Replication Document

Francesco Bailo

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Paper details

Packages

```
library(igraph)
library(truncnorm)
library(openssl)
library(data.table)
library(parallel)
library(knitr)
library(ggplot2)
library(scales)
library(DBI)
library(RSQLite)
library(rjson)
library(geosphere)
library(rgdal)
library(sp)
library(sf)
library(rgeos)
library(dplyr)
library(gridExtra)
library(scales)
library(egg)
library(srvyr)
library(stargazer)
library(reshape2)
library(intergraph)
library(statnet)
library(ergm)
library(rgeos)
library(stringr)
library(texreg)
library(RColorBrewer)
library(knitr)
```

Functions

```
sqliteGetTable <- function(database, table) {
  require(DBI)
  require(RSQLite)
  con <- dbConnect(RSQLite::SQLite(), dbname = database)
  query <- dbSendQuery(con, paste("SELECT * FROM ", table, ";", sep=""))
```

```
  result <- fetch(query, n = -1)
  dbClearResult(query)
  dbDisconnect(con)
  return(result)
}

addDegreeToVertices <- function (g) {
  require(igraph)
  try(if(!(is.igraph(g))) stop("Not an igraph graph"))
  if (is_directed(g)) {
    V(g)$indegree <- igraph::degree(g, V(g), mode = 'in')
    V(g)$outdegree <- igraph::degree(g, V(g), mode = 'out')
  } else {
    try(if('degree' %in% igraph::list.vertex.attributes(g))
      stop("Vertex attribure degree already exists"))
    V(g)$degree <- igraph::degree(g, V(g))
  }
  return(g)
}

vertexAttributesAsDataFrame <- function(g) {
  try(if(!(is.igraph(g))) stop("Not an igraph graph"))
  vertex_attributes <- igraph::list.vertex.attributes(g)
  df <- data.frame(matrix(NA, nrow = vcount(g), ncol = 0))
  for (a in vertex_attributes) {
    df <- cbind(df, data.frame(igraph::get.vertex.attribute(g, a)))
  }
  names(df) <- igraph::list.vertex.attributes(g)
  return(df)
}
```

Network and diffusion models

Network setup functions

```
read_chunk('replication_code_01_simulation_functions.R')
```

```
truncatedProp <- function(n, mean, sd = .25) {
  require(truncnorm)
  return(rtruncnorm(n=n, a=0, b=1, mean=mean, sd = sd))
}

randomSocialNetwork <- function(n_communities, g_size, min_comm_size,
                                within_p, between_p) {

  if(n_communities>20) stop("Up to 20 communities")

  library(igraph)
  library(openssl)

  g_list <- list()
```

```
  default_comm_size <- g_size / n_communities
  comm_sizes <- rep(default_comm_size, n_communities)

  # Randomise community size
  isOdd <- function(x) {x %% 2 != 0}
  for (i in 1:n_communities) {
    if (isOdd(i)) {
      if (i == n_communities) next
      this_change <-
        sample(-abs(default_comm_size-min_comm_size):abs(default_comm_size-min_comm_size),
               1)
      comm_sizes[i] <- comm_sizes[i] + this_change
      last_change <- -this_change
    } else {
      comm_sizes[i] <- comm_sizes[i] + last_change
    }
  }

  for (i in 1:n_communities) {
    # print(paste0(i, " ", comm_sizes[i]))
    g_list[[i]] <- random.graph.game(comm_sizes[i], within_p)
    V(g_list[[i]])$community <- LETTERS[i]
    V(g_list[[i]])$name <- paste0(LETTERS[i], 1:vcount(g_list[[i]]))
  }

  g <- do.call(disjoint_union, g_list)
  v_communities <- V(g)$community
  g_mat <- as_adj(g)
  from_is <- c(1,cumsum(comm_sizes)+1)
  from_is <- from_is[1:n_communities]
  to_is <- cumsum(comm_sizes)
  is <- mapply(seq, from_is, to_is, by = 1)
  for (i in 1:n_communities) {
    g_mat[is[[i]], unlist(is[which(1:n_communities != i)])] <-
      rbinom(n=length(as.numeric(g_mat[is[[i]],
                                       unlist(is[which(1:n_communities != i)])])),
             size=1, prob=between_p)
  }
  g <- graph.adjacency(g_mat, mode = 'undirected')
  V(g)$community <- v_communities
  return(g)
}

activationProb <- function(political_distress,
                           internal_drive, relational_drive, universal_drive,
                           neighborhood, i) {
  p <-
    1/2 * (political_distress * internal_drive) +
    1/2 * (political_distress * (relational_drive ^ (1/neighborhood)))
  return(p)
}

addSCNet <- function(g, prob = .3, mean = 1, sd = .25) {
```

```
  nodes <- V(g)$name[V(g)$internal_drive == 1]
  comb_nodes <- combn(nodes, 2)
  comb_nodes <- comb_nodes[,as.logical(rbinom(ncol(comb_nodes), size = 1, prob))]
  g <- g + edges(as.character(comb_nodes))
  g <- simplify(g)
  edge_attr(g, 'weight', get.edge.ids(g, as.character(comb_nodes))) <-
    trunctedProp(ncol(comb_nodes), mean=1, sd = .1)
  return(g)
}

getWeightedNeigh <- function(neigh, g) {
  len <- length(neigh)
  if (len == 1) return(0)
  ego <- neigh$name[1]
  neighbors <- neigh$name[2:len]
  active <- neigh$active[2:len]
  ids <- get.edge.ids(g, as.vector(rbind(rep(ego, len-1), neighbors)))
  weight <- edge_attr(g, name = 'weight', index = ids)
  return(weighted.mean(active, weight))
}

updateNetwork <- function(g, i, stay_active = TRUE, reset_each = NULL) {
  neigh_list <- neighborhood(g, order = 1)
  neigh <- unlist(lapply(neigh_list, getWeightedNeigh, g))
  neigh[is.na(neigh)] <- 0
  prob <- activationProb(V(g)$political_distress,
                         V(g)$internal_drive,
                         V(g)$relational_drive,
                         V(g)$universal_drive,
                         neigh, i)
  active <- as.logical(rbinom(vcount(g), size = 1, p = prob))
  if (stay_active == TRUE) {
    active[V(g)$active == TRUE] <- TRUE
  } else {
    active[V(g)$active == TRUE & V(g)$past < reset_each] <- TRUE
  }
  past <- ifelse(active == FALSE, 0, V(g)$past + active)
  return(list('active' = active, 'past' = past))
}

doNetSim <- function(i, g, path = NULL, print = FALSE) {
  if(i > 1) {
    res <- updateNetwork(g, i, stay_active = T)
    V(g)$active <- res[['active']]
    V(g)$past <- res[['past']]
  }
  if (print == TRUE) {
    jpeg(file = paste0(path, sprintf('%03d.jpg', i)),
         width = 2500, height = 2500)
    par(mar=c(0,0,4,0))
    plot(g, vertex.label = NA, vertex.size = 4, layout = g_lo,
         vertex.color = ifelse(V(g)$active, "black", "white"))
    title(main = paste0("Time: ", i,
```

```
                        "     Activation: ",
                        round(sum(V(g)$active) / vcount(g) *100, 2),
                        "%"),
          cex.main = 6)
    dev.off()
  }
  return(list(graph = g, activation = sum(V(g)$active) / vcount(g)))
}
```

Network initialisation

```
set.seed(28100)

g <- randomSocialNetwork(n_communities = 20, g_size = 490, min_comm_size = 15,
                         within_p = .115, between_p = 0.00005)
g_lo <- layout.fruchterman.reingold(g)

# Node attributes
V(g)$political_distress <- tructedProp(vcount(g), mean=.5, sd = .2)
V(g)$internal_drive_wtout_internet <- rbinom(vcount(g), 1, p = 0.1)
V(g)$internal_drive_wt_internet <- rbinom(vcount(g), 1, p = 0.5)
V(g)$relational_drive <- tructedProp(vcount(g), mean=.2, sd = .2)

# Edge attributes
E(g)$weight_sc <- tructedProp(ecount(g), mean=.6, sd = .15)
E(g)$weight_nosc <- tructedProp(ecount(g), mean=.2, sd = .15)

# Penalise cross-community edges
es <- as_edgelist(g)
es[,1] <- gsub("\\d", "", es[,1])
es[,2] <- gsub("\\d", "", es[,2])
is_same_comm <- es[,1] == es[,2]

E(g)$weight_nosc[!is_same_comm] <-
  tructedProp(sum(!is_same_comm), mean=0, sd = .15)

# Initialise
V(g)$active <- FALSE

# Create high social capital network
V(g)$internal_drive <- V(g)$internal_drive_wtout_internet
g_wt_sc_net <- addSCNet(g)

# Number of nodes
vcount(g)
```

```
## [1] 490
```

```
# Numebr of Edges
ecount(g)
```

```
## [1] 684
```

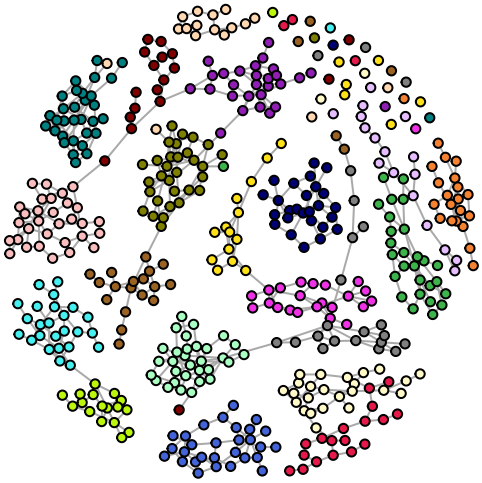
```r
# Percentage of edges running within a predefined social knot
el <- as_edgelist(g)
sum(gsub("\\d","", el[,1]) == gsub("\\d","", el[,2])) / nrow(el)
```

```
## [1] 0.9780702
```

```r
save(g, g_lo, file = "replication_file_01_simulated_net.RData")
```

Figure 1

```r
# Model network
colpal <- c('#e6194b', '#3cb44b', '#ffe119', '#4363d8', '#f58231',
            '#911eb4', '#46f0f0', '#f032e6', '#bcf60c', '#fabebe',
            '#008080', '#e6beff', '#9a6324', '#fffac8', '#800000',
            '#aaffc3', '#808000', '#ffd8b1', '#000075', '#808080',
            '#ffffff', '#000000')

plot(g, vertex.label = NA, vertex.size = 4, layout = g_lo,
     vertex.color = colpal[as.numeric(as.factor(V(g)$community))])
```

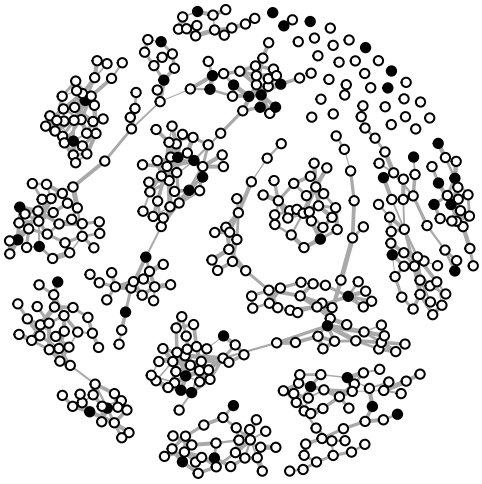


```r
pdf(file = "figure/network-model.pdf")
par(mar=c(0,0,0,0))
plot(g, vertex.label = NA, vertex.size = 4, layout = g_lo,
     vertex.color = colpal[as.numeric(as.factor(V(g)$community))])
dev.off()
```

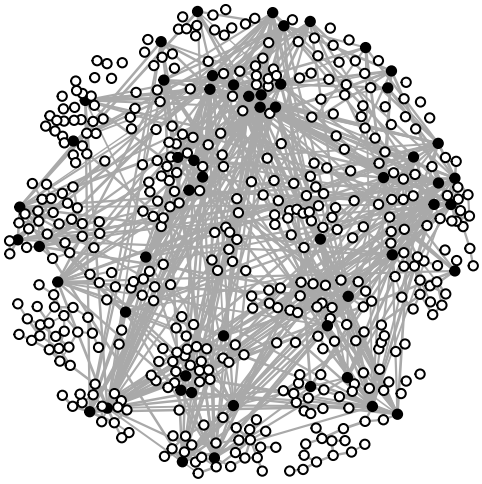
```
## pdf
##   2
```

Figure 2

```r
plot(g, vertex.label = NA, vertex.size = 4, layout = g_lo,
     vertex.color = ifelse(V(g)$internal_drive == 1, "black", "white"),
     edge.width = sqrt(E(g)$weight_nosc)*3.5)
```



```
plot(g_wt_sc_net, vertex.label = NA, vertex.size = 4, layout = g_lo,
     vertex.color = ifelse(V(g)$internal_drive == 1, "black", "white"),
     edge.width = sqrt(E(g)$weight_sc)*1.5)
```



```
pdf(file = "figure/network-model-low-high-capital.pdf",
    width  = 16, height = 7)
par(mar=c(0,0,0,0), mfrow=c(1,2))
plot(g, vertex.label = NA, vertex.size = 4, layout = g_lo,
     vertex.color = ifelse(V(g)$internal_drive == 1, "black", "white"),
     edge.width = sqrt(E(g)$weight_nosc)*3.5)
plot(g_wt_sc_net, vertex.label = NA, vertex.size = 4, layout = g_lo,
     vertex.color = ifelse(V(g)$internal_drive == 1, "black", "white"),
     edge.width = sqrt(E(g)$weight_sc)*1.5)
dev.off()
```

```
## pdf
##   2
```

Network simulation

```
read_chunk('replication_code_02_simulate_diffusion.R')
```

```r
library(parallel)
library(igraph)
library(data.table)

load("replication_file_01_simulated_net.RData")

no_cores <- detectCores() - 1
cl <- makeCluster(no_cores)

fun4Parallel <- function(j, sc_bin, internet_bin, save_plots = FALSE) {

  library(igraph)
  library(data.table)

  g <- randomSocialNetwork(n_communities = 20, g_size = 490, min_comm_size = 15,
                           within_p = .115, between_p = 0.00005)
  g_lo <- layout.fruchterman.reingold(g)

  # Node attributes
  V(g)$political_distress <- trunctedProp(vcount(g), mean=.5, sd = .2)
  V(g)$internal_drive_wtout_internet <- rbinom(vcount(g), 1, p = 0.1)
  V(g)$internal_drive_wt_internet <- rbinom(vcount(g), 1, p = 0.5)
  V(g)$relational_drive <- trunctedProp(vcount(g), mean=.2, sd = .2)

  # Edge attributes
  E(g)$weight_sc <- trunctedProp(ecount(g), mean=.6, sd = .15)
  E(g)$weight_nosc <- trunctedProp(ecount(g), mean=.2, sd = .15)

  # Penalise cross-community edges
  es <- as_edgelist(g)
  es[,1] <- gsub("\\d", "", es[,1])
  es[,2] <- gsub("\\d", "", es[,2])
  is_same_comm <- es[,1] == es[,2]

  E(g)$weight_nosc[!is_same_comm] <-
    trunctedProp(sum(!is_same_comm), mean=0, sd = .15)

  # Initialise
  V(g)$active <- FALSE

  V(g)$active <- FALSE

  # The network structure (edges) is determined by `internal_drive_wtout_internet` also
  # for the Internet scenario.
  V(g)$internal_drive <- V(g)$internal_drive_wtout_internet

  if (sc_bin == TRUE) {
    E(g)$weight <- E(g)$weight_sc
    g <- addSCNet(g)
  } else {
    E(g)$weight <- E(g)$weight_nosc
  }
```

```
  if (internet_bin == TRUE) {
    V(g)$internal_drive <- V(g)$internal_drive_wt_internet
  } else {
    V(g)$internal_drive <- V(g)$internal_drive_wtout_internet
  }

  what <- ifelse(sc_bin, "wt sc", "wtout sc")
  path <- ifelse(sc_bin, "sim_wt_sc", "sim_wtout_sc")
  if (internet_bin == TRUE) {
    what <- paste0(what, " wt internet")
    path <- paste0(path, "_wt_internet/")
  } else {
    what <- paste0(what, " wtout internet")
    path <- paste0(path, "_wtout_internet/")
  }
  this_dt <- data.table()
  for (i in 1:1000) {
    res <- doNetSim(i, g)
    g <- res$graph
    if (save_plots == TRUE) {
      jpeg(file = paste0(path, sprintf('%03d.jpg', i)),
           width = 2500, height = 2500)
      par(mar=c(0,0,4,0))
      plot(g, vertex.label = NA, vertex.size = 4, layout = g_lo,
           vertex.color = ifelse(V(g)$active, "black", "white"))
      title(main = paste0("Time: ", i,
                          "     Activation: ",
                          round(sum(V(g)$active) / vcount(g) *100, 2),
                          "%"),
            cex.main = 6)
      dev.off()
    }
    this_dt <- rbind(this_dt,
                     data.table(activation = res$activation,
                                t = i,
                                j,
                                what = what))
  }
  return(this_dt)
}
X <- lsf.str()
clusterExport(cl=cl, varlist=c(as.vector(X)), envir=environment())

print('active_nodes_wt_sc_wtout_internet')
active_nodes_wt_sc_wtout_internet <-
  rbindlist(parLapply(cl, 1:100, fun4Parallel, sc_bin = T,
                      internet_bin = F, save_plots = FALSE))
# ffmpeg -framerate 10 -i %03d.jpg -c:v libx264 -profile:v high -crf 20 -pix_fmt yuv420p
# sim_g_wt_sc_wtout_internet.mp4

print('active_nodes_wtout_sc_wtout_internet')
active_nodes_wtout_sc_wtout_internet <-
  rbindlist(parLapply(cl, 1:100, fun4Parallel, sc_bin = F,
```

```
                      internet_bin = F, save_plots = FALSE))
# ffmpeg -framerate 10 -i %03d.jpg -c:v libx264 -profile:v high -crf 20 -pix_fmt yuv420p
# sim_g_wtout_sc_wtout_internet.mp4

print('active_nodes_wt_sc_wt_internet')
active_nodes_wt_sc_wt_internet <-
  rbindlist(parLapply(cl, 1:100, fun4Parallel, sc_bin = T,
                      internet_bin = T, save_plots = FALSE))

print('active_nodes_wtout_sc_wt_internet')
active_nodes_wtout_sc_wt_internet <-
  rbindlist(parLapply(cl, 1:100, fun4Parallel, sc_bin = F,
                      internet_bin = T, save_plots = FALSE))

stopCluster(cl)

save(active_nodes_wt_sc_wtout_internet, active_nodes_wtout_sc_wtout_internet,
     active_nodes_wt_sc_wt_internet, active_nodes_wtout_sc_wt_internet,
     file = 'replication_file_02_active_nodes.RData')
```

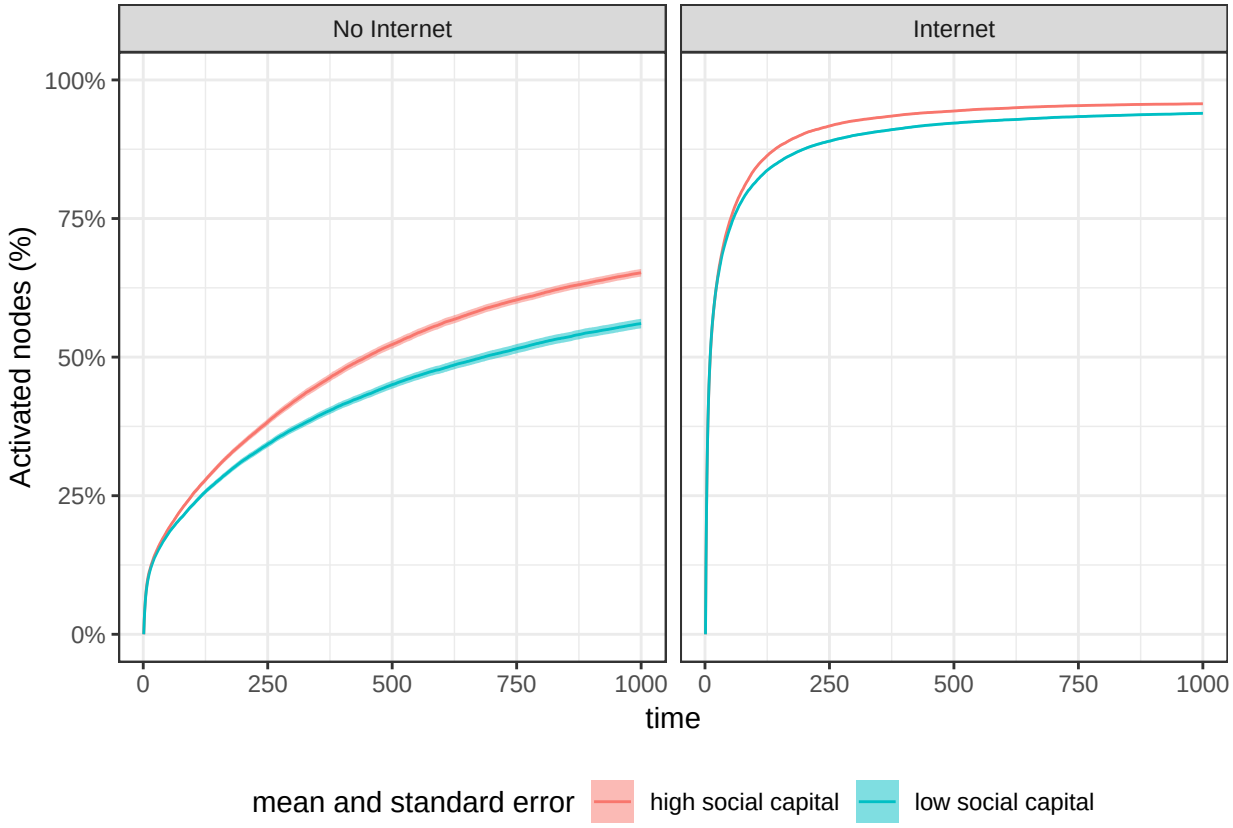
Simulations runs in parallel without any `set.seed()`. To run the simulation execute:

```
R -e 'setwd("/path/to/directory"); source("replication_code_01_simulation_functions.R"); source("replica
```

