R Notebook

Analysis of equilibrium resonse to power law scaling behaviors, single-consumer resource case.

```
library(tidyverse)
```

```
dat <- read_csv('socio-eco-nw equilibrium-pop-table.csv', skip = 6) %>%
  select(alpha, beta, h = 3, Population = 12) %>%
  full_join((read_csv('socio-eco-nw equilibrium-bio-table.csv', skip = 6) %>%
  select(alpha, beta, Biomass = 12))) %>%
  mutate(Welfare = Biomass * h * Population^(beta-1)) %>%
  select(-h)
```

Find equilibrium values

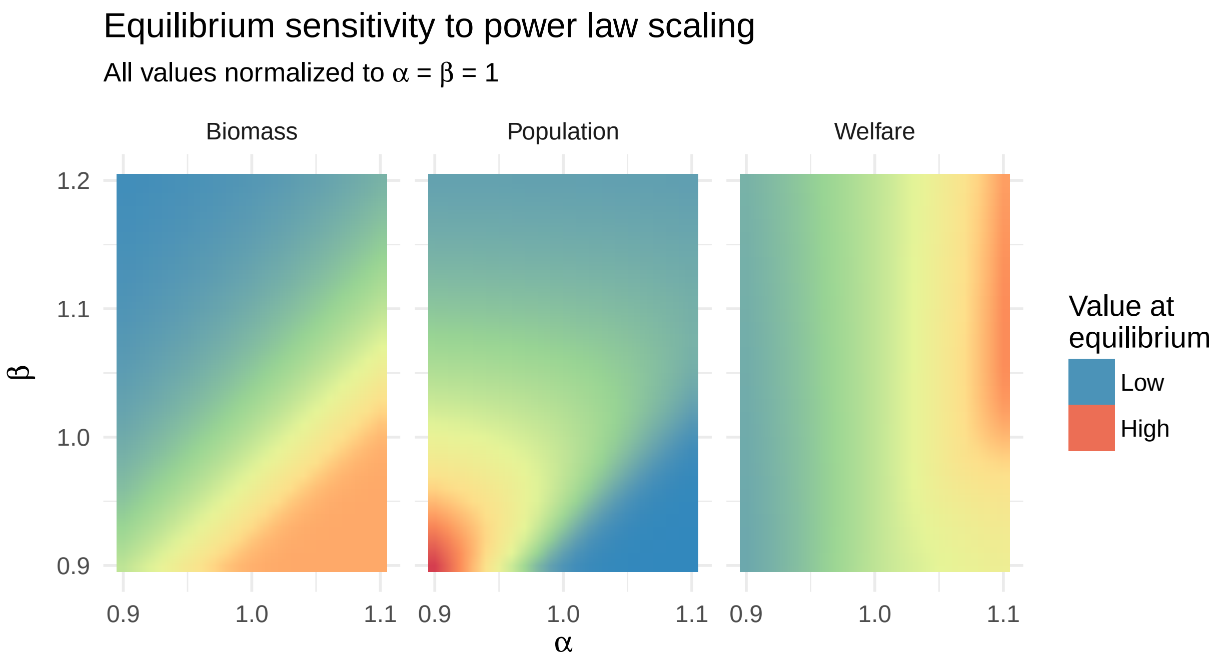
```
dat %>% filter(alpha == 1 & beta == 1) %>% select(3:5)
```

```
## # A tibble: 1 × 3
##   Population Biomass Welfare
##        <dbl>   <dbl>   <dbl>
## 1      60000     0.4   4e-07
```

Normalize data using equilibrium values

```
dat.norm <- dat %>%
  mutate(Population = Population / 60000, Biomass = Biomass / .4, Welfare = Welfare / 4e-07)
```

```
dat.norm %>% gather(variable, value, Population:Welfare) %>%
  ggplot(aes(alpha, beta, fill = value)) +
    facet_wrap(~variable) +
    geom_raster(interpolate = T) +
    labs(title = 'Equilibrium sensitivity to power law scaling', subtitle = expression('All values norma
    scale_fill_distiller(name = 'Value at \nequilibrium', palette = 'Spectral', guide = 'legend', breaks
    scale_x_continuous(breaks = c(.9, 1, 1.1)) +
    coord_equal() +
    theme_minimal()
```

