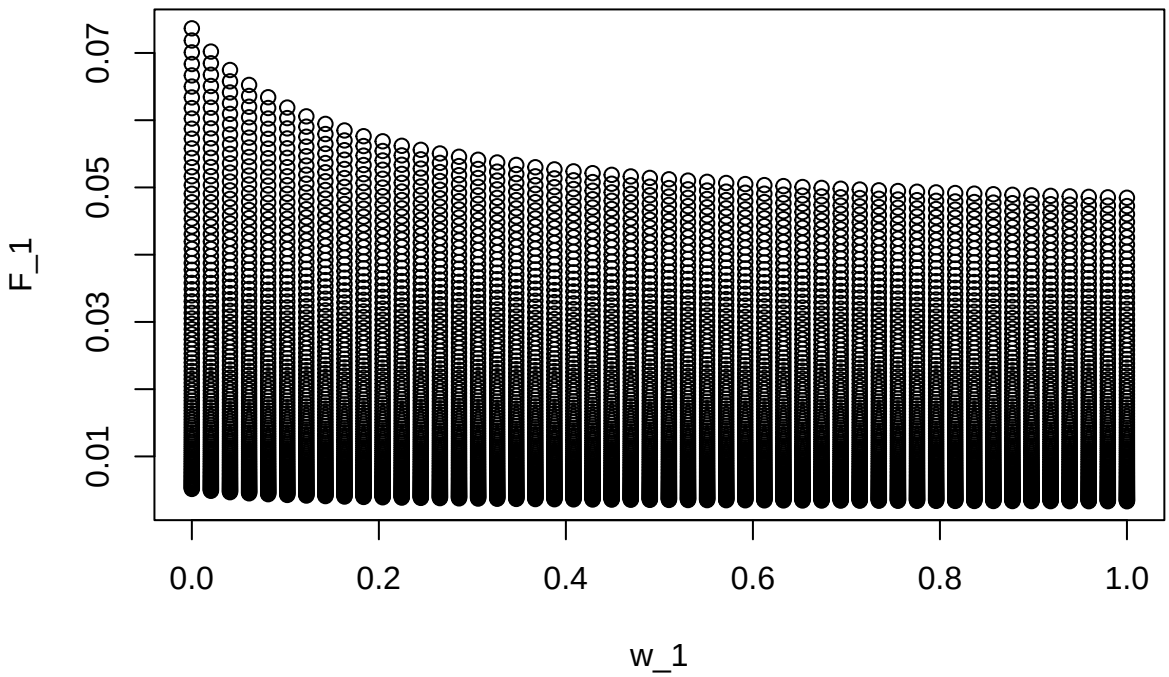
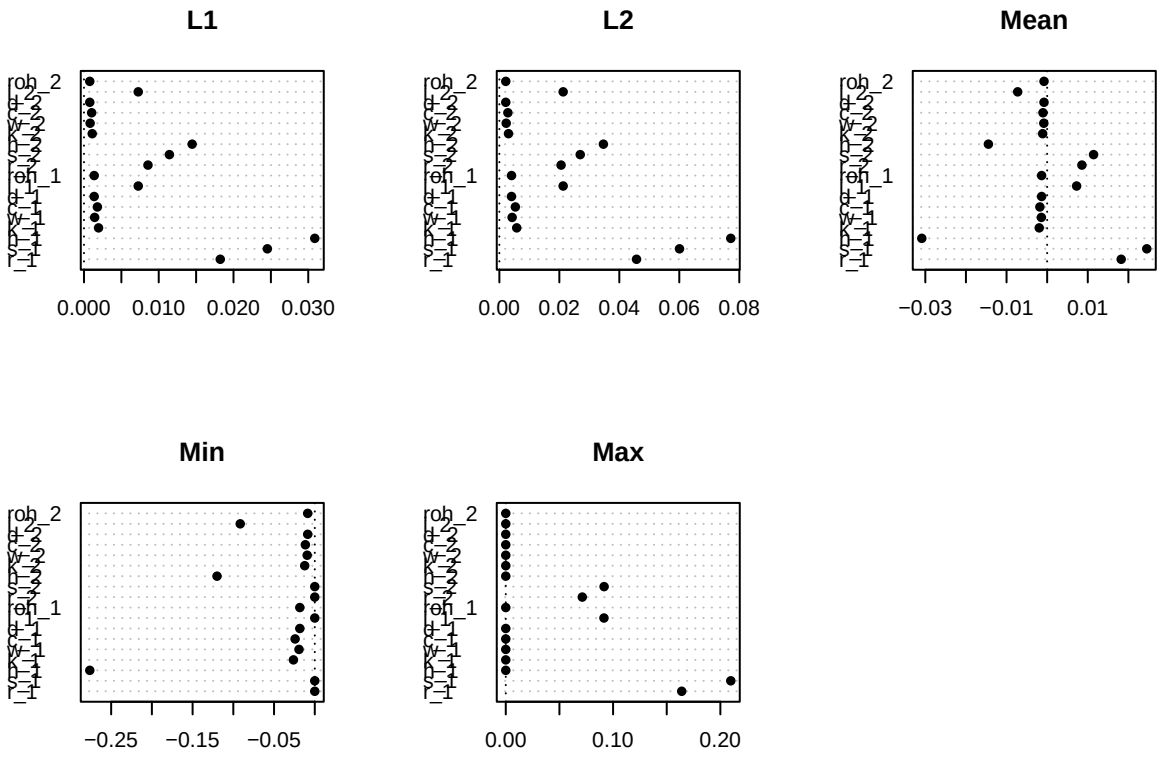
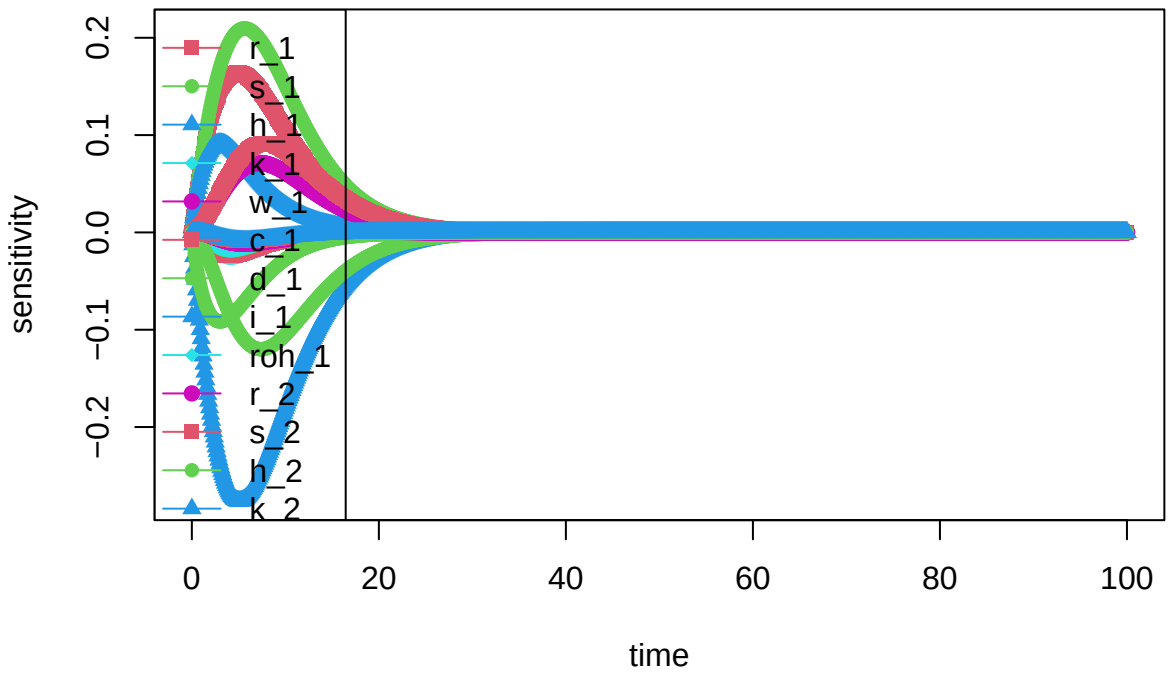