Figure 3

```
load("replication_file_02_active_nodes.RData")

active_nodes_df <-
  rbind(active_nodes_wt_sc_wtout_internet, active_nodes_wtout_sc_wt_internet,
        active_nodes_wtout_sc_wtout_internet, active_nodes_wt_sc_wt_internet)
active_nodes_df$group <- paste0(active_nodes_df$j, "-", active_nodes_df$what)

active_nodes_df <-
  active_nodes_df %>%
  dplyr::group_by(t, what) %>%
  dplyr::summarize(mean = mean(activation),
                   se = sqrt(var(activation)/length(activation)))

active_nodes_df$internet <-
  grepl("wt internet", active_nodes_df$what)
active_nodes_df$internet <-
  ifelse(active_nodes_df$internet, "Internet", "No Internet")
active_nodes_df$internet <-
  factor(active_nodes_df$internet, levels = c("No Internet", "Internet"))
active_nodes_df$label <-
  gsub(" (wt|wtout) internet", "", active_nodes_df$what)
active_nodes_df$label <-
  gsub("wt sc", "high social capital", active_nodes_df$label)
active_nodes_df$label <-
  gsub("wtout sc", "low social capital", active_nodes_df$label)
```

```
active_nodes_df$`mean and standard error` <- active_nodes_df$label

ggplot(active_nodes_df, aes(x=t, colour = `mean and standard error`)) +
  geom_line(aes(y=mean)) +
  geom_ribbon(aes(ymin = mean - se, ymax = mean + se, fill = `mean and standard error`),
              colour = NA, alpha = 0.5) +
  facet_wrap(~internet) +
  scale_y_continuous(label = percent, limits = c(0,1)) + theme_bw() +
  labs(x='time', y="Activated nodes (%)") + theme(legend.position = 'bottom')
```




```
pdf(file = "figure/network-model-diffusion.pdf",
    width  = 8, height = 5)
ggplot(active_nodes_df, aes(x=t, colour = `mean and standard error`)) +
  geom_line(aes(y=mean)) +
  geom_ribbon(aes(ymin = mean - se, ymax = mean + se, fill = `mean and standard error`),
              colour = NA, alpha = 0.5) +
  facet_wrap(~internet) +
  scale_y_continuous(label = percent, limits = c(0,1)) + theme_bw() +
  labs(x='time', y="Activated nodes (%)") + theme(legend.position = 'bottom') +
  theme(text = element_text(family = "Palatino"))
dev.off()
```

```
## pdf
##   2
```

Meetup

Meetup datasets

The following chunks are not replicable if you don't have access to `meetup_aug14.sqlite` and `meetup_mar15.sqlite`, which are password protected since they contain users' personal information.

The 2015 dataset was collected to correct the joining date of the 2014 dataset (`meetup_members_2014$joined`,), which was not correctly parse from the API response.

```
meetup_members_2014 <- sqliteGetTable('meetup_aug14.sqlite', 'member')
meetup_groups_2014 <- sqliteGetTable('meetup_aug14.sqlite', '[group]')
meetup_events_2014 <- sqliteGetTable('meetup_aug14.sqlite', 'event')
meetup_members_2015 <- sqliteGetTable('meetup_mar15.sqlite', 'member')
meetup_groups_2015 <- sqliteGetTable('meetup_mar15.sqlite', '[group]')
meetup_events_2015 <- sqliteGetTable('meetup_mar15.sqlite', 'event')
```

Data collection range

```
min(meetup_members_2014$timestamp)
```

```
## [1] "2014-08-01 09:56:21"
```

```
max(meetup_members_2014$timestamp)
```

```
## [1] "2014-08-02 09:52:33"
```

```
min(meetup_members_2015$timestamp)
```

```
## [1] "2015-03-02 08:17:01"
```

```
max(meetup_members_2015$timestamp)
```

```
## [1] "2015-03-02 09:15:48"
```

Number of records

```
length(unique(c(meetup_members_2015$member_id, meetup_members_2014$member_id)))
```

```
## [1] 104630
```

```
nrow(meetup_members_2014)
```

```
## [1] 97808
```

```
nrow(meetup_groups_2014)
```

```
## [1] 1883
```

```
nrow(meetup_events_2014)
```

```
## [1] 115335
```

```
nrow(meetup_members_2015)
```

```
## [1] 92486
```

```
nrow(meetup_groups_2015)
```

```
## [1] 1701
```

```
nrow(meetup_events_2015)
```

```
## [1] 128694
```

Users' joining date

```
meetup_members_2014$joined <-
  meetup_members_2015$joined[match(meetup_members_2014$member_id,
                                   meetup_members_2015$member_id)]

sum(!is.na(meetup_members_2014$joined))
```

```
## [1] 85664
```

```
min(meetup_members_2014$joined, na.rm = T)
```

```
## [1] "2005-07-11 15:07:47"
```

```
max(meetup_members_2014$joined, na.rm = T)
```

```
## [1] "2015-03-01 19:05:53"
```

Number of members indicating a Facebook account for which a joining date is available

```
sum(!is.na(meetup_members_2014$facebook) & !is.na(meetup_members_2014$joined))
```

```
## [1] 13350
```

Facebook

The following chunks are not fully replicable if you don't have access to ", which are password protected since they contain users' personal information.

To collect information about existing Facebook relations among Meetup users, I proceeded as following:

1. I scraped public information for each of the 15033 Facebook accounts indicated by Meetup members as of August 2014 with the Python script `replication_code_03_scrape_facebook.py`;
2. I scraped public information available on the Facebook "Friends" page of each of the Facebook users identified in the previous step with with the Python script `replication_code_04_scrape_facebook.py`;
3. I scraped public information available on the Facebook "Friendship" page corresponding to each Facebook relationship identified in the previous step with the Python script `replication_code_05_scrape_facebook.py`.

```
fb_user_timeline <-
  sqliteGetTable('facebook_user_timeline.sqlite', 'fbUsersTimeline')
fb_friendship_edgelist <-
  sqliteGetTable('facebook_friendship.sqlite', 'fb_friendship_edgelist')
```

The `fb_user_timeline` dataset contains the Facebook joining date of NA Facebook users. The `fb_friendship_edgelist` dataset contains the creation date of 165452 Facebook relationships.

The data collection process from Facebook can be summarised as following:

1. 15033 is the number of Meetup users indicating a Facebook account in August 2014;
2. 14381 is the number of Facebook accounts found publicly accessible;
3. 5387 is the number of Facebook accounts with a publicly accessible "Friends" page;
4. 9018 is the number of Facebook accounts indicated by Meetup users for which at least one Facebook friendship with another Meetup user is mapped (note: 3631 Meetup/Facebook users with no publicly accessible Facebook "Friends" page appeared in their friends' "Friends" pages).

Facebook friendship graph of meetup members

```
users <- fb_user_timeline
edgelist <- fb_friendship_edgelist

# Finding when user created their Facebook account (exclude all dates before 2007)
whenJoinedFB <- function(json) {
  if (length(json)==1 & json == 'null' | json == 'NA') return(NA)
  # print(json)
  # Tests
  # json1 = '[2013]'
  # json2 = '[2013, 2012, 1974]'
  # json3 = '[2013, 2012, 2009, 1943]'
  # json4 = '[2014, 1943]'
  require(rjson)
  fbActivity <- fromJSON(json)
  joined <- min(fbActivity[fbActivity>=2007])
  while(TRUE) {
    # Check whether there's continuity between supposed joining date and activity
    # (Possible the event in the timeline doesn't correspond to date of joining Facebook)
    if (joined == max(fbActivity)) {
      return(joined)
    } else if (((joined + 1) %in% fbActivity) & (joined %in% fbActivity))  {
      return(joined)
    } else {
      joined = joined + 1
    }
  }
  return(joined)
}

# Manual replace of missing data for
# V(g)[is.na(V(g)$joined)]
missing_data <- read.csv("replication_file_03_manually_coded.csv", header = FALSE)
users$joined[users$fb_id %in% missing_data$V1] <- missing_data$V2
users$joined_fb <- sapply(users$active_years, whenJoinedFB)

# Checks
unique_id <- unique(c(edgelist$from, edgelist$to))
fb_id <- users$fb_id
sum(unique_id %in% fb_id)

# Create graph
g <-
  graph.data.frame(edgelist[,2:8], directed=FALSE, vertices=users[fb_id %in% unique_id,])
```

```r
vcount(g)
ecount(g)

# Remove edges with error status (generated when requesting the friendship page)
g <- g - E(g)[E(g)$status == 2]
vcount(g)
ecount(g)

# Remove edges among users who are not friends
g <- g - E(g)[E(g)$friends == 0]
vcount(g)
ecount(g)

# There are 20 multiedges
g <- igraph::simplify(g, edge.attr.comb="first")
g_fship <- g


# Add Meetup joining date (note: collected only in 2015)
meetup_members_tmp <- meetup_members_2015
meetup_members_tmp$facebook <- NULL
meetup_members_tmp <-
  merge(meetup_members_tmp,
        meetup_members_2014[,c("member_id","facebook")],
        all.x = T, all.y = F)

V(g)$joined_mu <-
  meetup_members_tmp$joined[match(V(g)$name, meetup_members_tmp$facebook)]
V(g)$member_id <-
  meetup_members_tmp$member_id[match(V(g)$name, meetup_members_tmp$facebook)]

V(g)$lon <-
  meetup_members_2014$lon[match(V(g)$member_id, meetup_members_2014$member_id)]
V(g)$lat <-
  meetup_members_2014$lat[match(V(g)$member_id, meetup_members_2014$member_id)]

# Nodes with no joining date details
sum(is.na(V(g)$joined_mu))

## Removing them
g <- g - V(g)[is.na(V(g)$joined_mu)]
```

```r
# Counting potential recruiting ties
social_recruitment <- function(vindex, g, days) {
  # print(vindex)
  if(is.na(V(g)$joined_fb[vindex])) {
    return(NA)
  } else if(as.Date(V(g)$joined_mu[vindex]) <
            as.Date(paste0(V(g)$joined_fb[vindex], "-01-01"),
                    format="%Y-%m-%d", origin='1970-01-01')) {
    return(NA)
  } else {
    n <-
      sum(as.Date(paste0("01 ", E(g)[from(vindex)]$since), format=" %d %B %Y") + days
```

```
          < as.Date(V(g)$joined_mu[vindex]))
    # n <- vcount(neigh)
    return(n)
  }
}

# Computationally intense
V(g)$recruting_friends_90 <- sapply(1:vcount(g), social_recruitment, g, 90)

save(g, file="replication_file_04_friendship_graph.RData")
```

Create and save anonymised version

```
load("replication_file_04_friendship_graph.RData")

g_anonymised <- g
g_anonymised <-
  delete_vertex_attr(g_anonymised, "name")
g_anonymised <-
  delete_vertex_attr(g_anonymised, "member_id")
g_anonymised <-
  delete_vertex_attr(g_anonymised, "lon")
g_anonymised <-
  delete_vertex_attr(g_anonymised, "lat")
g_anonymised <-
  delete_edge_attr(g_anonymised, "grew_up")
g_anonymised <-
  delete_edge_attr(g_anonymised, "living")


save(g_anonymised, file="replication_file_05_friendship_graph_anonymised.RData")
```

Recruitment network (based on at least 90-day Facebook relationship)

```
load("replication_file_04_friendship_graph.RData")

friendship_edgelist <- as.data.frame(get.edgelist(g))
friendship_edgelist$friends <- E(g)$friends
friendship_edgelist$since <- E(g)$since
friendship_edgelist$grew_up <- E(g)$grew_up
friendship_edgelist$living <- E(g)$living

friendship_edgelist$joined_mu_A <-
  V(g)$joined_mu[match(friendship_edgelist$V1, V(g)$name)]
friendship_edgelist$joined_mu_B <-
  V(g)$joined_mu[match(friendship_edgelist$V2, V(g)$name)]
friendship_edgelist$A_joined_first <-
  friendship_edgelist$joined_mu_A < friendship_edgelist$joined_mu_B
```

```
returnV1 <- function(a, b, bool) {if (bool==TRUE) {return(a)} else {return(b)}}
returnV2 <- function(a, b, bool) {if (bool==TRUE) {return(b)} else{return(a)}}

recruitment_edgelist <- data.frame(V1=rep(NA, nrow(friendship_edgelist)),
                                   V2=rep(NA, nrow(friendship_edgelist)),
                                   recruiting=rep(NA, nrow(friendship_edgelist)),
                                   when=rep(NA, nrow(friendship_edgelist)))

recruitment_edgelist$V1[friendship_edgelist$A_joined_first==TRUE] <-
  as.character(friendship_edgelist$V1[friendship_edgelist$A_joined_first==TRUE])
recruitment_edgelist$V1[friendship_edgelist$A_joined_first==FALSE] <-
  as.character(friendship_edgelist$V2[friendship_edgelist$A_joined_first==FALSE])

recruitment_edgelist$V2[friendship_edgelist$A_joined_first==TRUE] <-
  as.character(friendship_edgelist$V2[friendship_edgelist$A_joined_first==TRUE])
recruitment_edgelist$V2[friendship_edgelist$A_joined_first==FALSE] <-
  as.character(friendship_edgelist$V1[friendship_edgelist$A_joined_first==FALSE])

recruitment_edgelist$when[friendship_edgelist$A_joined_first==TRUE] <-
  friendship_edgelist$joined_mu_B[friendship_edgelist$A_joined_first==TRUE]
recruitment_edgelist$when[friendship_edgelist$A_joined_first==FALSE] <-
  friendship_edgelist$joined_mu_A[friendship_edgelist$A_joined_first==FALSE]

recruitment_edgelist$recruiting <-
  (as.Date(paste0("01 ",
                  friendship_edgelist$since), format=" %d %B %Y") + 90) <
  as.Date(recruitment_edgelist$when)

recruitment_edgelist <- subset(recruitment_edgelist, recruiting==TRUE)

members <- meetup_members_2014

# Geo
recruitment_edgelist$lonA <-
  members$lon[match(recruitment_edgelist$V1, members$facebook)]
recruitment_edgelist$latA <-
  members$lat[match(recruitment_edgelist$V1, members$facebook)]
recruitment_edgelist$lonB <-
  members$lon[match(recruitment_edgelist$V2, members$facebook)]
recruitment_edgelist$latB <-
  members$lat[match(recruitment_edgelist$V2, members$facebook)]

require(geosphere)
recruitment_edgelist$distance <-
  distVincentySphere(
    cbind(recruitment_edgelist$lonA, recruitment_edgelist$latA),
    cbind(recruitment_edgelist$lonB, recruitment_edgelist$latB))

g_recruitment <-
  graph.data.frame(recruitment_edgelist[,c("V1","V2","when","distance")],
                   directed=TRUE,
                   vertices=unique(data.frame(name = c(recruitment_edgelist$V1,
```

```
                                                    recruitment_edgelist$V2),
                                          lon = c(recruitment_edgelist$lonA,
                                                  recruitment_edgelist$lonB),
                                          lat = c(recruitment_edgelist$latA,
                                                  recruitment_edgelist$latB))
                  ))

V(g_recruitment)$joined_mu <- V(g)$joined_mu[match(V(g_recruitment)$name, V(g)$name)]
V(g_recruitment)$joined_fb <- V(g)$joined_fb[match(V(g_recruitment)$name, V(g)$name)]

# Adding vertices removed from the recruitment network (because of no recruiting tie)
missing_vertices <- vertexAttributesAsDataFrame(g)
missing_vertices <- missing_vertices[!missing_vertices$name %in% V(g_recruitment)$name,]
# THIS MUST BE TRUE: nrow(missing_vertices) + vcount(g_recruitment) == vcount(g)
g_recruitment <-
  g_recruitment %>%
  add_vertices(nrow(missing_vertices),
               attr = list(name = as.character(missing_vertices$name),
                           lon = missing_vertices$lon,
                           lat = missing_vertices$lat,
                           joined_mu = as.character(missing_vertices$joined_mu),
                           joined_fb = as.character(missing_vertices$joined_fb)))

# Nodes
vcount(g_recruitment)
```

```
## [1] 8132
```

```
# Nodes with at least one recruiting ties
sum(igraph::degree(g_recruitment, mode="in") > 0)
```

```
## [1] 3804
```

```
sum(igraph::degree(g_recruitment, mode="in") > 0) / vcount(g_recruitment)
```

```
## [1] 0.4677816
```

```
# Nodes that joined Meetup.com after joining Facebook.com
sum(as.Date(V(g_recruitment)$joined_mu) >=
      as.Date(paste0(V(g_recruitment)$joined_fb, "-01-01"),
              format="%Y-%m-%d", origin='1970-01-01'), na.rm=TRUE)
```

```
## [1] 7874
```

```
sum(as.Date(V(g_recruitment)$joined_mu) >=
      as.Date(paste0(V(g_recruitment)$joined_fb, "-01-01"),
              format="%Y-%m-%d", origin='1970-01-01'), na.rm=TRUE) /
  vcount(g_recruitment)
```

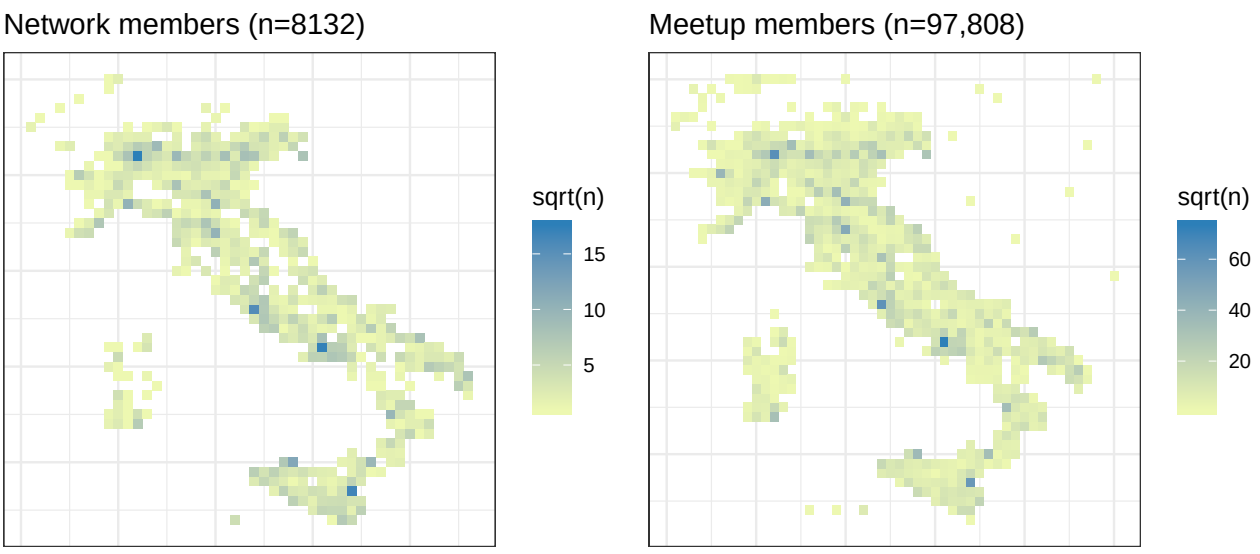
```
## [1] 0.9682735
```

```
save(g_recruitment, file = 'replication_file_06_recruitment_graph.RData')
```