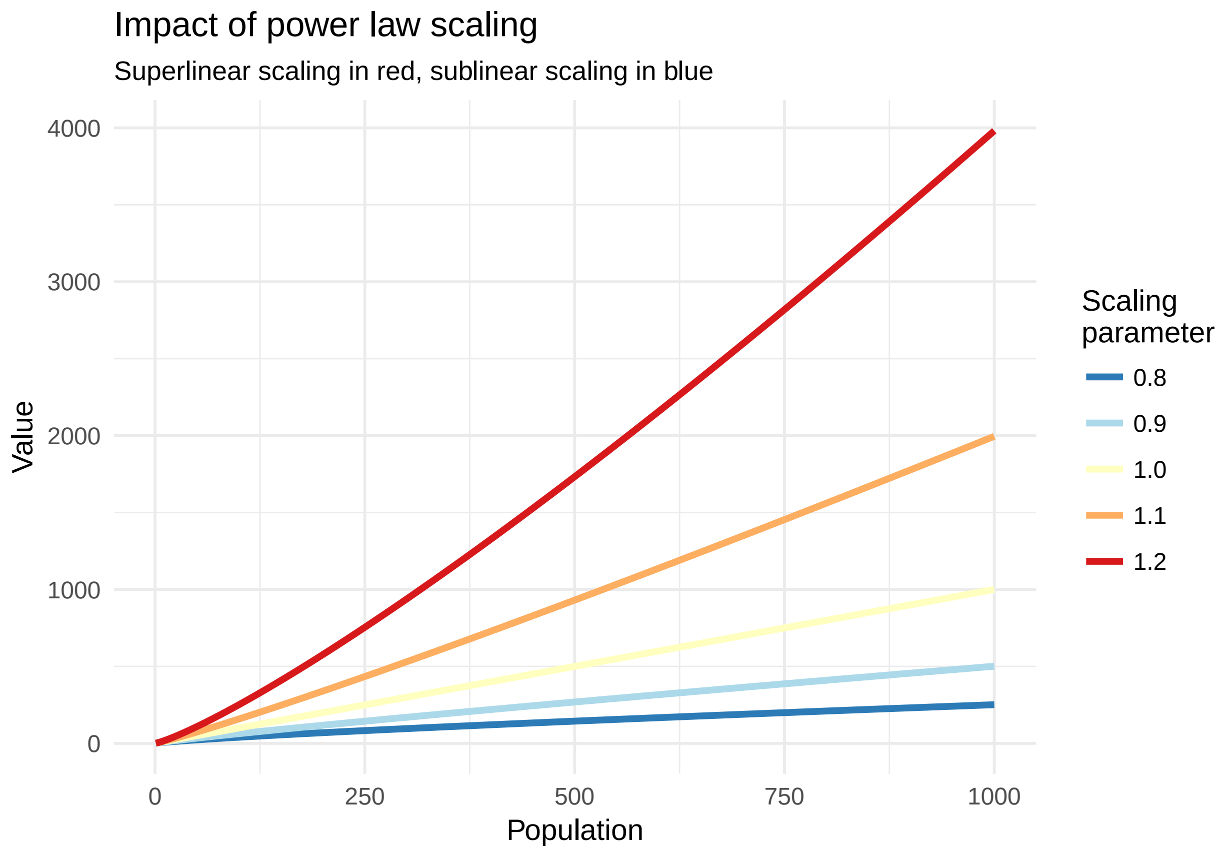


In natural language, resource biomass is highest when higher population leads to declining marignal returns to harvest

alpha beta plots

plots of how different exponents effect population size

```
dat <- data_frame(n = 1:1000) %>%
  mutate('0.8' = n^.8,
         '0.9' = n^.9,
         '1.0' = n^1,
         '1.1' = n^1.1,
         '1.2' = n^1.2) %>%
  gather(key, value, 2:6)

ggplot(dat, aes(x = n, y = value, color = key)) +
  geom_line(size = 1.2) +
  labs(title = 'Impact of power law scaling', subtitle = 'Superlinear scaling in red, sublinear scaling
  scale_color_brewer(palette = 'RdYlBu', direction = -1, name = 'Scaling \nparameter') +
  theme_minimal()
```