Figure out what this is doing - F1 appears to be going to fixed point

```
##        value scale      L1     L2     Mean     Min   Max    N
## r_1     0.35  0.35 0.01823 0.0457  0.01823  0.0000 0.164 1001
## s_1     0.80  0.80 0.02453 0.0601  0.02453  0.0000 0.210 1001
## h_1     0.50  0.50 0.03087 0.0772 -0.03087 -0.2763 0.000 1001
## k_1     1.01  1.01 0.00195 0.0058 -0.00195 -0.0262 0.000 1001
## w_1     0.35  0.35 0.00143 0.0043 -0.00143 -0.0193 0.000 1001
## c_1     1.50  1.50 0.00179 0.0053 -0.00179 -0.0242 0.000 1001
## d_1     0.50  0.50 0.00136 0.0041 -0.00136 -0.0183 0.000 1001
## i_1     0.20  0.20 0.00726 0.0213  0.00726  0.0000 0.092 1001
## roh_1   0.50  0.50 0.00136 0.0041 -0.00136 -0.0183 0.000 1001
## r_2     0.35  0.35 0.00856 0.0206  0.00856  0.0000 0.071 1001
## s_2     0.80  0.80 0.01143 0.0270  0.01143  0.0000 0.092 1001
## h_2     0.50  0.50 0.01447 0.0347 -0.01447 -0.1200 0.000 1001
## k_2     1.01  1.01 0.00110 0.0030 -0.00110 -0.0124 0.000 1001
## w_2     0.35  0.35 0.00082 0.0023 -0.00082 -0.0093 0.000 1001
## c_2     1.50  1.50 0.00103 0.0028 -0.00103 -0.0116 0.000 1001
## d_2     0.50  0.50 0.00077 0.0021 -0.00077 -0.0087 0.000 1001
## i_2     0.20  0.20 0.00726 0.0213 -0.00726 -0.0915 0.000 1001
## roh_2   0.50  0.50 0.00077 0.0021 -0.00077 -0.0087 0.000 1001
```



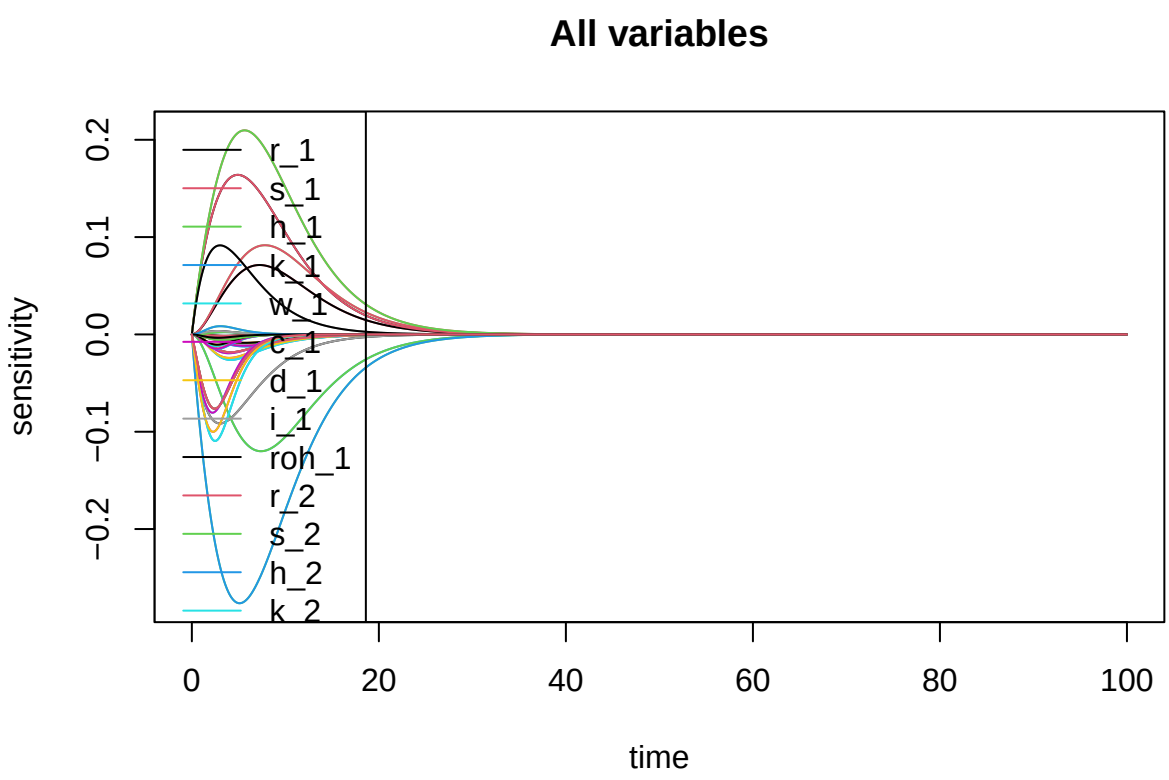
L1 (abs) and L2 (squared) refer to two different ways of calculating sensitivity from the fxn. Apparently L1 more robust because doesn't square/exacerbate outliers. Mean min and max all represent that of sensitivity fxn