Figure 4

```
load("replication_file_06_recruitment_graph.RData")

italy_box_y <- c(36, 47.5)
italy_box_x <- c(6.1, 19.5)

italy_seq_x <- seq(italy_box_x[1], italy_box_x[2], length.out = 51)
italy_seq_y <- seq(italy_box_y[1], italy_box_y[2], length.out = 51)

which_g <-
  V(g)$lon >= italy_box_x[1] & V(g)$lon <= italy_box_x[2] &
  V(g)$lat >= italy_box_y[1] & V(g)$lat <= italy_box_y[2]
lon_g <- V(g)$lon[which_g]
lat_g <- V(g)$lat[which_g]

which_mu <-
  meetup_members_2014$lon >=
  italy_box_x[1] & meetup_members_2014$lon <= italy_box_x[2] &
  meetup_members_2014$lat >=
  italy_box_y[1] & meetup_members_2014$lat <= italy_box_y[2]
lon_mu <- meetup_members_2014$lon[which_mu]
lat_mu <- meetup_members_2014$lat[which_mu]

lon_mu <-
  cut(lon_mu, breaks = italy_seq_x, labels = italy_seq_x[1:50])
lat_mu <-
  cut(lat_mu, breaks = italy_seq_y, labels = italy_seq_y[1:50])

lon_g <-
  cut(lon_g, breaks = italy_seq_x, labels = italy_seq_x[1:50])
lat_g <-
  cut(lat_g, breaks = italy_seq_y, labels = italy_seq_y[1:50])

g_lonlat_df <-
  data.frame(lon_g, lat_g) %>%
  group_by(lon_g, lat_g) %>%
  summarize(n = n())
mu_lonlat_df <-
  data.frame(lon_mu, lat_mu) %>%
  group_by(lon_mu, lat_mu) %>%
  summarize(n = n())

g_mu_lonlat_df <-
  merge(g_lonlat_df, mu_lonlat_df,
        by.x = c('lon_g','lat_g'),
        by.y = c('lon_mu','lat_mu'))

g_mu_lonlat_df$n_perc.x <-
  g_mu_lonlat_df$n.x / sum(g_mu_lonlat_df$n.x)
g_mu_lonlat_df$n_perc.y <-
  g_mu_lonlat_df$n.y / sum(g_mu_lonlat_df$n.y)
```

```
g_mu_lonlat_df$diff <- with(g_mu_lonlat_df, n_perc.x - n_perc.y)

grid.arrange(
  ggplot(g_lonlat_df,
         aes(x = as.numeric(lon_g), y = as.numeric(lat_g),
             fill = sqrt(n))) + geom_tile() +
    scale_fill_gradient(low = '#edf8b1', high = '#2c7fb8', na.value = 'white') +
    theme_bw() +
    labs(x=NULL, y=NULL, title = "Network members (n=8132)") +
    theme(axis.title=element_blank(),
          axis.text=element_blank(),
          axis.ticks=element_blank()),

  ggplot(mu_lonlat_df,
         aes(x = as.numeric(lon_mu),
             y = as.numeric(lat_mu),
             fill = sqrt(n))) +
    geom_tile() +
    scale_fill_gradient(low = '#edf8b1', high = '#2c7fb8', na.value = 'white') +
    theme_bw() +
    labs(x=NULL, y=NULL, title = "Meetup members (n=97,808)") +
    theme(axis.title=element_blank(),
          axis.text=element_blank(),
          axis.ticks=element_blank()),
  ncol = 2)
```




```
pdf(file = "figure/heatmap-dist-mu-g.pdf",
    width  = 8, height = 3.5)
grid.arrange(
  ggplot(g_lonlat_df,
         aes(x = as.numeric(lon_g),
             y = as.numeric(lat_g),
             fill = sqrt(n))) +
    geom_tile() +
    scale_fill_gradient(low = '#edf8b1', high = '#2c7fb8', na.value = 'white') +
    theme_bw() +
```

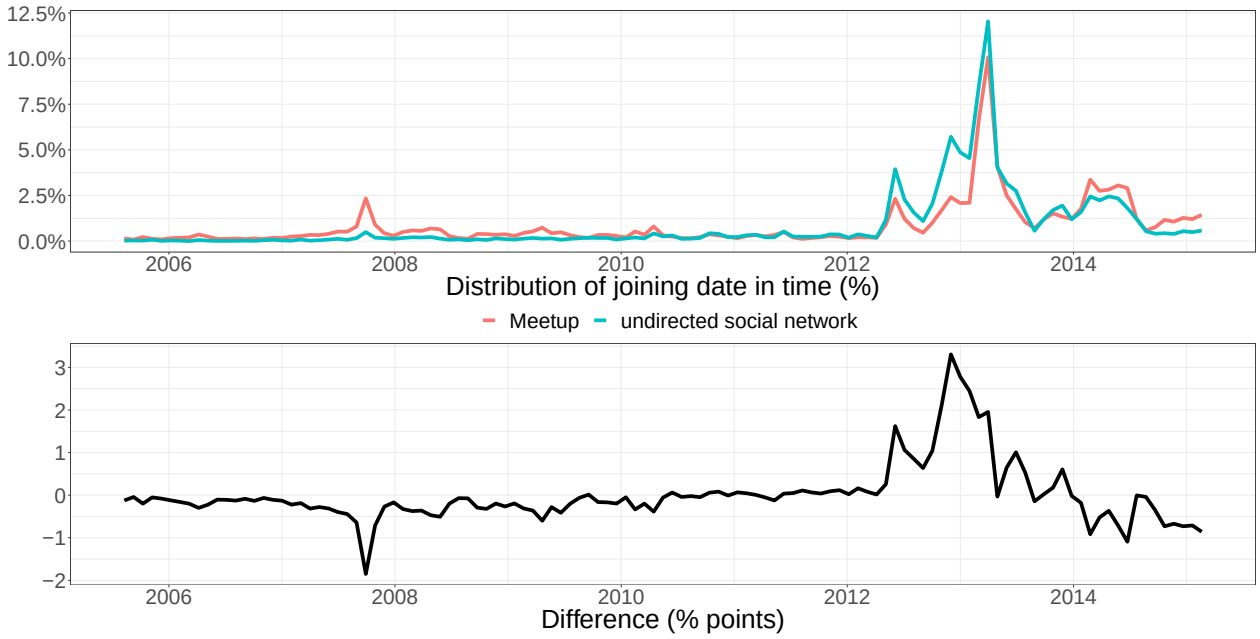
```
    labs(x=NULL, y=NULL, title = "Network members (n=8132)") +
    theme(axis.title=element_blank(),
          axis.text=element_blank(),
          axis.ticks=element_blank(),
          text = element_text(family = "Palatino")),

  ggplot(mu_lonlat_df,
         aes(x = as.numeric(lon_mu),
             y = as.numeric(lat_mu),
             fill = sqrt(n))) +
    geom_tile() +
    scale_fill_gradient(low = '#edf8b1', high = '#2c7fb8', na.value = 'white') +
    theme_bw() +
    labs(x=NULL, y=NULL, title = "Meetup members (n=97,808)") +
    theme(axis.title=element_blank(),
          axis.text=element_blank(),
          axis.ticks=element_blank(),
          text = element_text(family = "Palatino")),
  ncol = 2)
dev.off()
```

```
## pdf
##   2
```

Figure 5

```
member15 <- meetup_members_2015
member15$joined <- as.Date(member15$joined)

g_el <- as_edgelist(g)
g_el_lonlat_df <- data.frame(lon.x = V(g)$lon[match(g_el[,1], V(g)$name)],
                             lat.x = V(g)$lat[match(g_el[,1], V(g)$name)],
                             lon.y = V(g)$lon[match(g_el[,2], V(g)$name)],
                             lat.y = V(g)$lat[match(g_el[,2], V(g)$name)])

g_el_lonlat_df$dist <- distVincentySphere(g_el_lonlat_df[,1:2], g_el_lonlat_df[,3:4])
E(g)$distance <- g_el_lonlat_df$dist

sequence <- seq(from = min(member15$joined), max(member15$joined), by = 30)
ts_meetup_df <- as.data.frame(table(cut(member15$joined, breaks = sequence,
                                        labels = sequence[2:length(sequence)])))
ts_meetup_df$Prop <- ts_meetup_df$Freq / sum(ts_meetup_df$Freq)
ts_meetup_df$cumsum <- cumsum(ts_meetup_df$Prop)
ts_meetup_df$what <- "Meetup"

ts_g_df <- as.data.frame(table(cut(as.Date(V(g)$joined_mu), breaks = sequence,
                                   labels = sequence[2:length(sequence)])))

ts_g_df$Prop <- ts_g_df$Freq / sum(ts_g_df$Freq)
ts_g_df$cumsum <- cumsum(ts_g_df$Prop)
ts_g_df$what <- "undirected social network"
```

```
ts_df <- rbind(ts_meetup_df, ts_g_df)
ts_diff_df <- merge(ts_meetup_df, ts_g_df, by = "Var1")
ts_diff_df$diff <- ts_diff_df$Prop.y - ts_diff_df$Prop.x

p1 <-
  ggplot(ts_df, aes(x=as.Date(Var1), y=Prop, colour=what)) +
  geom_line(size = 2) + scale_y_continuous(label = percent) + theme_bw() +
  labs(y=NULL, colour=NULL, x="Distribution of joining date in time (%)") +
  theme(legend.position = 'bottom', text = element_text(size=30))

p2 <-
  ggplot(ts_diff_df, aes(x=as.Date(Var1), y=diff*100)) +
  geom_line(size = 2) + theme_bw() + labs(y=NULL, x="Difference (% points)") +
  theme(text = element_text(size=30))

ggarrange(p1, p2, ncol = 1)
```




```
p1 <-
  ggplot(ts_df, aes(x=as.Date(Var1), y=Prop, colour=what)) +
  geom_line(size = 2) + scale_y_continuous(label = percent) + theme_bw() +
  labs(y=NULL, colour=NULL, x="Distribution of joining date in time (%)") +
  theme(legend.position = 'bottom',
        text = element_text(family = "Palatino"))

p2 <-
  ggplot(ts_diff_df, aes(x=as.Date(Var1), y=diff*100)) +
  geom_line(size = 2) + theme_bw() + labs(y=NULL, x="Difference (% points)") +
  theme(text = element_text(family = "Palatino"))

pdf(file = "figure/ts-mu-g-joining-date.pdf",
    width  = 10, height = 5)
ggarrange(p1, p2, ncol = 1)
dev.off()
```

```
## pdf
##   2
```

Data analysis

Spatial polygons of Italian regions

Shapefiles are produced by Istat and also available here: https://www.istat.it/it/archivio/124086

```
region_2013.sp <- readOGR('.', 'Reg01012013_g_WGS84')
```

```
## OGR data source with driver: ESRI Shapefile
## Source: ".", layer: "Reg01012013_g_WGS84"
## with 20 features
## It has 5 fields
```

```
region_2013.sp <-
  spTransform(region_2013.sp,
              "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs")
region_2013.sp$COD_REG <- as.numeric(as.character(region_2013.sp$COD_REG))
```

ISTAT Survey

The following chunks are not replicable if you don't have access to `DF_AVQ_A2013.RData`, which is password protected in this repository (as third party data). You can get download the data package from the Istat website at this page: www.istat.it/en/archivio/129959 (accessed October 2018).

```
load("DF_AVQ_A2013.RData")

asIndexComp <- function(x) {
  x <- as.numeric(x)
  x[is.na(x)] <- 0
  x
}

reverse <- function(x) {
  if (is.na(x)) {
    res <- NA
  } else if (x == 1) {
    res <- 3
  } else if (x == 2) {
    res <- 2
  } else if (x == 3) {
    res <- 1
  } else if (x == 4) {
    res <- 0
  } else {
    res <- NA
  }
  return(res)
}

nrow(DF_AVQ_A2013)
```

```
## [1] 20275
```

```
# Demographics
DF_AVQ_A2013$male <- DF_AVQ_A2013$sesso == 1
DF_AVQ_A2013$age <- rescale(DF_AVQ_A2013$eta, from = c(1,18), to = c(0,1))
DF_AVQ_A2013$married <- DF_AVQ_A2013$stciv == 2
DF_AVQ_A2013$unemployed <-  DF_AVQ_A2013$cond %in% 2:3
DF_AVQ_A2013$income <- as.factor(DF_AVQ_A2013$redpr)
levels(DF_AVQ_A2013$income) <- c('emp','selfemp', 'pens', 'soc', 'rev', 'fam')
DF_AVQ_A2013$tv_hours <- DF_AVQ_A2013$hhtel
DF_AVQ_A2013$tv_hours[DF_AVQ_A2013$tv_hours == 99] <- NA
DF_AVQ_A2013$edu <- NA
DF_AVQ_A2013$edu[DF_AVQ_A2013$istr %in% 10:11] <- 1
DF_AVQ_A2013$edu[DF_AVQ_A2013$istr==9] <- 2
DF_AVQ_A2013$edu[DF_AVQ_A2013$istr==7] <- 3
DF_AVQ_A2013$edu[DF_AVQ_A2013$istr %in% 1:2] <- 4

# Geography
region_labels <-
  c("Piemonte", "Valle d'Aosta/Vallée d'Aoste", "Lombardia", "Bolzano", "Trento", "Veneto",
    "Friuli-Venezia Giulia", "Liguria", "Emilia-Romagna", "Toscana", "Umbria", "Marche",
    "Lazio", "Abruzzo", "Molise", "Campania", "Puglia", "Basilicata", "Calabria", "Sicilia",
    "Sardegna", "Trentino-Alto Adige/Südtirol")
names(region_labels) <-
  c("010", "020", "030", "041", "042", "050",
    "060", "070", "080", "090",
    "100", "110", "120", "130",
    "140", "150", "160", "170",
    "180", "190", "200", "040")
DF_AVQ_A2013$reg[DF_AVQ_A2013$reg %in% c(41,42)] <- 040
DF_AVQ_A2013$COD_REG <- as.numeric(gsub("0$", "", DF_AVQ_A2013$reg))
DF_AVQ_A2013$DEN_REG <-
  region_labels[match(sprintf("%03d", DF_AVQ_A2013$reg), names(region_labels))]
DF_AVQ_A2013$DEN_REG <-
  factor(DF_AVQ_A2013$DEN_REG,
         levels = region_labels[order(names(region_labels))])
DF_AVQ_A2013$north <-
  (!DF_AVQ_A2013$DEN_REG %in%
     c("Abruzzo", "Puglia", "Basilicata",
       "Campania", "Calabria", "Molise", "Sicilia", "Sardegna"))
DF_AVQ_A2013$north[is.na(DF_AVQ_A2013$DEN_REG)] <- NA

DF_AVQ_A2013$north_south <- ifelse(DF_AVQ_A2013$north, "North", "South")
prop.table(table(DF_AVQ_A2013$north_south))
```

```
##
##     North     South
## 0.5871763 0.4128237
```

```
# Social capital: networking
## `sc_net` without political participation
DF_AVQ_A2013$sc_net <-
  as.logical(as.numeric(with(DF_AVQ_A2013,
                             asIndexComp(volon==4) +
                               asIndexComp(psind == 4) +
```

```
                              asIndexComp(pgrvo == 6) +
                              asIndexComp(paeco == 2) +
                              asIndexComp(pcult == 4) +
                              asIndexComp(paspro == 6) > 0)))
summary(DF_AVQ_A2013$sc_net)
```

```
##    Mode   FALSE    TRUE
## logical   16327    3948
```

```
prop.table(table(DF_AVQ_A2013$sc_net))
```

```
##
##     FALSE      TRUE
## 0.8052774 0.1947226
```

```
## Political participation (active)
DF_AVQ_A2013$pol_part_act <-
  as.numeric(with(DF_AVQ_A2013,
                  asIndexComp(ppapo == 2) +
                    asIndexComp(volpa == 8))) > 0
summary(DF_AVQ_A2013$pol_part_act)
```

```
##    Mode   FALSE    TRUE
## logical   19573     702
```

```
prop.table(table(DF_AVQ_A2013$pol_part_act))
```

```
##
##      FALSE       TRUE
## 0.96537608 0.03462392
```

```
## `sc_net` now includes also political participation
DF_AVQ_A2013$sc_net <-
  DF_AVQ_A2013$sc_net == TRUE | DF_AVQ_A2013$pol_part_act == TRUE
summary(DF_AVQ_A2013$sc_net)
```

```
##    Mode   FALSE    TRUE
## logical   16085    4190
```

```
prop.table(table(DF_AVQ_A2013$sc_net))
```

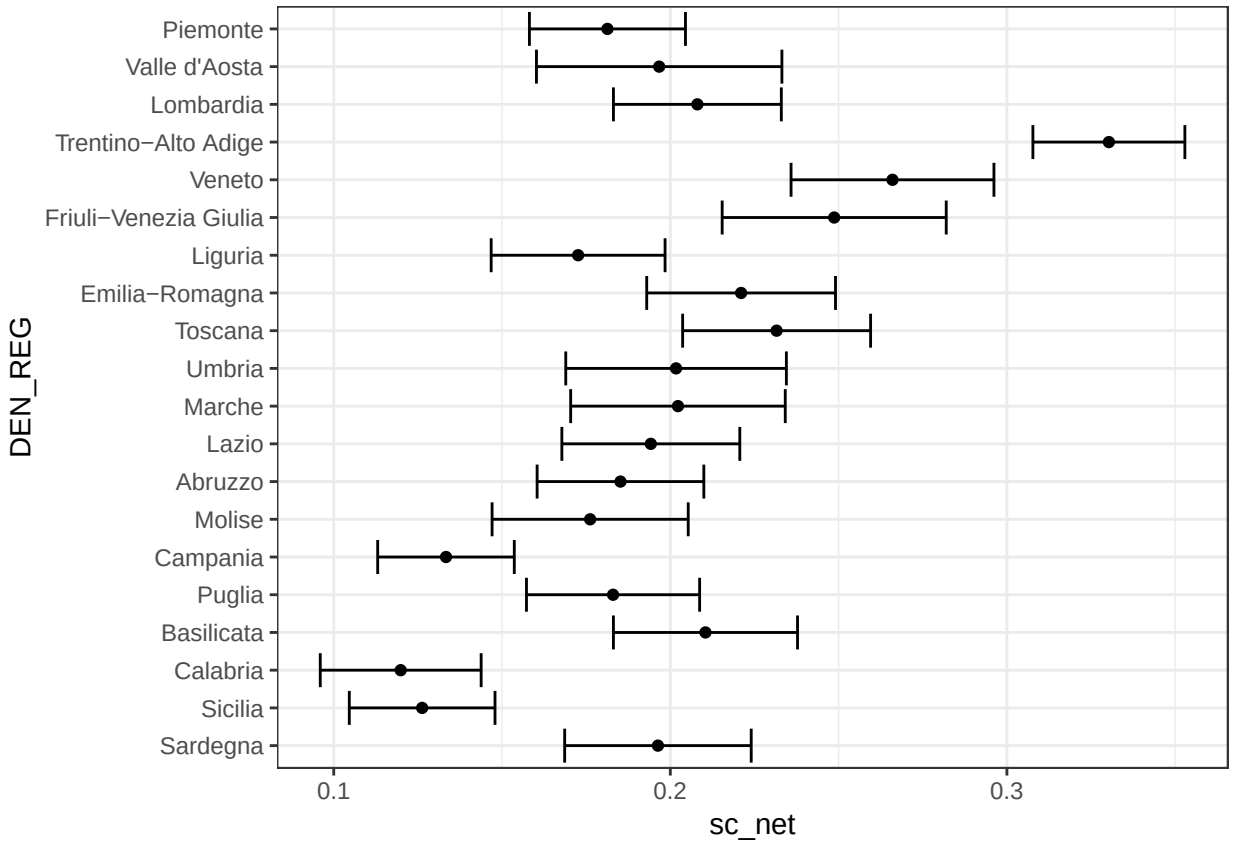
```
##
##     FALSE      TRUE
## 0.7933416 0.2066584
```

```
# `coemicro` is the weighting variable for regional-level averages
DF_AVQ_A2013$coemicro <-
  as.numeric(as.character(DF_AVQ_A2013$coemicro))

# Social capital: Trust.
DF_AVQ_A2013$sc_trust <-
  rescale(
    with(DF_AVQ_A2013,sapply(fidu3, reverse)),
    to = c(0, 1),
    from = c(0, 3))
summary(DF_AVQ_A2013$sc_trust)
```