network plots

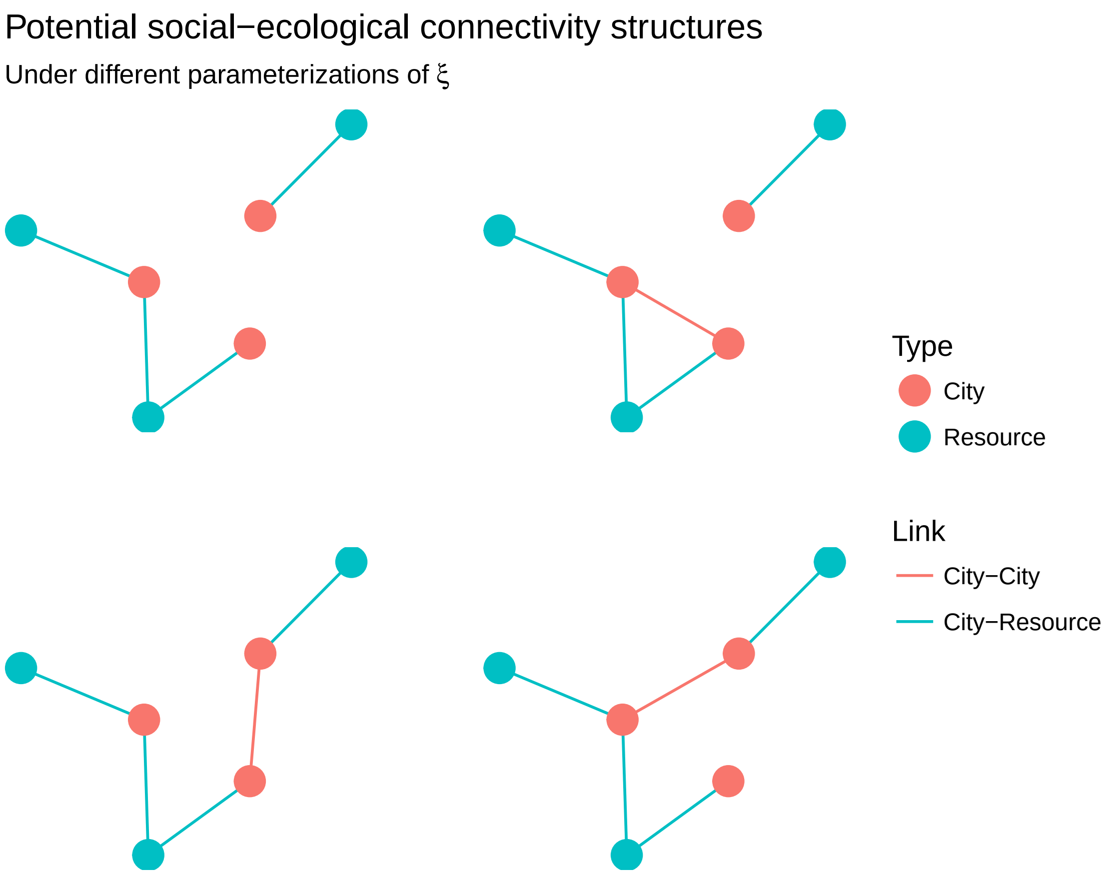
simple plots of networks

```
library(ggraph)
library(igraph)
```

```
##
## Attaching package: 'igraph'

## The following objects are masked from 'package:dplyr':
##
##     %>%, as_data_frame, groups, union

## The following objects are masked from 'package:purrr':
##
##     %>%, compose, simplify

## The following objects are masked from 'package:tidyr':
##
##     %>%, crossing

## The following object is masked from 'package:tibble':
##
##     as_data_frame

## The following objects are masked from 'package:stats':
##
##     decompose, spectrum
```

```
## The following object is masked from 'package:base':
##
##     union
```