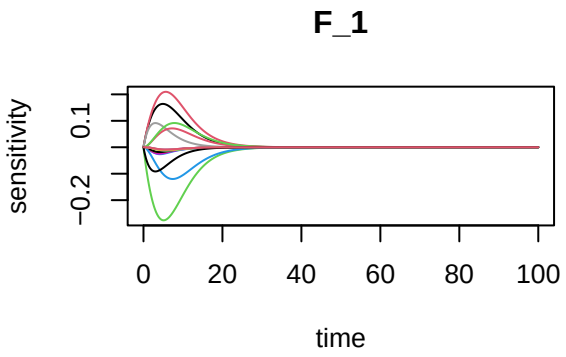
The sensitivity functions themselves. Is that normal for sensitivity to approach 0 for all params? What does that mean?

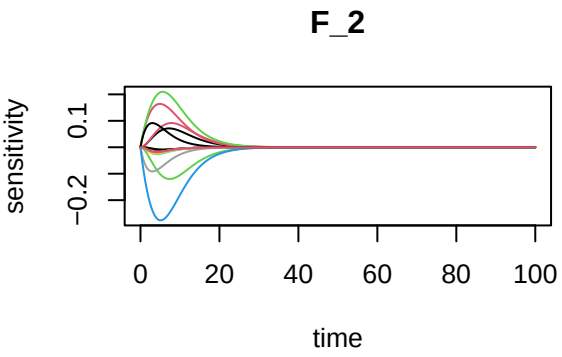
```
##        value scale      L1      L2     Mean     Min    Max    N var
## r_11    0.35  0.35 1.8e-02 0.04574  1.8e-02  0.0000 0.1640 1001 F_1
## r_12    0.35  0.35 8.6e-03 0.02058  8.6e-03  0.0000 0.0713 1001 F_2
## r_13    0.35  0.35 2.4e-04 0.00093 -2.4e-04 -0.0053 0.0000 1001 X_1
## r_14    0.35  0.35 6.8e-05 0.00026 -6.8e-05 -0.0015 0.0000 1001 X_2
## s_11    0.80  0.80 2.5e-02 0.06007  2.5e-02  0.0000 0.2097 1001 F_1
## s_12    0.80  0.80 1.1e-02 0.02697  1.1e-02  0.0000 0.0916 1001 F_2
## s_13    0.80  0.80 2.7e-04 0.00104 -2.7e-04 -0.0058 0.0000 1001 X_1
## s_14    0.80  0.80 7.5e-05 0.00029 -7.5e-05 -0.0016 0.0000 1001 X_2
## h_11    0.50  0.50 3.1e-02 0.07716 -3.1e-02 -0.2763 0.0000 1001 F_1
## h_12    0.50  0.50 1.4e-02 0.03469 -1.4e-02 -0.1200 0.0000 1001 F_2
## h_13    0.50  0.50 3.8e-04 0.00149  3.8e-04  0.0000 0.0084 1001 X_1
## h_14    0.50  0.50 1.1e-04 0.00041  1.1e-04  0.0000 0.0023 1001 X_2
## k_11    1.01  1.01 1.9e-03 0.00579 -1.9e-03 -0.0262 0.0000 1001 F_1
## k_12    1.01  1.01 1.1e-03 0.00304 -1.1e-03 -0.0124 0.0000 1001 F_2
## k_13    1.01  1.01 4.8e-03 0.01913 -4.8e-03 -0.1095 0.0000 1001 X_1
## k_14    1.01  1.01 5.7e-04 0.00243 -5.7e-04 -0.0149 0.0000 1001 X_2
## w_11    0.35  0.35 1.4e-03 0.00426 -1.4e-03 -0.0193 0.0000 1001 F_1
## w_12    0.35  0.35 8.2e-04 0.00228 -8.2e-04 -0.0093 0.0000 1001 F_2
## w_13    0.35  0.35 3.4e-03 0.01373 -3.4e-03 -0.0805 0.0000 1001 X_1
## w_14    0.35  0.35 4.5e-04 0.00193 -4.5e-04 -0.0120 0.0000 1001 X_2
## c_11    1.50  1.50 1.8e-03 0.00533 -1.8e-03 -0.0242 0.0000 1001 F_1
## c_12    1.50  1.50 1.0e-03 0.00284 -1.0e-03 -0.0116 0.0000 1001 F_2
## c_13    1.50  1.50 4.3e-03 0.01728 -4.3e-03 -0.1001 0.0000 1001 X_1
## c_14    1.50  1.50 5.6e-04 0.00237 -5.6e-04 -0.0147 0.0000 1001 X_2
## d_11    0.50  0.50 1.4e-03 0.00406 -1.4e-03 -0.0183 0.0000 1001 F_1
```