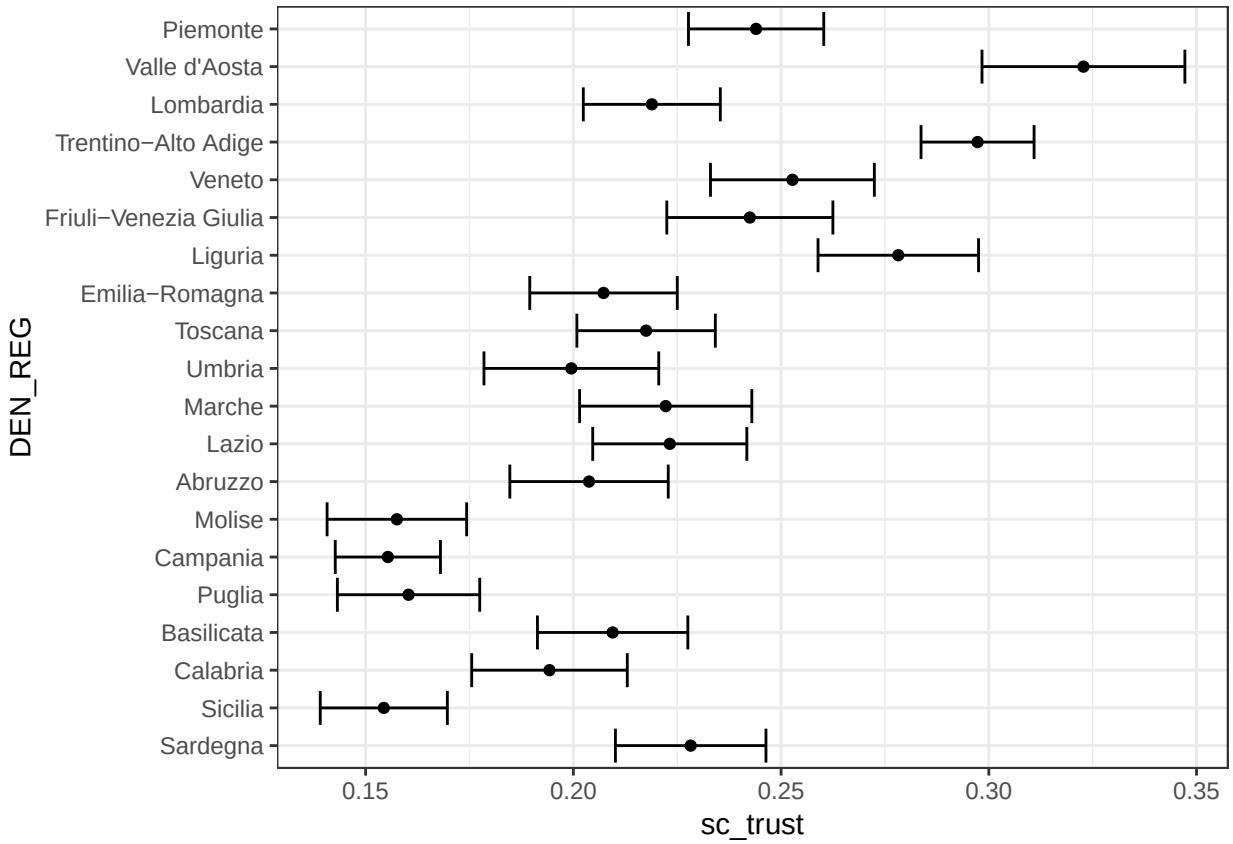
```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
```

```
##  0.0000  0.0000  0.3333  0.2198  0.3333  1.0000    3132
```

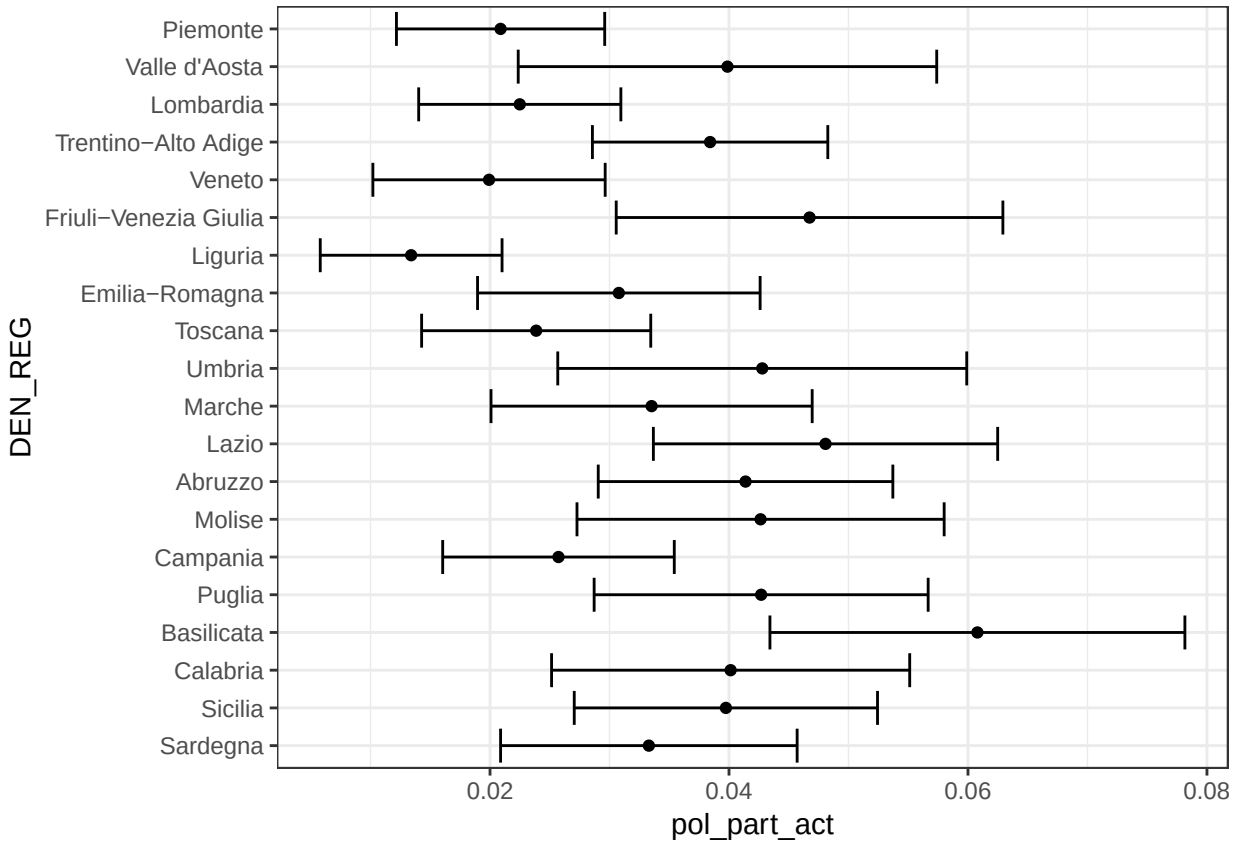
```
# Logistic regression
log_sc_net <-
  glm(sc_net ~ age + male + married + edu + unemployed + tv_hours + income + north_south,
      data = DF_AVQ_A2013,
      family = 'binomial')

lm_sc_trust <-
  glm(sc_trust ~ sc_net + age + male + married + edu + unemployed + tv_hours + income + north_south,
      data = DF_AVQ_A2013,
      family = 'binomial')

# Survey responses averaged at regional level
survey_reg_avg <-
  srvyr::as_survey_design(DF_AVQ_A2013, strata = COD_REG, weights = coemicro)

survey_reg_avg <-
  survey_reg_avg %>%
  group_by(COD_REG) %>%
  summarize_at(vars(sc_net, sc_trust, pol_part_act),
               survey_mean,
               vartype = "ci",
               na.rm = TRUE)

survey_reg_avg$DEN_REG <-
  region_2013.sp@data$DEN_REG[match(survey_reg_avg$COD_REG,
                                    region_2013.sp@data$COD_REG)]
survey_reg_avg$DEN_REG <- gsub("/(.*)$", "", survey_reg_avg$DEN_REG)
survey_reg_avg$DEN_REG <- factor(survey_reg_avg$DEN_REG, levels = rev(survey_reg_avg$DEN_REG))

ggplot(survey_reg_avg) +
  geom_point(aes(y=sc_net, x=DEN_REG)) +
  geom_errorbar(aes(ymin = sc_net_low, ymax = sc_net_upp, x=DEN_REG)) +
  coord_flip() +
  theme_bw()
```




```
ggplot(survey_reg_avg) +
  geom_point(aes(y=sc_trust, x=DEN_REG)) +
  geom_errorbar(aes(ymin = sc_trust_low, ymax = sc_trust_upp, x=DEN_REG)) +
  coord_flip() +
  theme_bw()
```



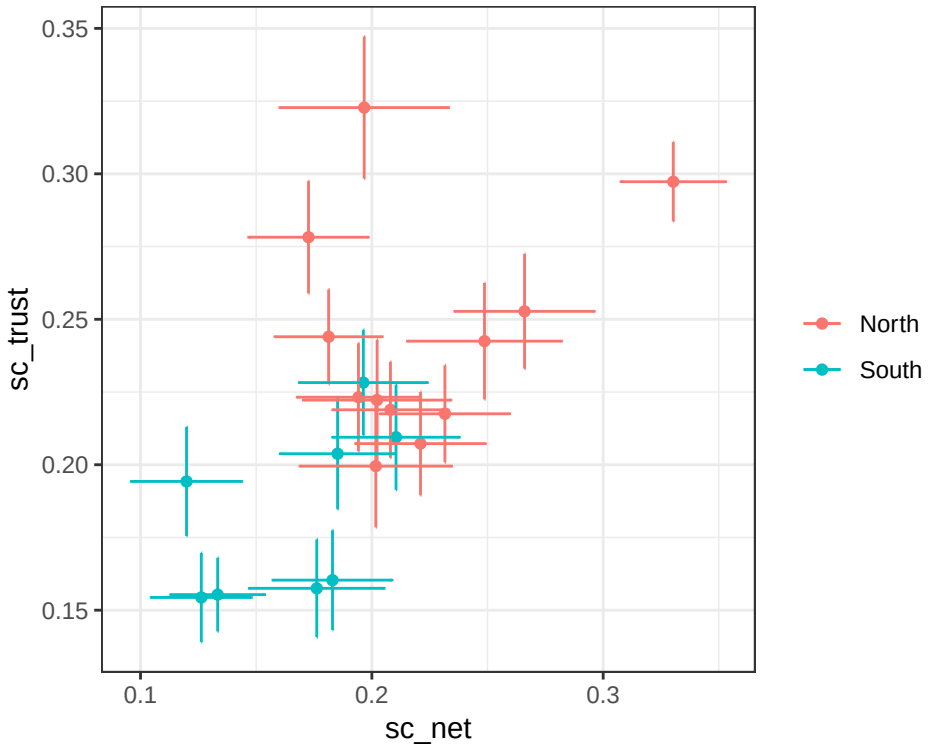

```
ggplot(survey_reg_avg) +
  geom_point(aes(y=pol_part_act, x=DEN_REG)) +
  geom_errorbar(aes(ymin = pol_part_act_low, ymax = pol_part_act_upp, x=DEN_REG)) +
  coord_flip() +
  theme_bw()
```




```
survey_reg_avg$north_south <- ifelse(survey_reg_avg$COD_REG < 13, 'North', 'South')
```

Figure 6

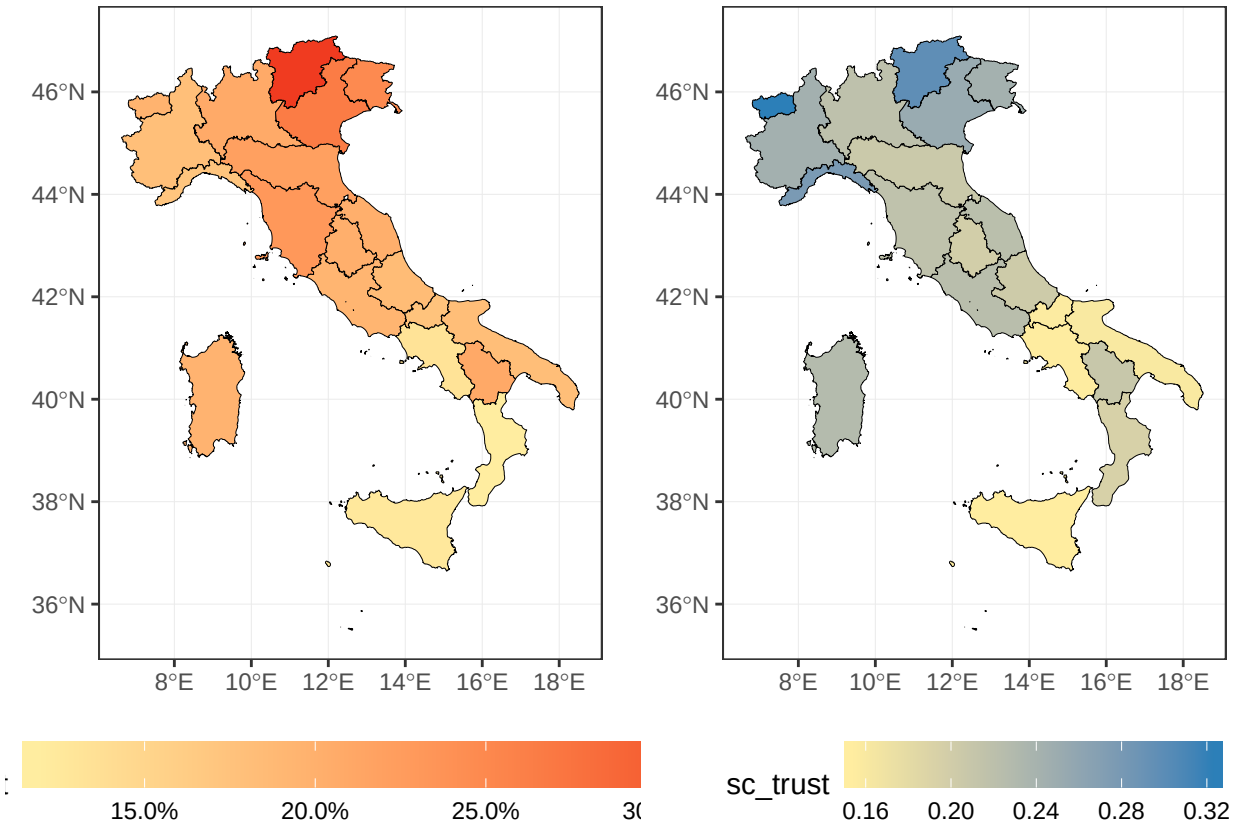
```
ggplot(survey_reg_avg) +
  geom_point(aes(x=sc_net, y=sc_trust, colour = north_south )) +
  geom_errorbar(aes(x=sc_net, ymin=sc_trust_low, ymax=sc_trust_upp, colour = north_south),
                width = 0) +
  geom_errorbarh(aes(y=sc_trust, xmin=sc_net_low, xmax=sc_net_upp, colour = north_south)) +
  theme_bw() +
  labs(colour=NULL)
```




```
ggsave(filename = "figure/sc-ita-regions.pdf", dpi = 300,
       width = 5, height = 4,
       ggplot(survey_reg_avg) +
         geom_point(aes(x=sc_net, y=sc_trust, colour = north_south )) +
         geom_errorbar(aes(x=sc_net, ymin=sc_trust_low, ymax=sc_trust_upp,
                           colour = north_south),
                       width = 0) +
         geom_errorbarh(aes(y=sc_trust, xmin=sc_net_low, xmax=sc_net_upp,
                            colour = north_south)) +
         theme_bw() + labs(colour=NULL))
```

Figure 12

```
region_2013.sf <- st_as_sf(region_2013.sp)

region_2013.sf$sc_trust <-
  survey_reg_avg$sc_trust[match(region_2013.sf$COD_REG, survey_reg_avg$COD_REG)]
region_2013.sf$sc_net <-
  survey_reg_avg$sc_net[match(region_2013.sf$COD_REG, survey_reg_avg$COD_REG)]

grid.arrange(
  ggplot(region_2013.sf) + geom_sf(aes(fill = sc_net), colour = 'black', size = .05) +
    scale_fill_gradient(low = '#ffeda0', high = '#f03b20', label = percent) + theme_bw() +
    theme(legend.position = 'bottom', legend.key.width=unit(2,"cm")) ,
  ggplot(region_2013.sf) + geom_sf(aes(fill = sc_trust), colour = 'black', size = .05) +
    scale_fill_gradient(low = '#ffeda0', high = '#2c7fb8')  + theme_bw() +
    theme(legend.position = 'bottom', legend.key.width=unit(1,"cm")),
  ncol=2)
```




```
pdf(file = "figure/map-ita-reg-sc.pdf", width  = 9, height = 4.5)
grid.arrange(
  ggplot(region_2013.sf) + geom_sf(aes(fill = sc_net), colour = 'black', size = .05) +
    scale_fill_gradient(low = '#ffeda0', high = '#f03b20', label = percent) + theme_bw() +
    theme(legend.position = 'bottom', legend.key.width=unit(1.4,"cm"),
          text = element_text(family = "Palatino")) ,
  ggplot(region_2013.sf) + geom_sf(aes(fill = sc_trust), colour = 'black', size = .05) +
    scale_fill_gradient(low = '#ffeda0', high = '#2c7fb8')  + theme_bw() +
    theme(legend.position = 'bottom', legend.key.width=unit(1.4,"cm"),
          text = element_text(family = "Palatino")),
  ncol=2)
```

Table 2

```
stargazer(log_sc_net, lm_sc_trust)
```

% Table created by stargazer v.5.2.2 by Marek Hlavac, Harvard University. E-mail: hlavac at fas.harvard.edu
% Date and time: Fri, Oct 19, 2018 - 03:50:11

```
stargazer(log_sc_net, lm_sc_trust,
          type = 'latex', out = 'table/sc-net-survey-mod.tex',
          report = "vc*",
          float = FALSE,
          style = 'ajps')
stargazer(log_sc_net, lm_sc_trust,
          type = 'html', out = 'table/sc-net-survey-mod.html',
          report = "vc*",
```

Table 1:

	Dependent variable:	
	sc_net	sc_trust
	(1)	(2)
sc_net		0.274***
		(0.051)
age	0.121	0.157
	(0.178)	(0.175)
male	0.421***	−0.031
	(0.046)	(0.047)
married	0.114**	0.056
	(0.049)	(0.049)
edu	0.604***	0.116***
	(0.027)	(0.028)
unemployed	−0.241**	−0.198**
	(0.094)	(0.094)
tv_hours	−0.089***	−0.021
	(0.015)	(0.013)
incomeselfemp	0.106	0.104
	(0.074)	(0.079)
incomepens	−0.259***	0.013
	(0.079)	(0.079)
incomesoc	−0.173	0.123
	(0.159)	(0.154)
incomerev	−0.839**	0.002
	(0.340)	(0.290)
incomefam	−0.224***	0.001
	(0.069)	(0.069)
north_southSouth	−0.353***	−0.318***
	(0.047)	(0.047)
Constant	−2.450***	−1.527***
	(0.149)	(0.149)
Observations	12,103	11,911
Log Likelihood	−6,253.930	−4,823.210
Akaike Inf. Crit.	12,533.860	9,674.419
Note:	*p<0.1; **p<0.05; ***p<0.01	

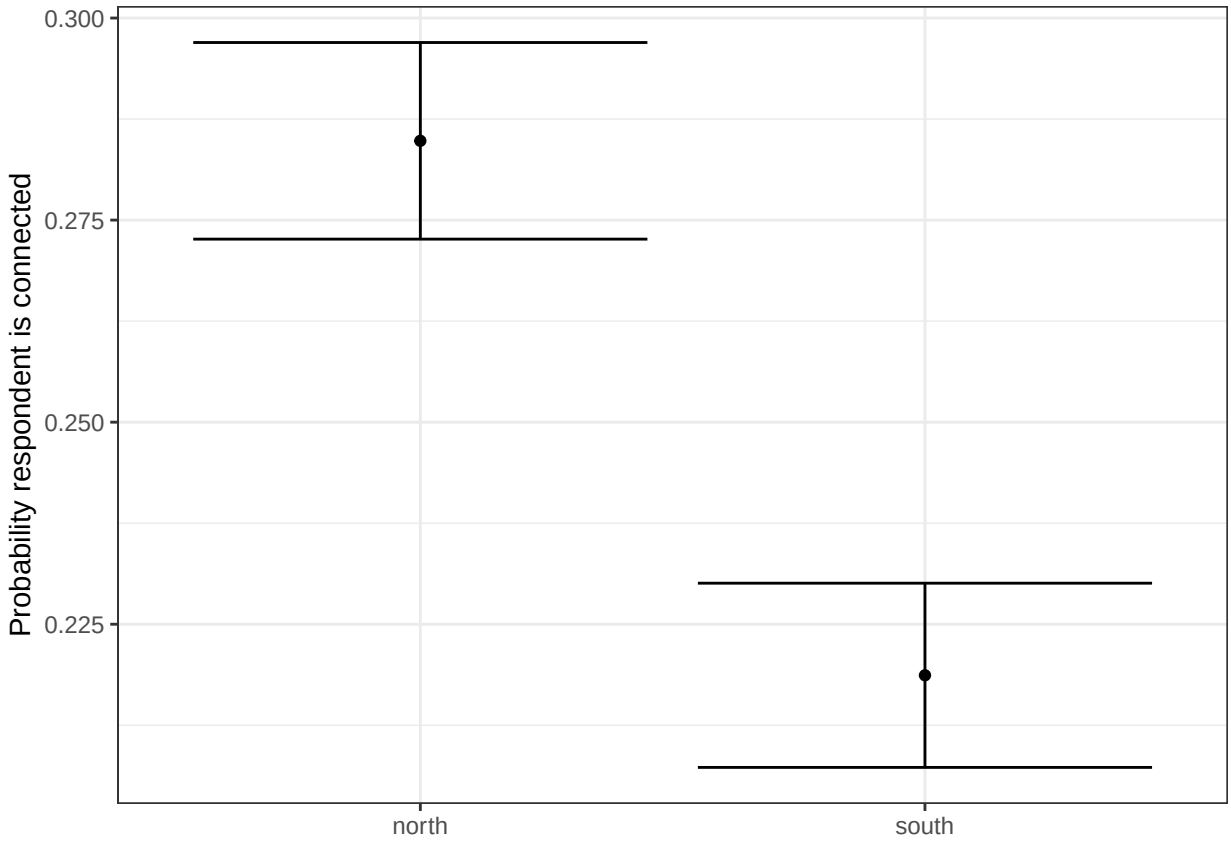
```
          float = FALSE,
          style = 'ajps')
```