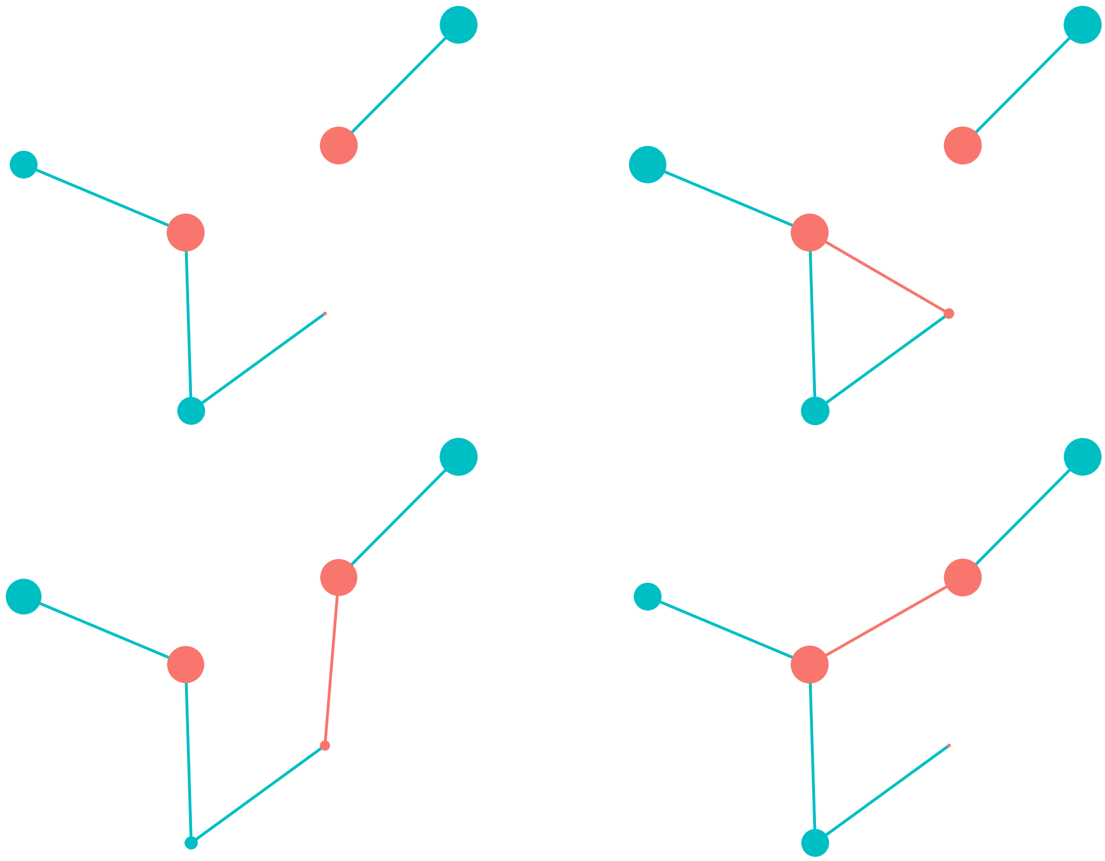
```
vert.dat <- data_frame(names = 1:6, Type = c('City', 'City', 'City', 'Resource', 'Resource', 'Resource'

net <- data_frame(from = c(1, 1, 2, 3, 1, 1, 2, 3, 1, 1, 1, 2, 3, 2, 1, 1, 2, 3, 1),
          to = c(4, 5, 5, 6, 4, 5, 5, 6, 2, 4, 5, 5, 6, 3, 4, 5, 5, 6, 3),
          structure = c(1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4),
          Link = c('City-Resource', 'City-Resource', 'City-Resource', 'City-Resource', 'City-Resource'

ggraph(net, 'kk') +
  geom_edge_fan(aes(color = Link)) +
  geom_node_point(aes(color = Type), size = 5) +
  facet_edges(~structure) +
  labs(title = 'Potential social-ecological connectivity structures', subtitle = expression('Under diff
  coord_equal() +
  theme_void() +
  theme(panel.spacing = unit(3, "lines"), strip.text = element_blank())
```




```
#dat %>% filter(alpha == .9 & beta == 1.2) %>% select(3:5)

n1.vert <- data_frame(names = 1:6,
                      Type = c('City', 'City', 'City', 'Resource', 'Resource', 'Resource'),
                      pop = c(c(14540, 0, 14401)/14400.75, c(.0113,.0113,.0226)/.0226227))

n1 <- data_frame(from = c(1, 1, 2, 3),
          to = c(4, 5, 5, 6),
```

```
           Link = c('City-Resource', 'City-Resource', 'City-Resource', 'City-Resource')) %>% graph_from_

orig.layout <- create_layout(net, 'kk') %>%
  select(x:y)

n1.layout <- create_layout(n1, 'kk')
n1.layout[,1] <-  orig.layout[,1]
n1.layout[,2] <- orig.layout[,2]

n1.plt <- ggraph(n1.layout, layout = my.layout) +
  geom_edge_fan(colour = '#00BFC4') +
  geom_node_point(aes(color = Type, size = pop)) +
  scale_size_area() +
  coord_equal() +
  theme_void() +
  theme(legend.position = 'none')

n2.vert <- data_frame(names = 1:6,
                      Type = c('City', 'City', 'City', 'Resource', 'Resource', 'Resource'),
                      pop = c(c(14409, 565, 14401)/14400.75, c(.0219, .0119,.0226)/.0226227))

n2 <- data_frame(from = c(1, 1, 2, 3, 1),
           to = c(4, 5, 5, 6, 2),
           Link = c('City-Resource', 'City-Resource', 'City-Resource', 'City-Resource', 'City-City')) %