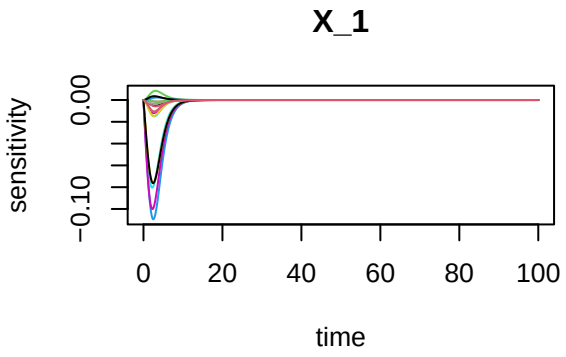
```
## d_12    0.50  0.50 7.7e-04 0.00214 -7.7e-04 -0.0087 0.0000 1001 F_2
## d_13    0.50  0.50 3.3e-03 0.01332 -3.3e-03 -0.0763 0.0000 1001 X_1
## d_14    0.50  0.50 4.1e-04 0.00172 -4.1e-04 -0.0106 0.0000 1001 X_2
## i_11    0.20  0.20 7.3e-03 0.02127  7.3e-03  0.0000 0.0915 1001 F_1
## i_12    0.20  0.20 7.3e-03 0.02127 -7.3e-03 -0.0915 0.0000 1001 F_2
## i_13    0.20  0.20 1.5e-04 0.00060 -1.5e-04 -0.0035 0.0000 1001 X_1
## i_14    0.20  0.20 1.5e-04 0.00060  1.5e-04  0.0000 0.0035 1001 X_2
## roh_11  0.50  0.50 1.4e-03 0.00406 -1.4e-03 -0.0183 0.0000 1001 F_1
## roh_12  0.50  0.50 7.7e-04 0.00214 -7.7e-04 -0.0087 0.0000 1001 F_2
## roh_13  0.50  0.50 3.3e-03 0.01332 -3.3e-03 -0.0763 0.0000 1001 X_1
## roh_14  0.50  0.50 4.1e-04 0.00172 -4.1e-04 -0.0106 0.0000 1001 X_2
## r_21    0.35  0.35 8.6e-03 0.02058  8.6e-03  0.0000 0.0713 1001 F_1
## r_22    0.35  0.35 1.8e-02 0.04574  1.8e-02  0.0000 0.1640 1001 F_2
## r_23    0.35  0.35 6.8e-05 0.00026 -6.8e-05 -0.0015 0.0000 1001 X_1
## r_24    0.35  0.35 2.4e-04 0.00093 -2.4e-04 -0.0053 0.0000 1001 X_2
## s_21    0.80  0.80 1.1e-02 0.02697  1.1e-02  0.0000 0.0916 1001 F_1
## s_22    0.80  0.80 2.5e-02 0.06007  2.5e-02  0.0000 0.2097 1001 F_2
## s_23    0.80  0.80 7.5e-05 0.00029 -7.5e-05 -0.0016 0.0000 1001 X_1
## s_24    0.80  0.80 2.7e-04 0.00104 -2.7e-04 -0.0058 0.0000 1001 X_2
## h_21    0.50  0.50 1.4e-02 0.03469 -1.4e-02 -0.1200 0.0000 1001 F_1
## h_22    0.50  0.50 3.1e-02 0.07716 -3.1e-02 -0.2763 0.0000 1001 F_2
## h_23    0.50  0.50 1.1e-04 0.00041  1.1e-04  0.0000 0.0023 1001 X_1
## h_24    0.50  0.50 3.8e-04 0.00149  3.8e-04  0.0000 0.0084 1001 X_2
## k_21    1.01  1.01 1.1e-03 0.00304 -1.1e-03 -0.0124 0.0000 1001 F_1
## k_22    1.01  1.01 1.9e-03 0.00579 -1.9e-03 -0.0262 0.0000 1001 F_2
## k_23    1.01  1.01 5.7e-04 0.00243 -5.7e-04 -0.0149 0.0000 1001 X_1
## k_24    1.01  1.01 4.8e-03 0.01913 -4.8e-03 -0.1095 0.0000 1001 X_2
## w_21    0.35  0.35 8.2e-04 0.00228 -8.2e-04 -0.0093 0.0000 1001 F_1
## w_22    0.35  0.35 1.4e-03 0.00426 -1.4e-03 -0.0193 0.0000 1001 F_2
## w_23    0.35  0.35 4.5e-04 0.00193 -4.5e-04 -0.0120 0.0000 1001 X_1
## w_24    0.35  0.35 3.4e-03 0.01373 -3.4e-03 -0.0805 0.0000 1001 X_2
## c_21    1.50  1.50 1.0e-03 0.00284 -1.0e-03 -0.0116 0.0000 1001 F_1
## c_22    1.50  1.50 1.8e-03 0.00533 -1.8e-03 -0.0242 0.0000 1001 F_2
## c_23    1.50  1.50 5.6e-04 0.00237 -5.6e-04 -0.0147 0.0000 1001 X_1
## c_24    1.50  1.50 4.3e-03 0.01728 -4.3e-03 -0.1001 0.0000 1001 X_2
## d_21    0.50  0.50 7.7e-04 0.00214 -7.7e-04 -0.0087 0.0000 1001 F_1
## d_22    0.50  0.50 1.4e-03 0.00406 -1.4e-03 -0.0183 0.0000 1001 F_2
## d_23    0.50  0.50 4.1e-04 0.00172 -4.1e-04 -0.0106 0.0000 1001 X_1
## d_24    0.50  0.50 3.3e-03 0.01332 -3.3e-03 -0.0763 0.0000 1001 X_2
## i_21    0.20  0.20 7.3e-03 0.02127 -7.3e-03 -0.0915 0.0000 1001 F_1
## i_22    0.20  0.20 7.3e-03 0.02127  7.3e-03  0.0000 0.0915 1001 F_2
## i_23    0.20  0.20 1.5e-04 0.00060  1.5e-04  0.0000 0.0035 1001 X_1
## i_24    0.20  0.20 1.5e-04 0.00060 -1.5e-04 -0.0035 0.0000 1001 X_2
## roh_21  0.50  0.50 7.7e-04 0.00214 -7.7e-04 -0.0087 0.0000 1001 F_1
## roh_22  0.50  0.50 1.4e-03 0.00406 -1.4e-03 -0.0183 0.0000 1001 F_2
## roh_23  0.50  0.50 4.1e-04 0.00172 -4.1e-04 -0.0106 0.0000 1001 X_1
## roh_24  0.50  0.50 3.3e-03 0.01332 -3.3e-03 -0.0763 0.0000 1001 X_2
```