Logistic regression prediction: MALE

```
pr <-
  predict(log_sc_net,
          newdata = data.frame(age = 0.6470588,
                               male = TRUE,
                               married = FALSE,
                               edu = 2,
                               unemployed = FALSE,
                               tv_hours = 2,
                               income = 'emp',
                               north_south = c('North', 'South')),
          type="response", se.fit = TRUE)
pr
```

```
## $fit
##         1         2
## 0.2848085 0.2186827
##
## $se.fit
##          1          2
## 0.01216219 0.01139579
##
## $residual.scale
## [1] 1
```

```
pr_df <- data.frame(where = c('north','south'),
                    fit = pr$fit,
                    se.fit = pr$se.fit)
ggplot(pr_df, aes(x = where, y = fit)) +
  geom_point() +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit)) +
  theme_bw() +
  labs(x = NULL, y = "Probability respondent is connected")
```

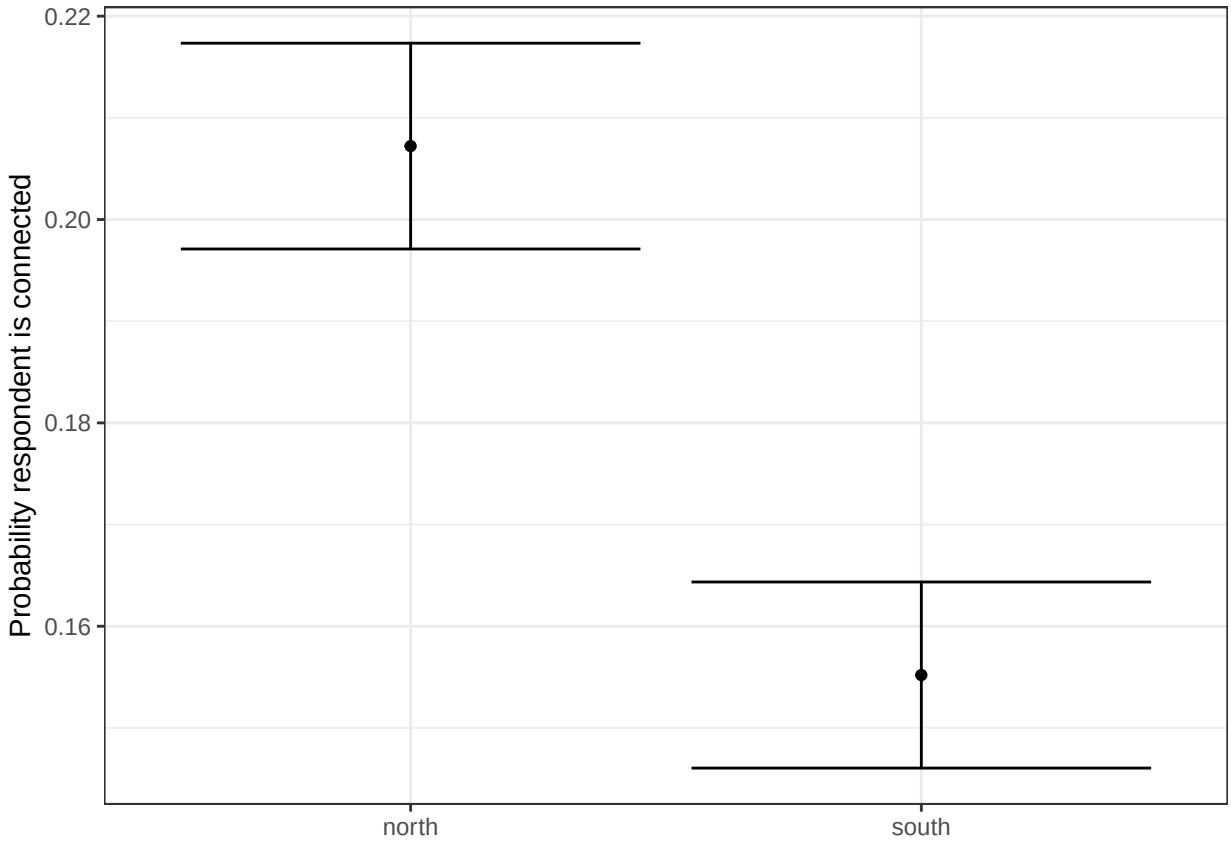


Logistic regression prediction: FEMALE

```
pr <-
  predict(log_sc_net,
          newdata = data.frame(age = 0.6470588,
                               male = FALSE,
                               married = FALSE,
                               edu = 2,
                               unemployed = FALSE,
                               tv_hours = 2,
                               income = 'emp',
                               north_south = c('North', 'South')),
          type="response", se.fit = TRUE)
pr
```

```
## $fit
##         1         2
## 0.2072220 0.1552009
##
## $se.fit
##           1           2
## 0.010119259 0.009150905
##
## $residual.scale
## [1] 1
```

```
pr_df <- data.frame(where = c('north','south'),
                    fit = pr$fit,
                    se.fit = pr$se.fit)
ggplot(pr_df, aes(x = where, y = fit)) +
  geom_point() +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit)) +
  theme_bw() +
  labs(x = NULL, y = "Probability respondent is connected")
```



Diffusion

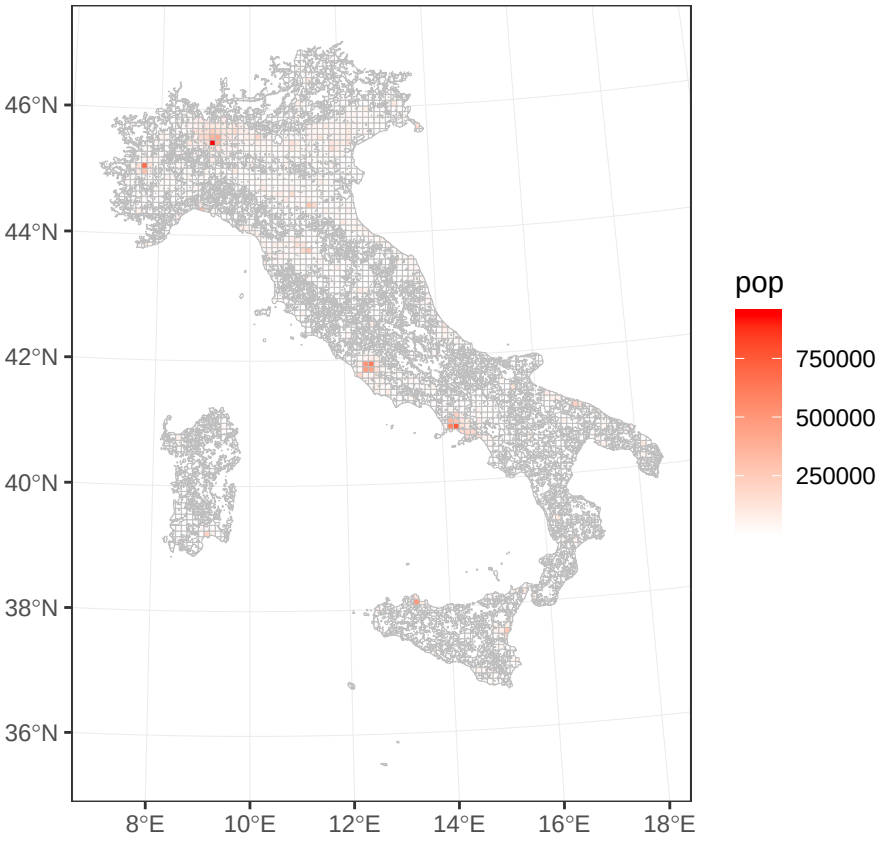
Create geographic grid

The geographic grid is a simplified version of the GEOSTAT 2011. The file is also available from https://www.istat.it/it/archivio/155162.

```
# See https://www.istat.it/it/archivio/155162
geostat_grid <- readOGR(".",'GEOSTAT_grid_POP_1K_IT_2011')

geostat_grid_simp.sf <- st_as_sf(geostat_grid)
geostat_grid_simp.sf <- geostat_grid_simp.sf %>% filter(POP > 0)
geostat_grid_simp.sf$GRID_ID_simp <- gsub("\\dE", "E", geostat_grid_simp.sf$GRID_ID)
geostat_grid_simp.sf$GRID_ID_simp <- gsub("\\d$", "", geostat_grid_simp.sf$GRID_ID_simp)

geostat_grid_simp.sf <-
  geostat_grid_simp.sf %>%
```

```
  group_by(GRID_ID_simp) %>%
  summarize(pop = sum(POP))

geostat_grid_simp.sf <-
  geostat_grid_simp.sf %>%
  filter(pop > 0)

save(geostat_grid_simp.sf, file = 'replication_file_07_geostat_grid.RData')
```

```
load('replication_file_07_geostat_grid.RData')
ggplot(geostat_grid_simp.sf) +
  geom_sf(aes(fill=pop), color = 'grey', size = 0.05) +
  scale_fill_gradient(low = "white", high = "red") +
  theme_bw()
```




```
# Number of cells
nrow(geostat_grid_simp.sf)
```

```
## [1] 3396
```

```
# Mean area
mean(st_area(geostat_grid_simp.sf))
```

```
## 60015607 m^2
```

Number of Meetup members by grid cells

To replicate the following chunks:

```
R -e 'setwd("/path/to/directory");
source("replication_code_06_measure_geographic_diffusion.R");'
```

```
read_chunk('replication_code_06_measure_geographic_diffusion.R')
```

```
# Packages
library(data.table)
library(parallel)
library(sp)
library(sf)
library(rgdal)

# Functions
sqliteGetTable <- function(database, table) {
  require(DBI)
  require(RSQLite)
  con <- dbConnect(RSQLite::SQLite(), dbname = database)
  query <- dbSendQuery(con, paste("SELECT * FROM ", table, ";", sep=""))
  result <- fetch(query, n = -1)
  dbClearResult(query)
  dbDisconnect(con)
  return(result)
}

countMembersByGrid <- function(i) {
  print(i)
  this_meetup_members.sp <- meetup_members.sp[meetup_members.sp$joined <= sequence[i],]
  res <- over(this_meetup_members.sp, geostat_grid.sp)
  res <- as.data.frame(table(res$GRID_ID_simp))
  res$member_density <- res$member_density <- res$Freq / sum(res$Freq)
  ita_popgrid$these_members <- res$Freq[match(ita_popgrid$GRID_ID_simp, res$Var1)]
  ita_popgrid$these_members[is.na(ita_popgrid$these_members)] <- 0
  return(data.frame(date = sequence[i],
                    members = ita_popgrid$these_members,
                    GRID_ID_simp = ita_popgrid$GRID_ID_simp,
                    COD_REG = ita_popgrid$COD_REG))
}

load('replication_file_07_geostat_grid.RData')

region_2013.sp <- readOGR('.', 'Reg01012013_g_WGS84')
region_2013.sp <-
  spTransform(region_2013.sp, "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs")
region_2013.sp$COD_REG <- as.numeric(as.character(region_2013.sp$COD_REG))

geostat_grid.sp <- as(geostat_grid_simp.sf,'Spatial')
geostat_grid.sp <-
  spTransform(geostat_grid.sp,
              '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0')
res <- over(geostat_grid.sp, region_2013.sp)
geostat_grid.sp$COD_REG <- res$COD_REG
geostat_grid.sp$DEN_REG <- as.character(res$DEN_REG)
ita_popgrid <- geostat_grid.sp[,c('GRID_ID_simp','pop','COD_REG')]
```

```
# Calculate density from entire meetup dataset
meetup_members <- sqliteGetTable('meetup_mar15.sqlite', 'member')
meetup_members <- meetup_members[meetup_members$country %in% c("it"),]
meetup_members$joined <- as.Date(meetup_members$joined)
meetup_members.sp <-
  SpatialPointsDataFrame(meetup_members[,c('lon','lat')],
                         data = meetup_members,
                         proj4string = CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))

sequence <-
  seq(from = as.Date('2005-07-23'),
      to = as.Date('2015-03-01'),
      by = 7)

no_cores <- detectCores() - 1
cl <- makeCluster(no_cores, type="FORK")
members_pop_grid_dt <- rbindlist(parLapply(cl, 1:length(sequence), countMembersByGrid))
stopCluster(cl)
members_pop_grid_dt$north_south <- ifelse(members_pop_grid_dt$COD_REG < 13, "North", "South")

members_pop_grid_dt$pop <-
  ita_popgrid$pop[match(members_pop_grid_dt$GRID_ID_simp, ita_popgrid$GRID_ID_simp)]

save(members_pop_grid_dt, file = "replication_file_08_geographic_diffusion.RData")
```

Figure 7

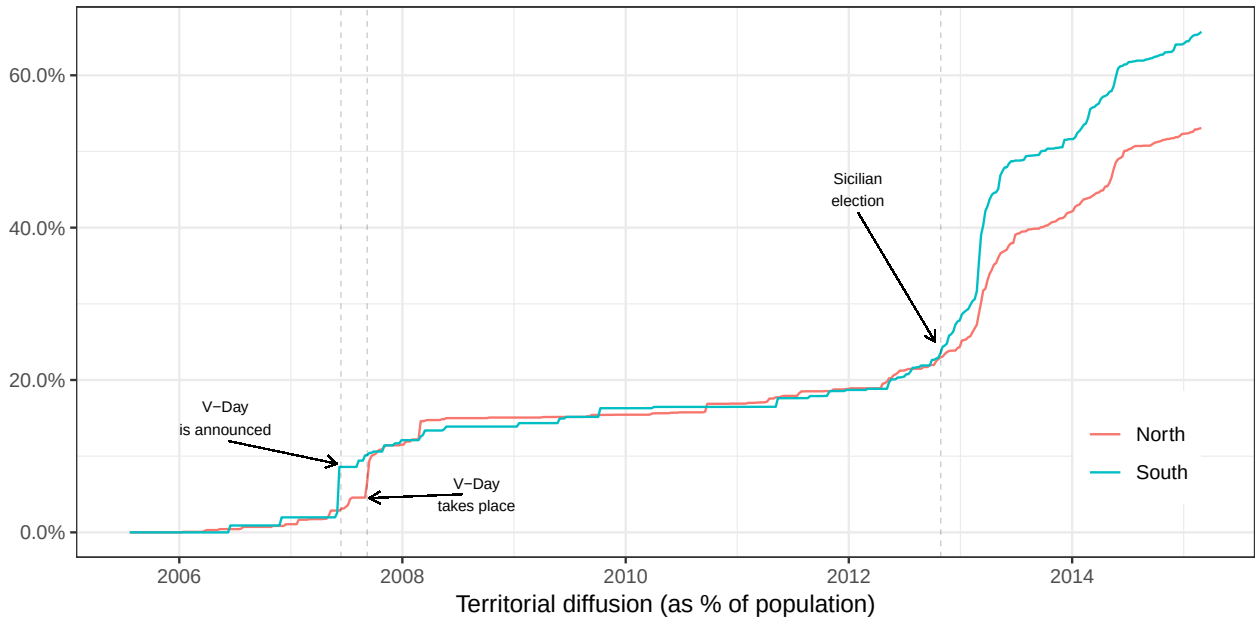
```
load("replication_file_08_geographic_diffusion.RData")

# Average number of residents for each Meetup member
1 /
  mean(members_pop_grid_dt$members[
    members_pop_grid_dt$date == max(members_pop_grid_dt$date) &
      members_pop_grid_dt$pop > 0] /
      members_pop_grid_dt$pop[
        members_pop_grid_dt$date == max(members_pop_grid_dt$date) &
          members_pop_grid_dt$pop > 0])
```

```
## [1] 1436.43
```

```
# Calculate density from entire meetup dataset
meetup_members <- meetup_members_2015
meetup_members <- meetup_members[meetup_members$country %in% c("it"),]
meetup_members$joined <- as.Date(meetup_members$joined)
meetup_members.sp <-
  SpatialPointsDataFrame(meetup_members[,c('lon','lat')],
                         data =
                           meetup_members,
                         proj4string =
                           CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))

geostat_grid.sp <- as(geostat_grid_simp.sf,'Spatial')
```

```
geostat_grid.sp <-
  spTransform(geostat_grid.sp,
              '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0')
res <- over(geostat_grid.sp, region_2013.sp)
geostat_grid.sp$COD_REG <- res$COD_REG
geostat_grid.sp$DEN_REG <- as.character(res$DEN_REG)

ita_popgrid <- geostat_grid.sp[,c('GRID_ID_simp','pop','COD_REG')]
ita_cells <- ita_popgrid$GRID_ID_simp[!is.na(ita_popgrid$COD_REG)]
north_cells <- ita_popgrid$GRID_ID_simp[ita_popgrid$COD_REG < 13]
south_cells <- ita_popgrid$GRID_ID_simp[ita_popgrid$COD_REG >= 13]
ita_pop <- sum(ita_popgrid$pop)
north_pop <- sum(ita_popgrid$pop[ita_popgrid$COD_REG < 13], na.rm = T)
south_pop <- sum(ita_popgrid$pop[ita_popgrid$COD_REG >= 13], na.rm = T)

# A cell is activated if a person every 2000 is a member (1*0.0005)
stats_dt <-
  members_pop_grid_dt[!is.na(members_pop_grid_dt$COD_REG)] %>%
  group_by(date) %>%
  summarize(ita_pop = sum(pop[GRID_ID_simp %in% ita_cells & members > pop*0.0005]) /
              ita_pop,
            north_pop = sum(pop[GRID_ID_simp %in% north_cells & members > pop*0.0005]) /
              north_pop,
            south_pop = sum(pop[GRID_ID_simp %in% south_cells & members > pop*0.0005]) /
              south_pop)

stats_melted_dt <- melt(stats_dt, id.vars = c('date'))
stats_melted_dt <- stats_melted_dt[stats_melted_dt$variable != 'ita_pop',]
stats_melted_dt$what <- ifelse(stats_melted_dt$variable == "north_pop", "North", "South")

ggplot(stats_melted_dt, aes(x=date, y=value, colour = what)) +
  geom_line() +
  scale_y_continuous(label = percent) +
  labs(x="Territorial diffusion (as % of population)", y=NULL, colour=NULL) +
  geom_vline(xintercept = as.Date('2007-06-14'),
             size = .3, linetype = 2, alpha  = .2) +
  geom_vline(xintercept = as.Date('2007-09-08'),
             size = .3, linetype = 2, alpha  = .2) +
  geom_vline(xintercept = as.Date('2012-10-28'),
             size = .3, linetype = 2, alpha  = .2) +
  annotate("text", x = as.Date("2006-06-01"),
           y = 0.15, label = "V-Day\nis announced",
           size = 2.5) +
  geom_segment(aes(x=as.Date("2006-06-10"), xend=as.Date('2007-06-01'),
                   y=0.12, yend=0.09),
               size = .3, arrow = arrow(length = unit(0.2, "cm")),
               colour = 'black') +
  annotate("text", x = as.Date("2008-08-31"), y = 0.05,
           label = "V-Day\ntakes place",
           size = 2.5) +
  geom_segment(aes(x=as.Date("2008-07-15"), xend=as.Date('2007-09-15'),
                   y=0.05, yend=0.045),
               size = .3, arrow = arrow(length = unit(0.2, "cm")),
```

```
              colour = 'black') +
  annotate("text", x = as.Date("2012-01-31"), y = 0.45,
           label = "Sicilian\nelection",
           size = 2.5) +
  geom_segment(aes(x=as.Date("2012-01-31"), xend=as.Date('2012-10-10'),
                   y=0.42, yend=0.25),
               size = .3, arrow = arrow(length = unit(0.2, "cm")), colour = 'black') +
  theme_bw() + theme(legend.position = c(0.9, 0.2))
```