n2.layout <- create_layout(n2, 'kk')
n2.layout[,1] <-  orig.layout[,1]
n2.layout[,2] <- orig.layout[,2]

n2.plt <- ggraph(n2.layout) +
  geom_edge_fan(aes(color = Link)) +
  geom_node_point(aes(color = Type, size = pop)) +
  scale_size_area() +
  coord_equal() +
  theme_void() +
  theme(legend.position = 'none')

n3.vert <- data_frame(names = 1:6,
                      Type = c('City', 'City', 'City', 'Resource', 'Resource', 'Resource'),
                      pop = c(c(14423, 540, 14387)/14400.75, c(.0208, .0018, .0238)/.0226227))

n3 <- data_frame(from = c(1, 1, 2, 3, 2),
           to = c(4, 5, 5, 6, 3),
           Link = c('City-Resource', 'City-Resource', 'City-Resource', 'City-Resource', 'City-City')) %

n3.layout <- create_layout(n3, 'kk')
n3.layout[,1] <-  orig.layout[,1]
n3.layout[,2] <- orig.layout[,2]

n3.plt <- ggraph(n3.layout) +
  geom_edge_fan(aes(color = Link)) +
  geom_node_point(aes(color = Type, size = pop)) +
  scale_size_area() +
  coord_equal() +
  theme_void() +
```

```
  theme(legend.position = 'none')

n4.vert <- data_frame(names = 1:6,
                      Type = c('City', 'City', 'City', 'Resource', 'Resource', 'Resource'),
                      pop = c(c(14539, 0, 14402)/14400.75, c(.0113, .0113, .0225)/.0226227))

n4 <- data_frame(from = c(1, 1, 2, 3, 1),
           to = c(4, 5, 5, 6, 3),
           Link = c('City-Resource', 'City-Resource', 'City-Resource', 'City-Resource', 'City-City')) %

n4.layout <- create_layout(n4, 'kk')
n4.layout[,1] <-  orig.layout[,1]
n4.layout[,2] <- orig.layout[,2]

n4.plt <- ggraph(n4.layout) +
  geom_edge_fan(aes(color = Link)) +
  geom_node_point(aes(color = Type, size = pop)) +
  scale_size_area() +
  coord_equal() +
  theme_void() +
  theme(legend.position = 'none')

library(gridExtra)

##
## Attaching package: 'gridExtra'

## The following object is masked from 'package:dplyr':
##
##     combine

grid.arrange(n1.plt, n2.plt, n3.plt, n4.plt)
```



```
gg_color_hue <- function(n){
  hues = seq(15, 375, length = n+1)
  hcl(h = hues, l = 65, c = 100)[1:n]
}
gg_color_hue(2)
```

```
## [1] "#F8766D" "#00BFC4"
```