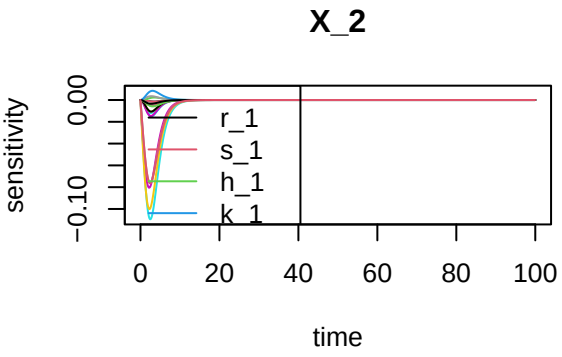


Same thing but this function you can explicitly say which variables you want to calc sensitivity for



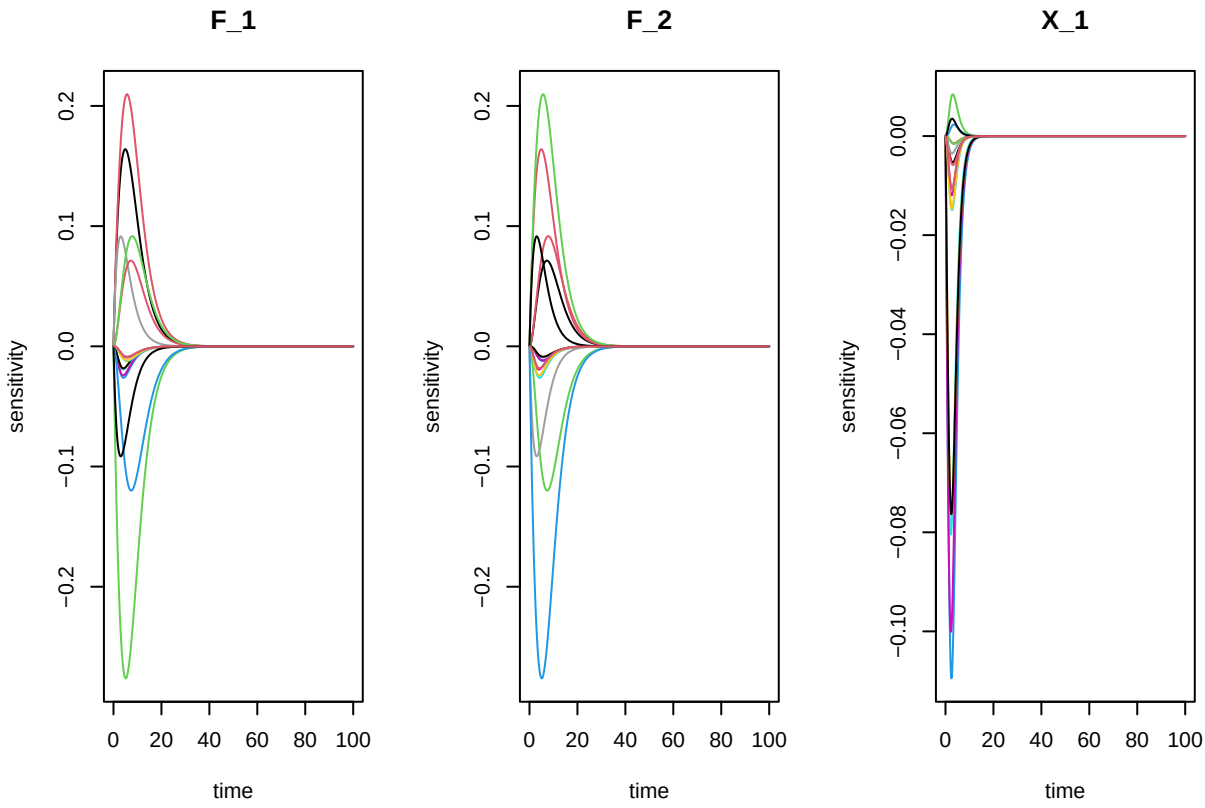


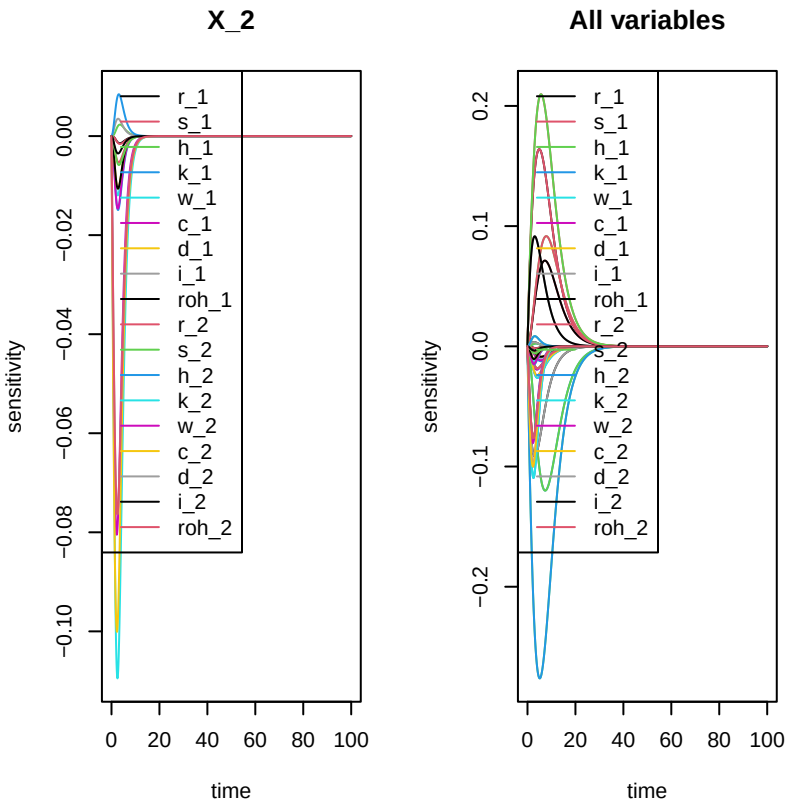




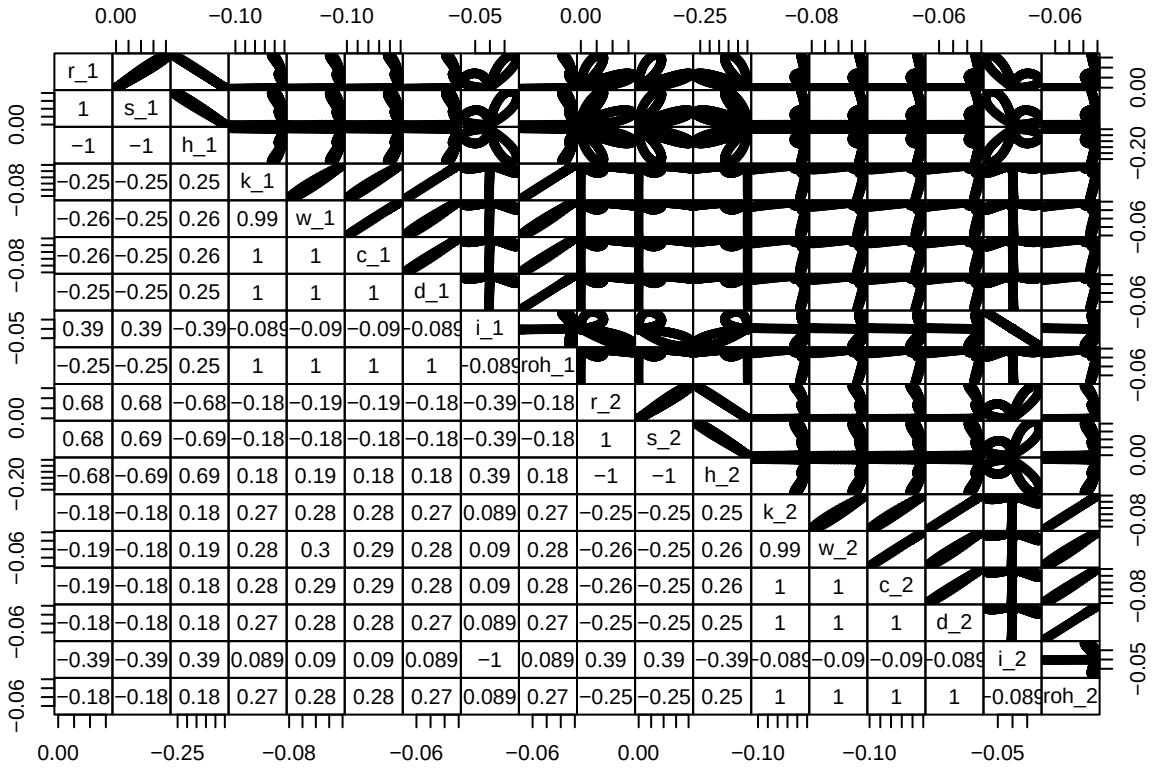