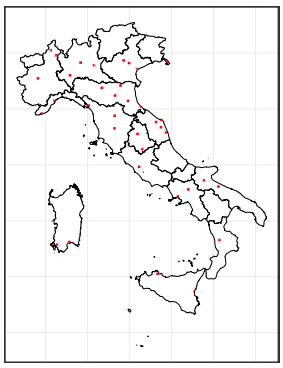

```
ggsave(filename = "figure/ts-meetup-diffusion.pdf", dpi = 300, width = 8, height = 4,
       ggplot(stats_melted_dt, aes(x=date, y=value, colour = what)) +
         geom_line() +
         scale_y_continuous(label = percent) +
         labs(x="Territorial diffusion (as % of population)", y=NULL, colour=NULL) +
         geom_vline(xintercept = as.Date('2007-06-14'),
                    size = .3, linetype = 2, alpha  = .2) +
         geom_vline(xintercept = as.Date('2007-09-08'),
                    size = .3, linetype = 2, alpha  = .2) +
         geom_vline(xintercept = as.Date('2012-10-28'),
                    size = .3, linetype = 2, alpha  = .2) +
         annotate("text", x = as.Date("2006-06-01"),
                  y = 0.15, label = "V-Day\nis announced",
                  size = 3) +
         geom_segment(aes(x=as.Date("2006-06-10"), xend=as.Date('2007-06-01'),
                          y=0.12, yend=0.09),
                      size = .3, arrow = arrow(length = unit(0.2, "cm")),
                      colour = 'black') +
         annotate("text", x = as.Date("2008-08-31"), y = 0.05,
                  label = "V-Day\ntakes place",
                  size = 3) +
         geom_segment(aes(x=as.Date("2008-07-15"), xend=as.Date('2007-09-15'),
                          y=0.05, yend=0.045),
                      size = .3, arrow = arrow(length = unit(0.2, "cm")),
                      colour = 'black') +
```

```
        annotate("text", x = as.Date("2012-01-31"), y = 0.45,
                 label = "Sicilian\nelection",
                 size = 3) +
        geom_segment(aes(x=as.Date("2012-01-31"), xend=as.Date('2012-10-10'),
                         y=0.42, yend=0.25),
                     size = .3, arrow = arrow(length = unit(0.2, "cm")),
                     colour = 'black') +
        theme_bw() + theme(legend.position = c(0.9, 0.2))
)
```

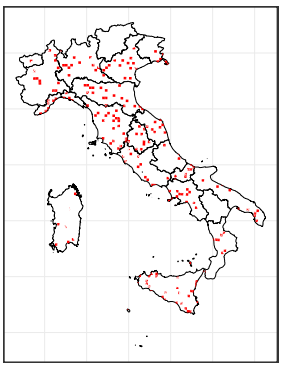
Figure 11

```
geostat_grid.sf <- geostat_grid_simp.sf

ita_grid_plot1 <- members_pop_grid_dt[date == '2007-09-15']
ita_grid_plot1 <- merge(geostat_grid.sf,ita_grid_plot1, by = 'GRID_ID_simp')
ita_grid_plot1$act <- ita_grid_plot1$members > (ita_grid_plot1$pop.x*0.0005)

ita_grid_plot2 <- members_pop_grid_dt[date == '2012-11-03']
ita_grid_plot2 <- merge(geostat_grid.sf, ita_grid_plot2, by = 'GRID_ID_simp')
ita_grid_plot2$act <- ita_grid_plot2$members > (ita_grid_plot2$pop.x*0.0005)

ita_grid_plot3 <- members_pop_grid_dt[date == '2013-03-02']
ita_grid_plot3 <- merge(geostat_grid.sf,ita_grid_plot3, by = 'GRID_ID_simp')
ita_grid_plot3$act <- ita_grid_plot3$members > (ita_grid_plot3$pop.x*0.0005)

ita_grid_plot4 <- members_pop_grid_dt[date == '2015-02-28']
ita_grid_plot4 <- merge(geostat_grid.sf,ita_grid_plot4, by = 'GRID_ID_simp')
ita_grid_plot4$act <- ita_grid_plot4$members > (ita_grid_plot4$pop.x*0.0005)

geostat_grid.sf$cut <-
  cut(geostat_grid.sf$pop,
      breaks = quantile(geostat_grid.sf$pop, probs = seq(0, 1, 0.1)),
      include.lowest = TRUE)

grid.arrange(
  ggplot() +
    geom_sf(data=region_2013.sf, colour = 'black', size = .05,
            fill = 'white') +
    labs(caption = '2007-09-15') +
    geom_sf(data=ita_grid_plot1[ita_grid_plot1$act == TRUE,],
            fill='red', colour = NA, show.legend=F) +
    theme_bw() + theme(axis.text.x=element_blank(),
                       axis.text.y=element_blank(),
                       axis.ticks=element_blank(),
                       axis.title.x=element_blank(),
                       axis.title.y=element_blank()),
  ggplot() +
    geom_sf(data=region_2013.sf, colour = 'black', size = .05,
            fill = 'white') +
    labs(caption = '2012-11-03') +
    geom_sf(data=ita_grid_plot2[ita_grid_plot2$act == TRUE,],
```

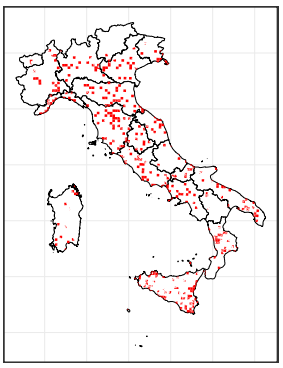
```
          fill='red', colour = NA, show.legend=F) +
  theme_bw() + theme(axis.text.x=element_blank(),
                     axis.text.y=element_blank(),
                     axis.ticks=element_blank(),
                     axis.title.x=element_blank(),
                     axis.title.y=element_blank()),
ggplot() +
  geom_sf(data=region_2013.sf, colour = 'black', size = .05,
          fill = 'white') +
  labs(caption = '2013-03-02') +
  geom_sf(data=ita_grid_plot3[ita_grid_plot3$act == TRUE,],
          fill='red', colour = NA, show.legend=F) +
  theme_bw() + theme(axis.text.x=element_blank(),
                     axis.text.y=element_blank(),
                     axis.ticks=element_blank(),
                     axis.title.x=element_blank(),
                     axis.title.y=element_blank()),
ggplot() +
  geom_sf(data=region_2013.sf, colour = 'black', size = .1,
          fill = 'white') +
  labs(caption = '2015-02-28') +
  geom_sf(data=ita_grid_plot4[ita_grid_plot3$act == TRUE,],
          fill='red', colour = NA, show.legend=F) +
  theme_bw() + theme(axis.text.x=element_blank(),
                     axis.text.y=element_blank(),
                     axis.ticks=element_blank(),
                     axis.title.x=element_blank(),
                     axis.title.y=element_blank()),
ggplot() +
  labs(caption = 'Population density (2011 census)') +
  geom_sf(data=geostat_grid.sf, aes(fill=cut), colour = NA, show.legend=F) +
  scale_fill_manual(values = c('white',brewer.pal(9, "YlGn"))) +
  theme_bw() + theme(axis.text.x=element_blank(),
                     axis.text.y=element_blank(),
                     axis.ticks=element_blank(),
                     axis.title.x=element_blank(),
                     axis.title.y=element_blank()),
ncol = 3)
```



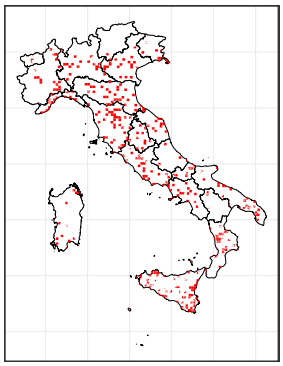
2007−09−15



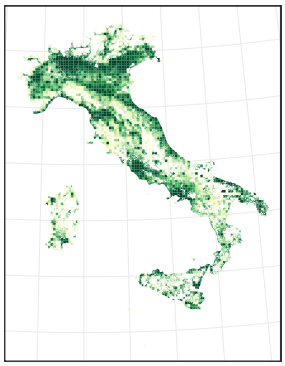
2012−11−03



2013−03−02



2015−02−28



Population density (2011 census)

```
pdf(file = "figure/map-ita-pop-act.pdf", width = 10, height = 20)
grid.arrange(
  ggplot() +
    geom_sf(data=region_2013.sf, colour = 'black', size = .05, fill = 'white') +
    labs(caption = '2007-09-15') +
    geom_sf(data=ita_grid_plot1[ita_grid_plot1$act == TRUE,],
            fill='red', colour = NA, show.legend=F) +
    theme_bw() + theme(axis.text.x=element_blank(),
                       axis.text.y=element_blank(),
                       axis.ticks=element_blank(),
                       axis.title.x=element_blank(),
                       axis.title.y=element_blank(),
                       text = element_text(family = "Palatino")),
  ggplot() +
    geom_sf(data=region_2013.sf, colour = 'black', size = .05, fill = 'white') +
    labs(caption = '2012-11-03') +
    geom_sf(data=ita_grid_plot2[ita_grid_plot2$act == TRUE,],
            fill='red', colour = NA, show.legend=F) +
    theme_bw() + theme(axis.text.x=element_blank(),
                       axis.text.y=element_blank(),
                       axis.ticks=element_blank(),
                       axis.title.x=element_blank(),
                       axis.title.y=element_blank(),
                       text = element_text(family = "Palatino")),
  ggplot() +
    geom_sf(data=region_2013.sf, colour = 'black', size = .05, fill = 'white') +
    labs(caption = '2013-03-02') +
```

```
    geom_sf(data=ita_grid_plot3[ita_grid_plot3$act == TRUE,],
            fill='red', colour = NA, show.legend=F) +
    theme_bw() + theme(axis.text.x=element_blank(),
                       axis.text.y=element_blank(),
                       axis.ticks=element_blank(),
                       axis.title.x=element_blank(),
                       axis.title.y=element_blank(),
                       text = element_text(family = "Palatino")),
  ggplot() +
    geom_sf(data=region_2013.sf, colour = 'black', size = .1, fill = 'white') +
    labs(caption = '2015-02-28') +
    geom_sf(data=ita_grid_plot4[ita_grid_plot3$act == TRUE,],
            fill='red', colour = NA, show.legend=F) +
    theme_bw() + theme(axis.text.x=element_blank(),
                       axis.text.y=element_blank(),
                       axis.ticks=element_blank(),
                       axis.title.x=element_blank(),
                       axis.title.y=element_blank(),
                       text = element_text(family = "Palatino")),
  ggplot() +
    labs(caption = 'Population density (2011 census)') +
    geom_sf(data=geostat_grid.sf, aes(fill=cut), colour = NA, show.legend=F) +
    scale_fill_manual(values = c('white',brewer.pal(9, "YlGn"))) +
    theme_bw() + theme(axis.text.x=element_blank(),
                       axis.text.y=element_blank(),
                       axis.ticks=element_blank(),
                       axis.title.x=element_blank(),
                       axis.title.y=element_blank(),
                       text = element_text(family = "Palatino")),
  ncol = 2)
dev.off()
```

```
## pdf
##   2
```

Analysis of recruitment and Post-recruitment networks

To replicate the following chunks:

```
R -e 'setwd("/path/to/directory");
source("replication_code_06_measure_geographic_diffusion.R");'
```

```
read_chunk('replication_code_07_network_density.R')
```

```
load("replication_file_04_friendship_graph.RData")
load("replication_file_06_recruitment_graph.RData")
load('replication_file_07_geostat_grid.RData')

library(data.table)
library(parallel)
library(igraph)
library(sp)
library(sf)
library(rgdal)
```

```r
library(dplyr)

region_2013.sp <- readOGR('.', 'Reg01012013_g_WGS84')
region_2013.sp <-
  spTransform(region_2013.sp, "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs")
region_2013.sp$COD_REG <- as.numeric(as.character(region_2013.sp$COD_REG))

region_2013.sf <- st_as_sf(region_2013.sp)
region_south_2013.sf <- region_2013.sf %>% filter(COD_REG >= 13)

lonlat_node_df <- data.frame(lon = V(g_recruitment)$lon,
                             lat = V(g_recruitment)$lat)
lonlat_node.sp <-
  SpatialPoints(lonlat_node_df,
                proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))
res <- over(lonlat_node.sp, region_2013.sp)

V(g_recruitment)$DEN_REG <- as.character(res$DEN_REG)
V(g_recruitment)$COD_REG <- res$COD_REG
V(g_recruitment)$north_south <-
  ifelse(V(g_recruitment)$COD_REG < 13, "North", "South")

sequence <-
  seq(from = min(as.Date(V(g_recruitment)$joined_mu)), t
      o = as.Date(max(V(g_recruitment)$joined_mu)),
      by = 7)

geostat_grid.sp <-
  as(geostat_grid_simp.sf,'Spatial')
geostat_grid.sp <-
  spTransform(geostat_grid.sp,
              '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0')

# Italy only
g_recruitment <-
  g_recruitment - V(g_recruitment)[is.na(V(g_recruitment)$north_south)]
lonlat_node_df <-
  data.frame(lon = V(g_recruitment)$lon,
             lat = V(g_recruitment)$lat)
lonlat_node.sp <-
  SpatialPoints(lonlat_node_df,
                proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))

lonlat_north_node.df <-
  data.frame(lon = V(g_recruitment)$lon[V(g_recruitment)$north_south == "North"],
             lat = V(g_recruitment)$lat[V(g_recruitment)$north_south == "North"])
lonlat_north_node.sp <-
  SpatialPoints(lonlat_north_node.df,
                proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))

lonlat_south_node.df <-
  data.frame(lon = V(g_recruitment)$lon[V(g_recruitment)$north_south == "South"],
             lat = V(g_recruitment)$lat[V(g_recruitment)$north_south == "South"])
```

```
lonlat_south_node.sp <-
  SpatialPoints(as.matrix(lonlat_south_node.df),
                proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))

geostat_grid.sp <-
  as(geostat_grid_simp.sf,'Spatial')
geostat_grid.sp <-
  spTransform(geostat_grid.sp,
              '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0')

res <- over(geostat_grid.sp, region_2013.sp)
geostat_grid.sp$COD_REG <- res$COD_REG
geostat_grid.sp$DEN_REG <- as.character(res$DEN_REG)

tot_pop <- sum(geostat_grid.sp$pop)
tot_north_pop <- sum(geostat_grid.sp$pop[geostat_grid.sp$COD_REG < 13], na.rm = T)
tot_south_pop <- sum(geostat_grid.sp$pop[geostat_grid.sp$COD_REG >= 13], na.rm = T)

## Tot
res <- over(lonlat_node.sp, geostat_grid.sp)
res <- as.data.frame(table(res$GRID_ID_simp))
geostat_grid.sp$n_nodes <- res$Freq[match(geostat_grid.sp$GRID_ID_simp, res$Var1)]
geostat_grid.sp$n_nodes[is.na(geostat_grid.sp$n_nodes)] <- 0

## North
res <- over(lonlat_north_node.sp, geostat_grid.sp)
res <- as.data.frame(table(res$GRID_ID_simp))
geostat_grid.sp$n_north_nodes <- res$Freq[match(geostat_grid.sp$GRID_ID_simp, res$Var1)]
geostat_grid.sp$n_north_nodes[is.na(geostat_grid.sp$n_north_nodes)] <- 0

## South
res <- over(lonlat_south_node.sp, geostat_grid.sp)
res <- as.data.frame(table(res$GRID_ID_simp))
geostat_grid.sp$n_south_nodes <- res$Freq[match(geostat_grid.sp$GRID_ID_simp, res$Var1)]
geostat_grid.sp$n_south_nodes[is.na(geostat_grid.sp$n_south_nodes)] <- 0

# Tot node
tot_max_act_cells <- sum(geostat_grid.sp$n_nodes > 0)
north_max_act_cells <- sum(geostat_grid.sp$n_north_nodes > 0)
south_max_act_cells <- sum(geostat_grid.sp$n_south_nodes > 0)

getPnt <- function(g) {
  require(igraph)
  lonlat_node.df <-
    data.frame(lon = V(g)$lon,
               lat = V(g)$lat)
  lonlat_node.sp <-
    SpatialPoints(lonlat_node.df,
                  proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))
  return(lonlat_node.sp)
}

computeNetStats <- function(i) {
```

```
require(igraph)
require(sp)
print(i)
this_g <-
  g_recruitment - V(g_recruitment)[as.Date(V(g_recruitment)$joined_mu) >= sequence[i]]

this_g <- this_g -  V(this_g)[is.na(V(this_g)$north_south)]
this_g_north <- this_g - V(this_g)[V(this_g)$north_south == 'South']
this_g_south <- this_g - V(this_g)[V(this_g)$north_south == 'North']

res <- over(getPnt(this_g), geostat_grid.sp)
res <- unique(res[,c('GRID_ID_simp','pop')])
this_act_cells <- nrow(res)
this_act_pop <- sum(res$pop, na.rm = T)

if (vcount(this_g_north) > 0) {
  res <- over(getPnt(this_g_north), geostat_grid.sp)
  res <- unique(res[,c('GRID_ID_simp','pop')])
  this_north_act_cells <- nrow(res)
  this_north_act_pop <- sum(res$pop, na.rm = T)
} else {
  this_north_act_cells <- 0
  this_north_act_pop <- 0
}

res <- over(getPnt(this_g_south), geostat_grid.sp)
res <- unique(res[,c('GRID_ID_simp','pop')])
this_south_act_cells <- nrow(res)
this_south_act_pop <- sum(res$pop, na.rm = T)

density_cum_df <-
  data.frame(time = sequence[i],
             density = edge_density(this_g),
             n = vcount(this_g),
             act_cells =  this_act_cells / tot_max_act_cells,
             act_pop = this_act_pop / tot_pop,
             scope = 'all')
density_cum_df <-
  rbind(density_cum_df,
        data.frame(time = sequence[i],
                   density = edge_density(this_g_north),
                   n = vcount(this_g_north),
                   act_cells = this_north_act_cells / north_max_act_cells,
                   act_pop = this_north_act_pop / tot_north_pop,
                   scope = 'north'))
density_cum_df <-
  rbind(density_cum_df,
        data.frame(time = sequence[i],
                   density = edge_density(this_g_south),
                   n = vcount(this_g_south),
                   act_cells = this_south_act_cells / south_max_act_cells,
                   act_pop = this_south_act_pop / tot_south_pop,
                   scope = 'south'))
```

```
  return(density_cum_df)
}

no_cores <- detectCores() - 1
cl <- makeCluster(no_cores, type="FORK")

density_cum_dt <- rbindlist(parLapply(cl, 2:length(sequence), computeNetStats))
stopCluster(cl)

save(density_cum_dt, file = "replication_file_09_network_density.RData")
```

```
load("replication_file_04_friendship_graph.RData")
load("replication_file_06_recruitment_graph.RData")

region_south_2013.sf <- region_2013.sf %>% filter(COD_REG >= 13)

lonlat_node_df <- data.frame(lon = V(g_recruitment)$lon,
                             lat = V(g_recruitment)$lat)
lonlat_node.sp <-
  SpatialPoints(lonlat_node_df,
                proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))
res <- over(lonlat_node.sp, region_2013.sp)

V(g_recruitment)$DEN_REG <- as.character(res$DEN_REG)
V(g_recruitment)$COD_REG <- res$COD_REG
V(g_recruitment)$north_south <-
  ifelse(V(g_recruitment)$COD_REG < 13, "North", "South")
```

Recruitment density

```
indegree_north <-
  igraph::degree(g_recruitment -
                   V(g_recruitment)[as.Date(V(g_recruitment)$joined_mu) >
                                      as.Date('2012-10-28') |
                                      V(g_recruitment)$north_south %in% "South"],
                 mode = 'in')
indegree_south <-
  igraph::degree(g_recruitment -
                   V(g_recruitment)[as.Date(V(g_recruitment)$joined_mu) >
                                      as.Date('2012-10-28') |
                                      V(g_recruitment)$north_south %in% "North"],
                 mode = 'in')
indegree_test_df <- data.frame(degree = c(indegree_north, indegree_south),
                               where = c(rep('North',length(indegree_north)),
                                         rep('South',length(indegree_south))))

t.test(degree ~ where, data = indegree_test_df, var.equal = FALSE)
```

```
##
##  Welch Two Sample t-test
##
## data:  degree by where
## t = 1.827, df = 2347.4, p-value = 0.06783
## alternative hypothesis: true difference in means is not equal to 0
```

```
## 95 percent confidence interval:
##  -0.01436314  0.40596479
## sample estimates:
## mean in group North mean in group South
##           0.8032305           0.6074297
```

Post-recruitment density

```
postrecruitment_el <- as.data.frame(get.edgelist(g))
postrecruitment_el$since <- as.Date(paste0("01 ", E(g)$since), "%d %B %Y")
postrecruitment_el$joined_A <- as.Date(V(g)$joined_mu[match(postrecruitment_el$V1, V(g)$name)])
postrecruitment_el$joined_B <- as.Date(V(g)$joined_mu[match(postrecruitment_el$V2, V(g)$name)])
postrecruitment_el <- subset(postrecruitment_el, since > joined_A & since > joined_B)
g_postrecruitment <- graph_from_data_frame(postrecruitment_el[,1:3], directed = F)
missing_v <- V(g)$name[! V(g)$name %in% V(g_postrecruitment)$name]
g_postrecruitment <-
  g_postrecruitment %>% add_vertices(nv = length(missing_v), attr = list(name = missing_v))
V(g_postrecruitment)$joined_mu <- V(g)$joined_mu[match(V(g_postrecruitment)$name, V(g)$name)]
V(g_postrecruitment)$COD_REG <-
  V(g_recruitment)$COD_REG[match(V(g_postrecruitment)$name, V(g_recruitment)$name)]

postrecruiment_density_df <- data.frame()
sequence <-
  seq(from = min(as.Date(meetup_members_2015$joined)),
      max(as.Date(meetup_members_2015$joined)), by = 30)
for (i in 1:length(sequence)) {

  this_g <-
    g_postrecruitment -
    V(g_postrecruitment)[as.Date(V(g_postrecruitment)$joined_mu) >= sequence[i]]

  this_g_north <- this_g - V(this_g)[V(this_g)$COD_REG %in% 13:20]
  this_g_south <- this_g - V(this_g)[V(this_g)$COD_REG %in% 1:12]

  postrecruiment_density_df <-
    rbind(postrecruiment_density_df, data.frame(time = sequence[i],
                                                density = c(edge_density(this_g_north),
                                                            edge_density(this_g_south)),
                                                where = c("North", "South")))
}


degree_north <-
  igraph::degree(g_postrecruitment -
                   V(g_postrecruitment)[as.Date(V(g_postrecruitment)$joined_mu) >
                                          as.Date('2012-10-28') |
                                          V(g_postrecruitment)$COD_REG %in% 13:20],
                 mode = 'all')
degree_south <-
  igraph::degree(g_postrecruitment -
                   V(g_postrecruitment)[as.Date(V(g_postrecruitment)$joined_mu) >
                                          as.Date('2012-10-28') |
                                          V(g_postrecruitment)$COD_REG %in% 1:12],
                 mode = 'all')
```

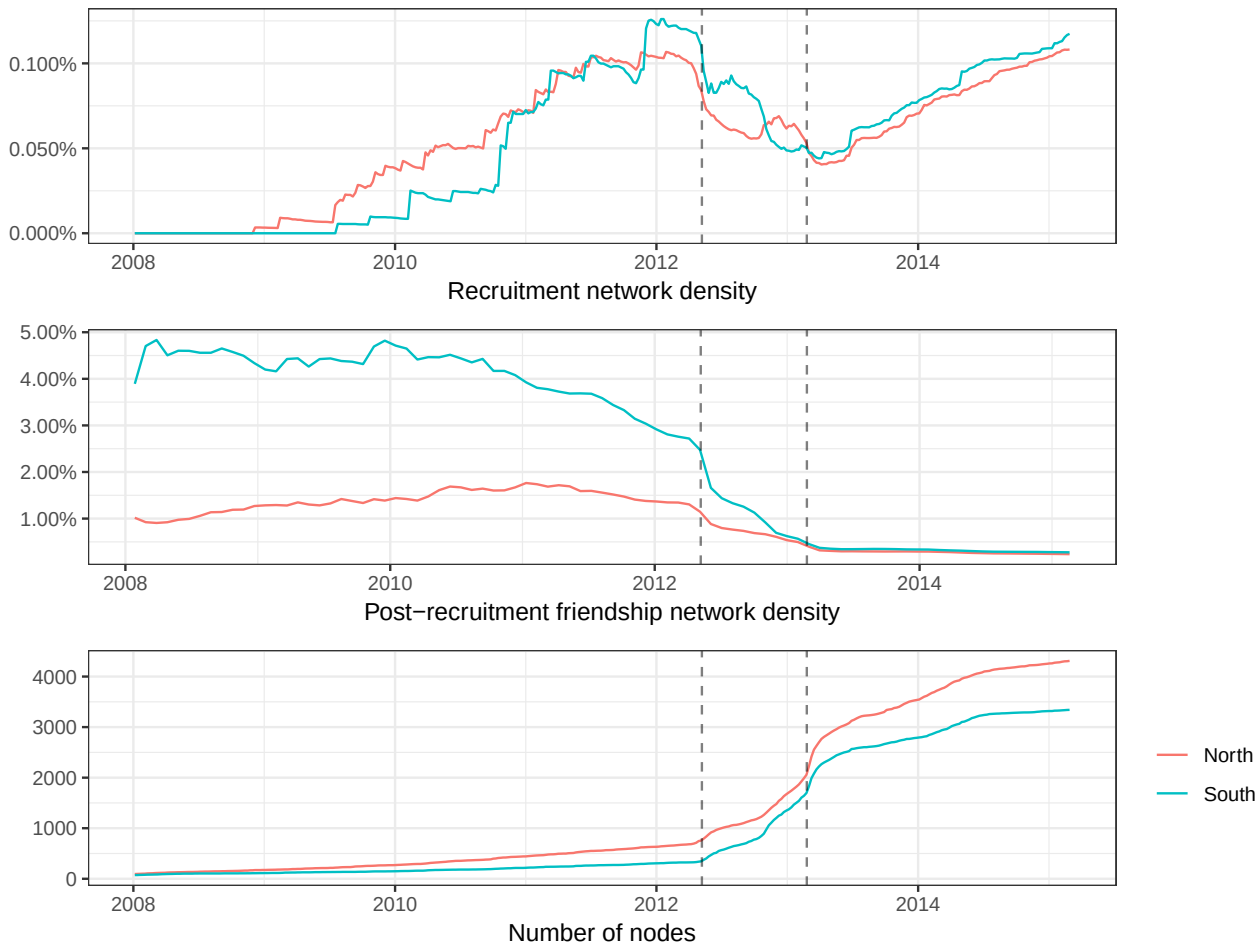
```r
degree_test_df <- data.frame(degree = c(degree_north, degree_south),
                             where = c(rep('North',length(degree_north)),
                                       rep('South',length(degree_south))))

t.test(degree ~ where, data = degree_test_df, var.equal = FALSE)
```

```
##
##  Welch Two Sample t-test
##
## data:  degree by where
## t = -1.0779, df = 2081.7, p-value = 0.2812
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -2.1332163  0.6199386
## sample estimates:
## mean in group North mean in group South
##            9.004405            9.761044
```

Figure 8

```r
load("replication_file_09_network_density.RData")

p1 <-
  ggplot(density_cum_dt[density_cum_dt$scope!='all' &
                          density_cum_dt$time > as.Date("2008-01-01"),],
         aes(x=time, y=density, colour=scope)) +
  geom_line() +
  geom_vline(xintercept = as.numeric(as.Date(c("2012-05-07", "2013-02-24"))),
             linetype = 2, alpha = .5) +
  labs(y = NULL, x="Recruitment network density") +
  scale_y_continuous(labels = percent) + guides(colour=FALSE) + theme_bw()

p2 <-
  ggplot(postrecruiment_density_df[postrecruiment_density_df$time >
                                     as.Date("2008-01-01"),],
         aes(x=time, y=density, colour=where)) +
  geom_line() +
  geom_vline(xintercept = as.numeric(as.Date(c("2012-05-07", "2013-02-24"))),
             linetype = 2, alpha = .5) +
  labs(y = NULL, x="Post-recruitment friendship network density") +
  scale_y_continuous(labels = percent) + guides(colour=FALSE) + theme_bw()

density_cum_dt$label <- ifelse(density_cum_dt$scope == "north", "North", "South")

p3 <-
  ggplot(density_cum_dt[density_cum_dt$scope!='all' &
                          density_cum_dt$time > as.Date("2008-01-01"),],
         aes(x=time, y=n, colour=label)) +
  geom_line() +
  geom_vline(xintercept = as.numeric(as.Date(c("2012-05-07", "2013-02-24"))),
             linetype = 2, alpha = .5) +
  labs(y = NULL, x="Number of nodes", colour = NULL) +
```

```
  theme(legend.position = 'bottom') + theme_bw()

egg::ggarrange(p1, p2, p3, ncol = 1)
```




```
p1 <-
  ggplot(density_cum_dt[density_cum_dt$scope!='all' &
                          density_cum_dt$time > as.Date("2008-01-01"),],
         aes(x=time, y=density, colour=scope)) +
  geom_line() +
  geom_vline(xintercept = as.numeric(as.Date(c("2012-05-07", "2013-02-24"))),
             linetype = 2, alpha = .5) +
  labs(y = NULL, x="Recruitment network density") +
  scale_y_continuous(labels = percent) + guides(colour=FALSE) +
  theme_bw() +
  theme(legend.position = 'bottom', text = element_text(family = "Palatino"))

p2 <-
  ggplot(postrecruiment_density_df[postrecruiment_density_df$time >
                                     as.Date("2008-01-01"),],
         aes(x=time, y=density, colour=where)) +
  geom_line() +
  geom_vline(xintercept = as.numeric(as.Date(c("2012-05-07", "2013-02-24"))),
             linetype = 2, alpha = .5) +
```

```
  labs(y = NULL, x="Post-recruitment friendship network density") +
  scale_y_continuous(labels = percent) + guides(colour=FALSE) +
  theme_bw() +
  theme(legend.position = 'bottom', text = element_text(family = "Palatino"))

density_cum_dt$label <- ifelse(density_cum_dt$scope == "north", "North", "South")

p3 <-
  ggplot(density_cum_dt[density_cum_dt$scope!='all' & density_cum_dt$time >
                          as.Date("2008-01-01"),],
         aes(x=time, y=n, colour=label)) +
  geom_line() +
  geom_vline(xintercept = as.numeric(as.Date(c("2012-05-07", "2013-02-24"))),
             linetype = 2, alpha = .5) +
  labs(y = NULL, x="Number of nodes", colour = NULL) +
  theme_bw() +
  theme(legend.position = 'bottom', text = element_text(family = "Palatino"))

pdf(file = "figure/ts-net-density.pdf", width = 8, height = 6)
egg::ggarrange(p1, p2, p3, ncol = 1)
dev.off()
```

```
## pdf
##   2
```

Exponential Random Graph Models

Create control variable `pre_active_buff_20km`

```
read_chunk('replication_code_08_buffer_density.R')
```

```
load("replication_file_04_friendship_graph.RData")
load("replication_file_06_recruitment_graph.RData")

library(parallel)
library(data.table)
library(igraph)
library(sp)
library(sf)
library(rgdal)
library(dplyr)
library(DBI)
library(RSQLite)

# Functions
sqliteGetTable <- function(database, table) {
  require(DBI)
  require(RSQLite)
  con <- dbConnect(RSQLite::SQLite(), dbname = database)
  query <- dbSendQuery(con, paste("SELECT * FROM ", table, ";", sep=""))
  result <- fetch(query, n = -1)
  dbClearResult(query)
  dbDisconnect(con)
```

```
  return(result)
}

region_2013.sp <- readOGR('.', 'Reg01012013_g_WGS84')
region_2013.sp <-
  spTransform(region_2013.sp, "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs")
region_2013.sp$COD_REG <- as.numeric(as.character(region_2013.sp$COD_REG))

region_2013.sf <- st_as_sf(region_2013.sp)
region_south_2013.sf <- region_2013.sf %>% filter(COD_REG >= 13)

lonlat_node_df <- data.frame(lon = V(g_recruitment)$lon,
                             lat = V(g_recruitment)$lat)
lonlat_node.sp <-
  SpatialPoints(lonlat_node_df,
                proj4string=CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))
res <- over(lonlat_node.sp, region_2013.sp)

V(g_recruitment)$DEN_REG <- as.character(res$DEN_REG)
V(g_recruitment)$COD_REG <- res$COD_REG
V(g_recruitment)$north_south <- ifelse(V(g_recruitment)$COD_REG < 13, "North", "South")

# Italy only
g_recruitment <-
  g_recruitment - V(g_recruitment)[is.na(V(g_recruitment)$north_south)]

g_pnts <-
  SpatialPointsDataFrame(cbind(V(g_recruitment)$lon,
                               V(g_recruitment)$lat),
                         proj4string = CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'),
                         data = data.frame(joined_mu = V(g_recruitment)$joined_mu,
                                           name = as.character(V(g_recruitment)$name)))
g_pnts <- spTransform(g_pnts, CRS("+proj=utm +zone=32 +datum=WGS84 +units=m +no_defs"))

meetup_members <- sqliteGetTable('meetup_mar15.sqlite', 'member')
italy_box_y <- c(36, 47.5)
italy_box_x <- c(6.1, 19.5)
meetup_members <- meetup_members[meetup_members$lon >= italy_box_x[1] &
                                 meetup_members$lon <= italy_box_x[2] &
                                 meetup_members$lat >= italy_box_y[1] &
                                 meetup_members$lat <= italy_box_y[2],]
mu_pnts <-
  SpatialPoints(cbind(meetup_members$lon,
                      meetup_members$lat),
                proj4string = CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))
mu_pnts <-
  spTransform(mu_pnts, CRS("+proj=utm +zone=32 +datum=WGS84 +units=m +no_defs"))

countGeoActive <- function(i) {
  this_buff <- rgeos::gBuffer(g_pnts[i,], width = 20000)
  these_pre_pnts <-
    g_pnts[as.POSIXct(g_pnts$joined_mu) < as.POSIXct(g_pnts$joined_mu[i]),]
  if (nrow(these_pre_pnts) == 0) {
```

```
    pre_active_buff_20km <- 0
  } else {
    pre_res <- over(these_pre_pnts, this_buff)
    pre_active_buff_20km <- sum(!is.na(pre_res))
  }
  tot_res <- over(mu_pnts, this_buff)
  return(list(pre_active_buff_20km = pre_active_buff_20km,
              tot_active_buff_20km = sum(!is.na(tot_res)),
              name = g_pnts$name[i]))
}

no_cores <- detectCores() - 1
cl <- makeCluster(no_cores, type="FORK")

res <- parLapply(cl, 1:vcount(g_recruitment), countGeoActive)
net_active_buff_20km_df <-
  data.frame(name = sapply(res, FUN = function(x) x$name),
             pre_active_buff_20km = sapply(res, FUN = function(x) x$pre_active_buff_20km),
             tot_active_buff_20km = sapply(res, FUN = function(x) x$tot_active_buff_20km))

save(net_active_buff_20km_df,
     file  = "replication_file_10_net_active_buff_20km.RData")
```

Create control variable gender

```
read_chunk('replication_code_09_gender_attribution.R')
```

```
italian_names_by_gender <- read.csv("replication_file_11_italian_names_by_gender.csv", header=FALSE)
italian_names_by_gender <- unique(italian_names_by_gender)
italian_names_by_gender <- italian_names_by_gender[
  (!duplicated(italian_names_by_gender$V1) &
     !duplicated(italian_names_by_gender$V1, fromLast = TRUE)),]

sqliteGetTable <- function(database, table) {
  require(DBI)
  require(RSQLite)
  con <- dbConnect(RSQLite::SQLite(), dbname = database)
  query <- dbSendQuery(con, paste("SELECT * FROM ", table, ";", sep=""))
  result <- fetch(query, n = -1)
  dbClearResult(query)
  dbDisconnect(con)
  return(result)
}
meetup_members_2014 <- sqliteGetTable('meetup_aug14.sqlite', 'member')

# Functions
simpleCap <- function(string) {
  s <- strsplit(string, " ")[[1]]
  paste(toupper(substring(s, 1, 1)), substring(s, 2), sep = "", collapse = " ")
}

firstnamesFirst <- function (name, name_dictionary) {
```

```
  name_dictionary <- tolower(as.character(name_dictionary[[1]]))
  name <- as.character(name)
  name <- tolower(name)
  name <- unlist(strsplit(name, " "))

  for (char in name) {
    if (char %in% name_dictionary) {
      return(char)
    }

  }
  return(NA)
}

genderAttribution <- function(string, dictionary) {
  require(stringr)

  # First name first
  string <- firstnamesFirst(string, dictionary)

  # Substring first word (first name)
  string <- stringr::word(string, 1)

  # Remove white spaces
  string <- gsub("-", " ", string)

  # Capitalise first letter to match dictionary
  string <- simpleCap(string)

  # Create vector with matched gender
  return(as.character(dictionary[[2]][match(string, dictionary[[1]])]))
}

require(parallel)
no_cores <- detectCores() - 1
cl <- makeCluster(no_cores)
X <- lsf.str()
clusterExport(cl=cl, varlist=c(as.vector(X)), envir=environment())

assigned_gender_vec <-
  unlist(parLapply(cl, meetup_members_2014$name, genderAttribution, italian_names_by_gender))

stopCluster(cl)

meetup_members_2014_gender <-
  data.frame(member_id = meetup_members_2014$member_id,
             gender = assigned_gender_vec, stringsAsFactors = FALSE)
save(meetup_members_2014_gender,
     file = 'replication_file_12_meetup_members_2014_gender.RData')
```

```
load('replication_file_12_meetup_members_2014_gender.RData')
meetup_members_2014$gender <-
  meetup_members_2014_gender$gender[match(meetup_members_2014$member_id,
                                          meetup_members_2014_gender$member_id)]
```

```
prop.table(table(meetup_members_2014$gender, useNA = 'always'))
```

```
##
##       female         male    undefined         <NA>
## 0.1888393587 0.6724807787 0.0001329135 0.1385469491
```

ERGM

```
load("replication_file_10_net_active_buff_20km.RData")

region_2013.sp$sc_net <-
  survey_reg_avg$sc_net[match(region_2013.sp$COD_REG, survey_reg_avg$COD_REG)]
region_2013.sp$sc_trust <-
  survey_reg_avg$sc_trust[match(region_2013.sp$COD_REG, survey_reg_avg$COD_REG)]

g_recruitment_df <-
  vertexAttributesAsDataFrame(addDegreeToVertices(g_recruitment))
g_recruitment_df$joined_mu_year <-
  format(as.Date(g_recruitment_df$joined_mu), "%Y")
g_recruitment.sp <-
  SpatialPoints(g_recruitment_df[,c('lon','lat')],
                proj4string =
                  CRS('+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))

res <-
  over(g_recruitment.sp,
       spTransform(region_2013.sp,
                   '+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs'))
g_recruitment_df <-
  cbind(g_recruitment_df,
        res[,c("sc_net", "sc_trust" )])
g_recruitment_df$pre_active_buff_20km <-
  net_active_buff_20km_df$pre_active_buff_20km[
    match(g_recruitment_df$name, net_active_buff_20km_df$name)]

g_recruitment_df$joined_mu <-
  as.Date(as.character(g_recruitment_df$joined_mu))
g_recruitment_df$joined_mu_num <-
  as.numeric(g_recruitment_df$joined_mu)
g_recruitment_df$gender <-
  meetup_members_2014$gender[match(g_recruitment_df$name,
                                   meetup_members_2014$facebook)]

## Add to network
V(g_recruitment)$sc_net <-
  g_recruitment_df$sc_net[match(g_recruitment_df$name,
                                V(g_recruitment)$name)]
V(g_recruitment)$sc_trust <-
  g_recruitment_df$sc_trust[match(g_recruitment_df$name,
                                  V(g_recruitment)$name)]
V(g_recruitment)$pre_active_buff_20km <-
  g_recruitment_df$pre_active_buff_20km[
```

```
    match(g_recruitment_df$name, V(g_recruitment)$name)]
V(g_recruitment)$gender <-
  g_recruitment_df$gender[match(g_recruitment_df$name,
                                V(g_recruitment)$name)]

# Exclude nodes out of Italy
net_recruitment <-
  asNetwork(g_recruitment -
              V(g_recruitment)[is.na(V(g_recruitment)$COD_REG)])

mod_egrm_recruitment <-
  ergm(net_recruitment ~ edges +
         nodeicov("pre_active_buff_20km") +
         nodeifactor("north_south", base = 1) +
         nodeifactor("gender", base = 1) +
         nodeofactor("gender", base = 1) +
         nodematch("gender") +
         nodeicov("sc_net") + nodeicov("sc_trust")
  )
```

```
## Evaluating log-likelihood at the estimate.
```

```
net_recruitment
```

```
##  Network attributes:
##   vertices = 7654
##   directed = TRUE
##   hyper = FALSE
##   loops = FALSE
##   multiple = FALSE
##   bipartite = FALSE
##   total edges= 44790
##     missing edges= 0
##     non-missing edges= 44790
##
##  Vertex attribute names:
##     COD_REG DEN_REG gender joined_fb joined_mu lat lon north_south pre_active_buff_20km sc_net sc_tru
##
##  Edge attribute names not shown
```

```
V(g_postrecruitment)$pre_active_buff_20km <-
  V(g_recruitment)$pre_active_buff_20km[
    match(V(g_postrecruitment)$name, V(g_recruitment)$name)]
V(g_postrecruitment)$north_south <-
  V(g_recruitment)$north_south[
    match(V(g_postrecruitment)$name, V(g_recruitment)$name)]
V(g_postrecruitment)$gender <-
  V(g_recruitment)$gender[
    match(V(g_postrecruitment)$name, V(g_recruitment)$name)]
V(g_postrecruitment)$sc_net <-
  V(g_recruitment)$sc_net[
    match(V(g_postrecruitment)$name, V(g_recruitment)$name)]
V(g_postrecruitment)$sc_trust <-
  V(g_recruitment)$sc_trust[
    match(V(g_postrecruitment)$name, V(g_recruitment)$name)]
```

```r
# Exclude nodes out of Italy
net_postrecruitment <- asNetwork(g_postrecruitment - V(g_postrecruitment)[is.na(V(g_postrecruitment)$COD

mod_egrm_postrecruitment <-
  ergm(net_postrecruitment ~ edges +
         nodecov("pre_active_buff_20km") +
         nodefactor("north_south", base = 1) +
         nodefactor("gender") +
         nodematch("gender") +
         nodecov("sc_net") + nodecov("sc_trust")
  )
```

```
## Evaluating log-likelihood at the estimate.
```

```r
net_postrecruitment
```

```
##  Network attributes:
##   vertices = 7654
##   directed = FALSE
##   hyper = FALSE
##   loops = FALSE
##   multiple = FALSE
##   bipartite = FALSE
##   total edges= 57875
##     missing edges= 0
##     non-missing edges= 57875
##
##  Vertex attribute names:
##     COD_REG gender joined_mu north_south pre_active_buff_20km sc_net sc_trust vertex.names
##
##  Edge attribute names not shown
```

```r
save(g_recruitment, g_postrecruitment, file = 'debug_replication.RData')
```