Sensitivy but split

interestging but need to have better understanding of what

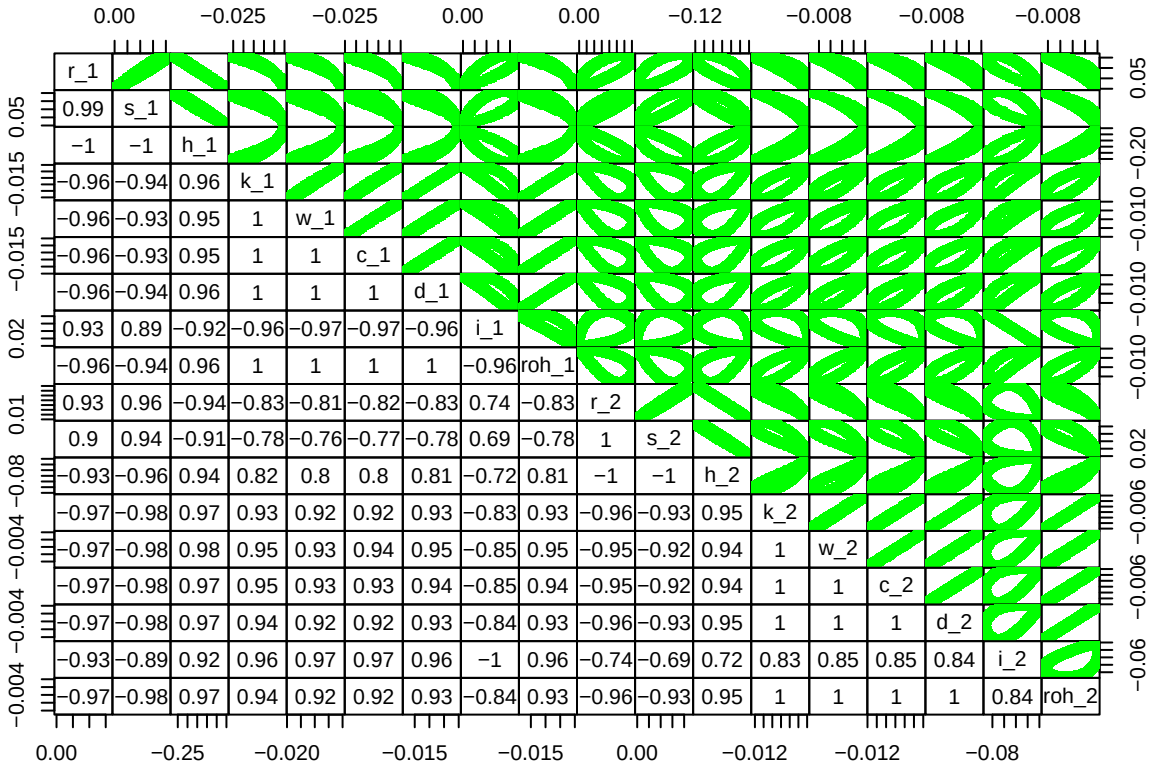

F_1
F_2
X_1
sensitivity
time
0.2
0.1
0.0
−0.1
−0.2
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
0
20
40
60
80
100



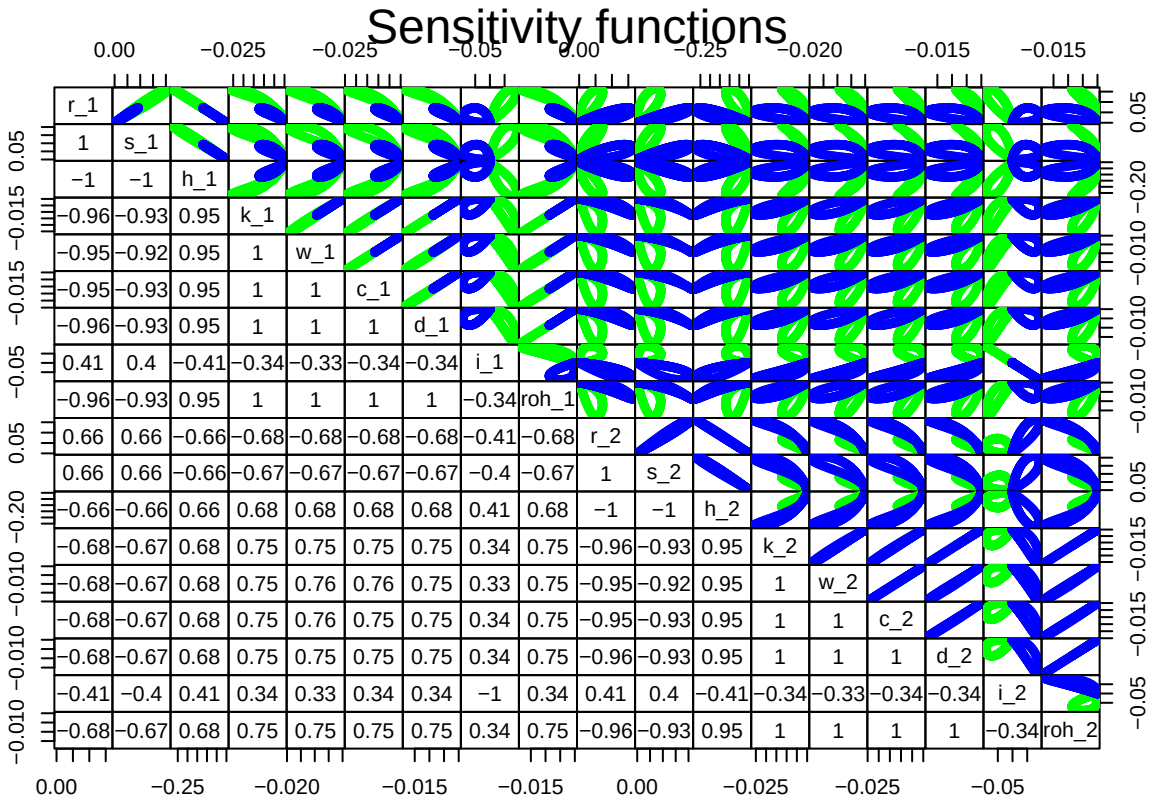
Really just different ways of coding the same thing



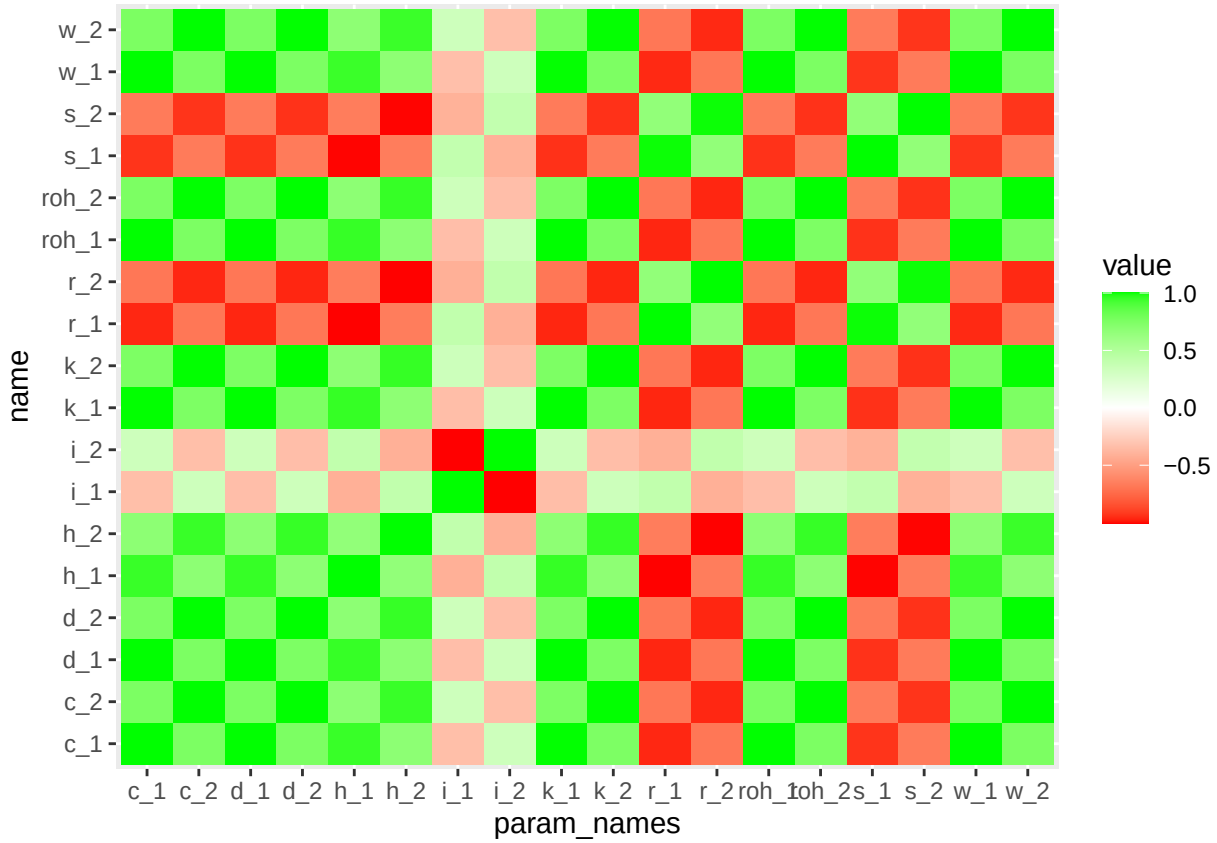
Bivariate sensitivity All vars



Bivariate sensitivity: F1



Bivariate sensitivity: F1 (green) and F2 (blue). TBH I have NO idea how to interpret these



Having a hard time interpreting this too

Table 3: Default parameter values used in this analysis

Parameter	Population_1	Population_2	Def
r	0.4	0.35	Fish net growth
s	0.8	0.8	Supply and demand
h	0.25	0.5	Harvesting efficiency
k	1.014	1.014	Social learning rate
ω	0.2	0.35	Conservation cost
c	1.5	1.5	Rarity valuation
d	0.5	0.5	Social norm strength (within pop)
i	0.2	0.2	Fish immigration (from patch)
ρ	0.5	0.5	Social norm strength (opposite pop)

Scenarios

One groups unsustainable practices can tank whole fishery;

params_socialr_1 < $-0.4 params_social r_2$ <- 0.4 params_socialw_1 < $-0.2 params_social w_2$ <- 0.2 params_socialh_1 < $-0.25 params_social h_2$ <- 0.25 Goes up

Vs.

params_socialr_1 < $-0.4 params_social r_2$ <- 0.35 params_socialw_1 < $-0.2 params_social w_2$ <- 0.35 params_socialh_1 < $-0.25 params_social h_2$ <- 0.5 Goes down

BUT increasing rarity val can save that params_social$c_1 < -0.25 params_social c_2 <- 0.25 Goes up

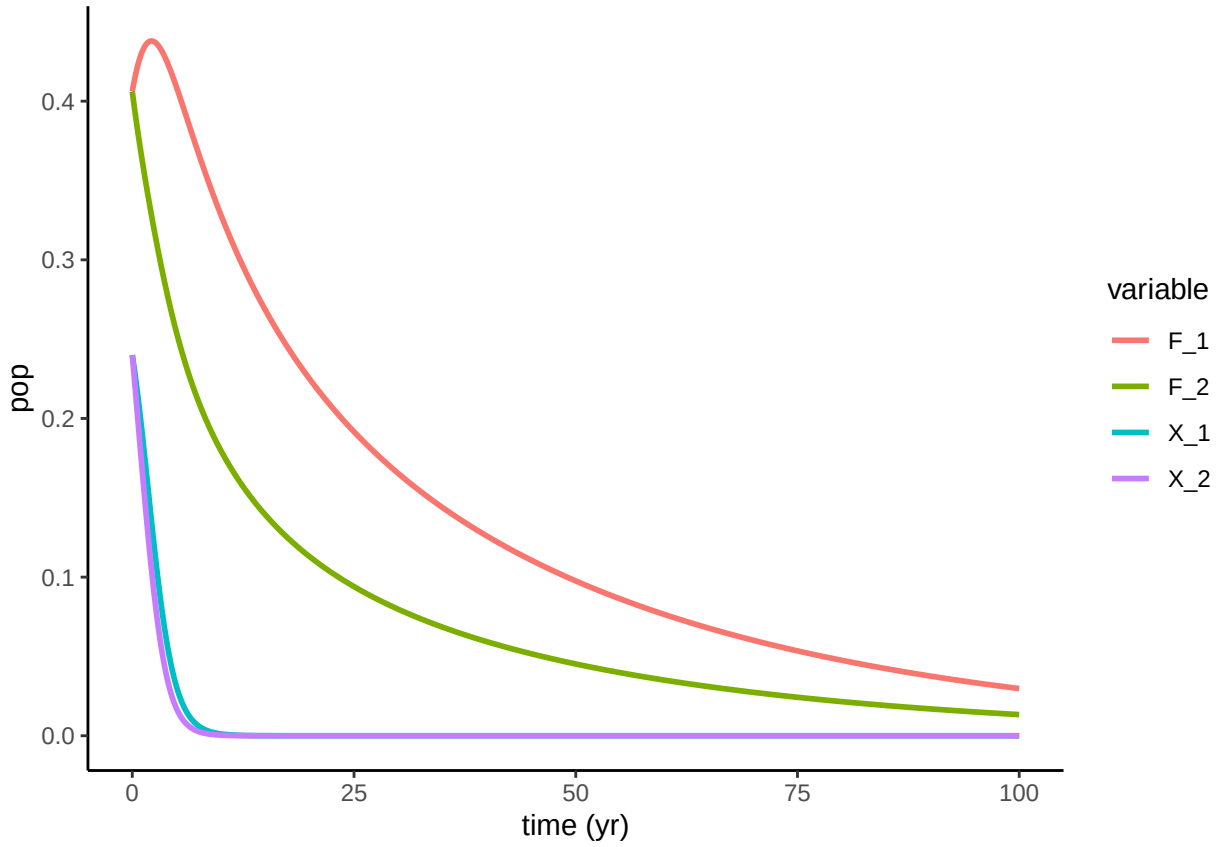


Figure 3: Social inequity scenario where roh_1 = 0.25 and h_1 = 1

- Bifurcation plots
- Sensitivity Analysis: d, roh, s, w, c, i
- Scenarios
- Stability and dynamics - Sigdel 2017 good example
- Go through bauch, thampi, and other papers to see what analysis ideas I can also apply
- Bauch 2012 does probabilistic sensitivity analysis (PSA). Also see supporting info
- Phase plane analysis in cressman 2004 and go through your own phase planes to find interesting dynamics

Things that are bugging me:
Can't seem to get any oscillations at all
D and rho just don't seem to matter that much