Table 3

```r
texreg(list(mod_egrm_recruitment, mod_egrm_postrecruitment))
```

```r
texreg(list(mod_egrm_recruitment, mod_egrm_postrecruitment),
       file = "table/ergm-coef.tex",
       custom.model.names = c("Recruitment network", "Post-recruitment network"))
htmlreg(list(mod_egrm_recruitment, mod_egrm_postrecruitment),
        file = "table/ergm-coef.html",
        custom.model.names = c("Recruitment network", "Post-recruitment network"))
```

Logistic regression predicting at least one recruiting tie

```r
g_recruitment_df$joined_mu <- as.Date(g_recruitment_df$joined_mu)
g_recruitment_df$at_least_one_indegree <- g_recruitment_df$indegree > 0

# First phase
prop.table(table(g_recruitment_df[g_recruitment_df$joined_mu <
                                    as.Date("2012-10-28"), ]$at_least_one_indegree,
```

	Model 1	Model 2
edges	-8.17^{***}	-4.48^{***}
	(0.06)	(0.08)
nodeicov.pre_active_buff_20km	0.00^{***}	
	(0.00)	
nodeifactor.north_south.South	0.17^{***}	
	(0.02)	
nodeifactor.gender.male	-0.05^{***}	
	(0.02)	
nodeofactor.gender.male	-0.06^{***}	
	(0.02)	
nodematch.gender	-0.18^{***}	-0.22^{***}
	(0.02)	(0.01)
nodeicov.sc_net	0.80^{***}	
	(0.18)	
nodeicov.sc_trust	3.23^{***}	
	(0.24)	
nodecov.pre_active_buff_20km		-0.00^{***}
		(0.00)
nodefactor.north_south.South		-0.20^{***}
		(0.01)
nodefactor.gender.male		-0.05^{***}
		(0.01)
nodecov.sc_net		-0.24^{*}
		(0.11)
nodecov.sc_trust		-3.06^{***}
		(0.15)
AIC	724596.58	834853.44
BIC	724723.66	834959.79
Log Likelihood	-362290.29	-417419.72

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table 2: Statistical models

```
                g_recruitment_df[g_recruitment_df$joined_mu <
                                   as.Date("2012-10-28"), ]$north_south),
          2)
```

```
##
##             North     South
##   FALSE 0.7705696 0.7552836
##   TRUE  0.2294304 0.2447164
```

```
mean(g_recruitment_df[g_recruitment_df$joined_mu <
                        as.Date("2012-10-28"), ]$at_least_one_indegree)
```

```
## [1] 0.2320319
```

```
# Second phase
prop.table(table(g_recruitment_df[g_recruitment_df$joined_mu >=
                                   as.Date("2012-10-28") &
                                   g_recruitment_df$joined_mu <
                                   as.Date("2013-02-24"), ]$at_least_one_indegree,
                g_recruitment_df[g_recruitment_df$joined_mu >=
                                   as.Date("2012-10-28") &
                                   g_recruitment_df$joined_mu <
                                   as.Date("2013-02-24"), ]$north_south),
          2)
```

```
##
##             North     South
##   FALSE 0.6567164 0.6394052
##   TRUE  0.3432836 0.3605948
```

```
mean(g_recruitment_df[g_recruitment_df$joined_mu >=
                        as.Date("2012-10-28") &
                        g_recruitment_df$joined_mu <
                        as.Date("2013-02-24"), ]$at_least_one_indegree)
```

```
## [1] 0.3459119
```

```
# Third phase
prop.table(table(g_recruitment_df[g_recruitment_df$joined_mu >=
                                   as.Date("2013-02-24"), ]$at_least_one_indegree,
                g_recruitment_df[g_recruitment_df$joined_mu >=
                                   as.Date("2013-02-24"), ]$north_south),
          2)
```

```
##
##             North     South
##   FALSE 0.3678110 0.3365913
##   TRUE  0.6321890 0.6634087
```

```
mean(g_recruitment_df[g_recruitment_df$joined_mu >=
                        as.Date("2013-02-24"), ]$at_least_one_indegree)
```

```
## [1] 0.6480988
```

```
log_mod1 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south + gender + pre_active_buff_20km,
      data = g_recruitment_df[g_recruitment_df$joined_mu <
```

```
                                as.Date("2012-10-28"), ],
      family = 'binomial')

log_mod2 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south + gender + pre_active_buff_20km,
      data = g_recruitment_df[g_recruitment_df$joined_mu >=
                                as.Date("2012-10-28") &
                                g_recruitment_df$joined_mu <
                                as.Date("2013-02-24"), ],
      family = 'binomial')

log_mod3 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south + gender + pre_active_buff_20km,
      data = g_recruitment_df[g_recruitment_df$joined_mu >=
                                as.Date("2013-02-24"), ],
      family = 'binomial')

log_mod0 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south + gender + pre_active_buff_20km,
      data = g_recruitment_df,
      family = 'binomial')
```

```
newdata <-
  data.frame(gender =
               'male',
             pre_active_buff_20km = mean(g_recruitment_df$pre_active_buff_20km, na.rm = T),
             sc_net =
               c(mean(g_recruitment_df$sc_net[
                 g_recruitment_df$DEN_REG %in% 'Veneto']),
                 mean(g_recruitment_df$sc_net[
                   g_recruitment_df$DEN_REG %in% 'Calabria'])),
             sc_trust =
               c(mean(g_recruitment_df$sc_trust[
                 g_recruitment_df$DEN_REG %in% 'Veneto']),
                 mean(g_recruitment_df$sc_trust[
                   g_recruitment_df$DEN_REG %in% 'Calabria'])),
             north_south = c("North", "South"))

pr1 <-
  predict(log_mod1,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr2 <-
  predict(log_mod2,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr3 <-
  predict(log_mod3,
          newdata = newdata,
```

```
          type="response", se.fit = TRUE)

pr0 <-
  predict(log_mod0,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr_df <-
  data.frame(where = rep(c('Veneto (North)','Calabria (South)'), 4),
             time = c(rep("2005-2012", 2),
                      rep("2012-2013", 2),
                      rep("2013-2015", 2),
                      rep("2005-2015", 2)),
             fit = c(pr1$fit, pr2$fit, pr3$fit, pr0$fit),
             se.fit = c(pr1$se.fit, pr2$se.fit, pr3$se.fit, pr0$se.fit),
             stringsAsFactors = F)

pr_df$time <-
  factor(pr_df$time,
         levels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"))

pr_df$panel <-
  factor(ifelse(pr_df$time == "2005-2015", "whole", "partial"),
         levels = c("partial","whole"))

ggplot(pr_df, aes(colour = where, y = fit, x = time)) +
  geom_point() +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .3) +
  theme_bw() +
  labs(x = NULL, y = "Probability node has 1 recruiting tie or more") +
  facet_wrap(~panel, scales = "free_x") + scale_y_continuous(labels = percent)
```

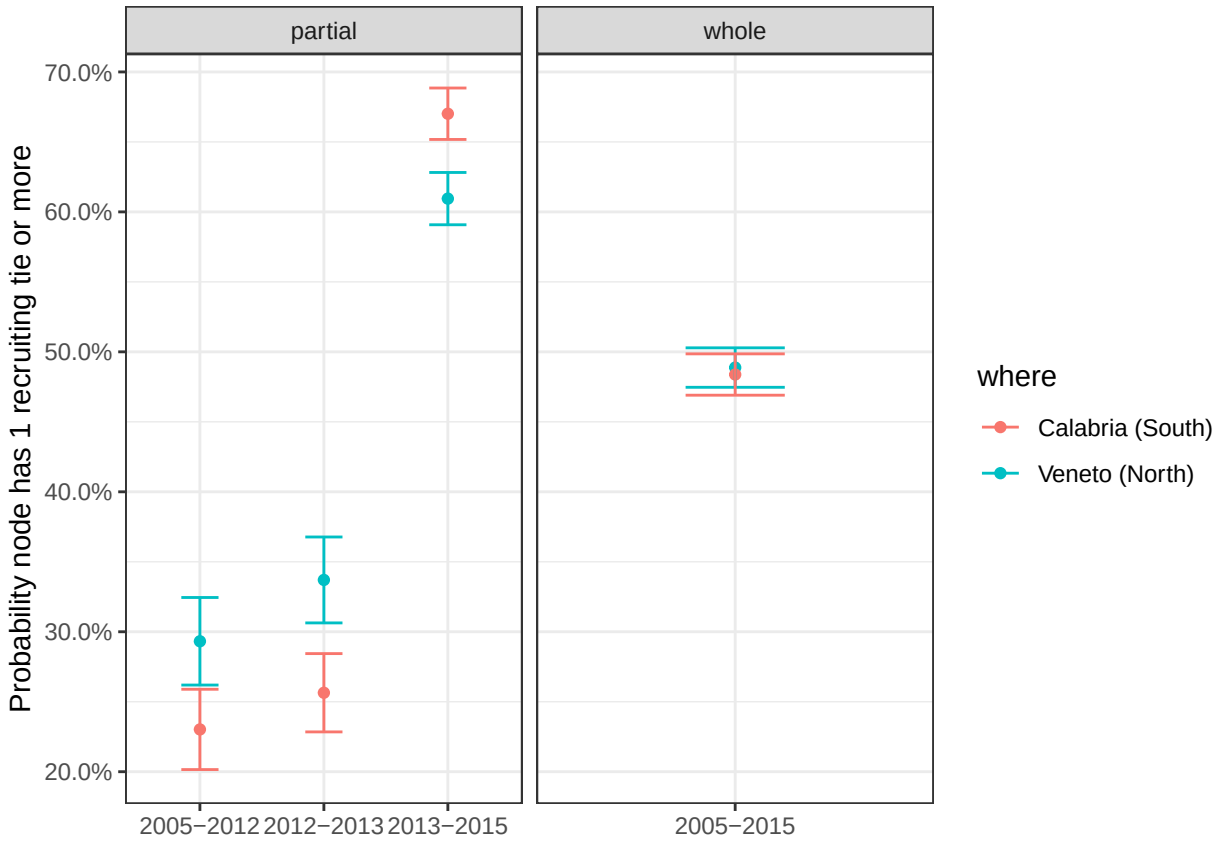


Table 4

```
stargazer(log_mod1, log_mod2, log_mod3, log_mod0,
          column.labels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"))
```

% Table created by stargazer v.5.2.2 by Marek Hlavac, Harvard University. E-mail: hlavac at fas.harvard.edu
% Date and time: Fri, Oct 19, 2018 - 03:56:34

```
stargazer(log_mod1, log_mod2, log_mod3, log_mod0,
          column.labels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"),
          type = 'latex', out = 'table/logistic-coef.tex',
          report = "vc*",
          float = FALSE,
          style = 'ajps')
stargazer(log_mod1, log_mod2, log_mod3, log_mod0,
          column.labels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"),
          type = 'html', out = 'table/logistic-coef.html',
          report = "vc*",
          float = FALSE,
          style = 'ajps')
```

Only sc_net varies

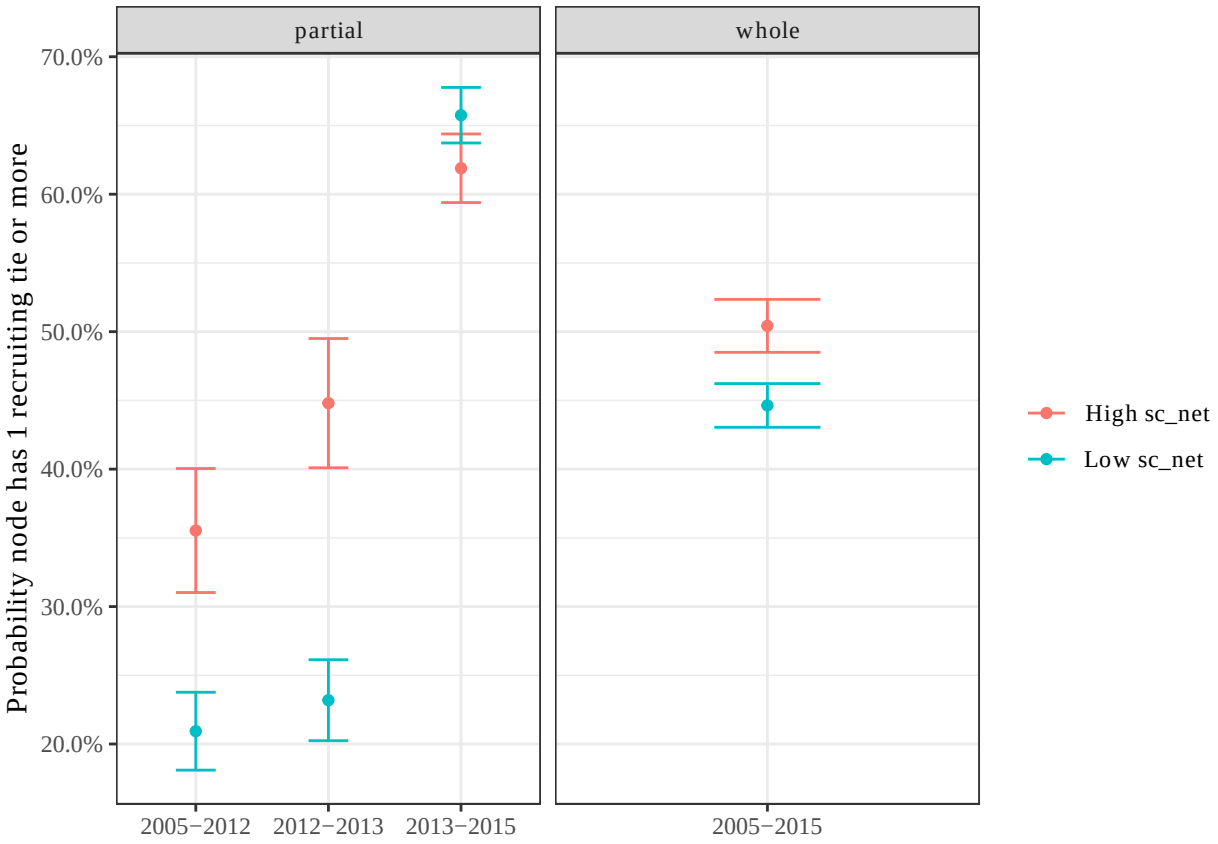
```
g_recruitment_df$north_south_num <- as.numeric(g_recruitment_df$north_south)

log_mod1 <-
```

Table 3:

	Dependent variable:			
	at_least_one_indegree			
	2005-2012	2012-2013	2013-2015	2005-2015
	(1)	(2)	(3)	(4)
sc_net	5.018**	6.769***	−1.145	1.591*
	(2.177)	(2.230)	(1.214)	(0.882)
sc_trust	−4.997	−10.310***	0.523	2.735**
	(3.091)	(3.104)	(1.663)	(1.197)
north_southSouth	0.114	−0.002	0.127	0.372***
	(0.238)	(0.232)	(0.131)	(0.096)
gendermale	−0.427***	−0.271*	−0.059	−0.211***
	(0.138)	(0.149)	(0.091)	(0.065)
pre_active_buff_20km	0.009***	0.0004	0.002***	0.006***
	(0.002)	(0.001)	(0.0005)	(0.0004)
Constant	−0.998	0.380	0.586	−1.249***
	(0.723)	(0.720)	(0.418)	(0.298)
Observations	1,962	1,495	3,640	7,097
Log Likelihood	−1,057.303	−955.112	−2,350.082	−4,779.037
Akaike Inf. Crit.	2,126.607	1,922.224	4,712.165	9,570.074
Note:				*p<0.1; **p<0.05; ***p<0.01

```
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south_num + gender + pre_active_buff_20km,
      data = g_recruitment_df[g_recruitment_df$joined_mu <
                                as.Date("2012-10-28"), ],
      family = 'binomial')

log_mod2 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south_num + gender + pre_active_buff_20km,
      data = g_recruitment_df[g_recruitment_df$joined_mu >=
                                as.Date("2012-10-28") &
                                g_recruitment_df$joined_mu <
                                as.Date("2013-02-24"), ],
      family = 'binomial')

log_mod3 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south_num + gender + pre_active_buff_20km,
      data = g_recruitment_df[g_recruitment_df$joined_mu >=
                                as.Date("2013-02-24"), ],
      family = 'binomial')

log_mod0 <-
  glm(at_least_one_indegree ~ sc_net + sc_trust +
        north_south_num + gender + pre_active_buff_20km,
      data = g_recruitment_df,
      family = 'binomial')

newdata <-
  data.frame(gender =
               'male',
             pre_active_buff_20km = mean(g_recruitment_df$pre_active_buff_20km, na.rm = T),
             sc_net =
               c(mean(g_recruitment_df$sc_net[
                 g_recruitment_df$DEN_REG %in% 'Veneto']),
                 mean(g_recruitment_df$sc_net[
                   g_recruitment_df$DEN_REG %in% 'Calabria'])),
             sc_trust =
               median(g_recruitment_df$sc_trust, na.rm = T),
             north_south_num = 1.5)

pr1 <-
  predict(log_mod1,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr2 <-
  predict(log_mod2,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr3 <-
  predict(log_mod3,
```

```
          newdata = newdata,
          type="response", se.fit = TRUE)

pr0 <-
  predict(log_mod0,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr_df <-
  data.frame(where = rep(c('High sc_net','Low sc_net'), 4),
             time = c(rep("2005-2012", 2),
                      rep("2012-2013", 2),
                      rep("2013-2015", 2),
                      rep("2005-2015", 2)),
             fit = c(pr1$fit, pr2$fit, pr3$fit, pr0$fit),
             se.fit = c(pr1$se.fit, pr2$se.fit, pr3$se.fit, pr0$se.fit),
             stringsAsFactors = F)

pr_df$time <-
  factor(pr_df$time,
         levels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"))

pr_df$panel <-
  factor(ifelse(pr_df$time == "2005-2015", "whole", "partial"),
         levels = c("partial","whole"))

ggplot(pr_df, aes(colour = where, y = fit, x = time)) +
  geom_point() +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .3) +
  theme_bw() +
  labs(x = NULL, y = "Probability node has 1 recruiting tie or more", colour = NULL) +
  facet_wrap(~panel, scales = "free_x") + scale_y_continuous(labels = percent) +
  theme(text = element_text(family = "Palatino"))
```

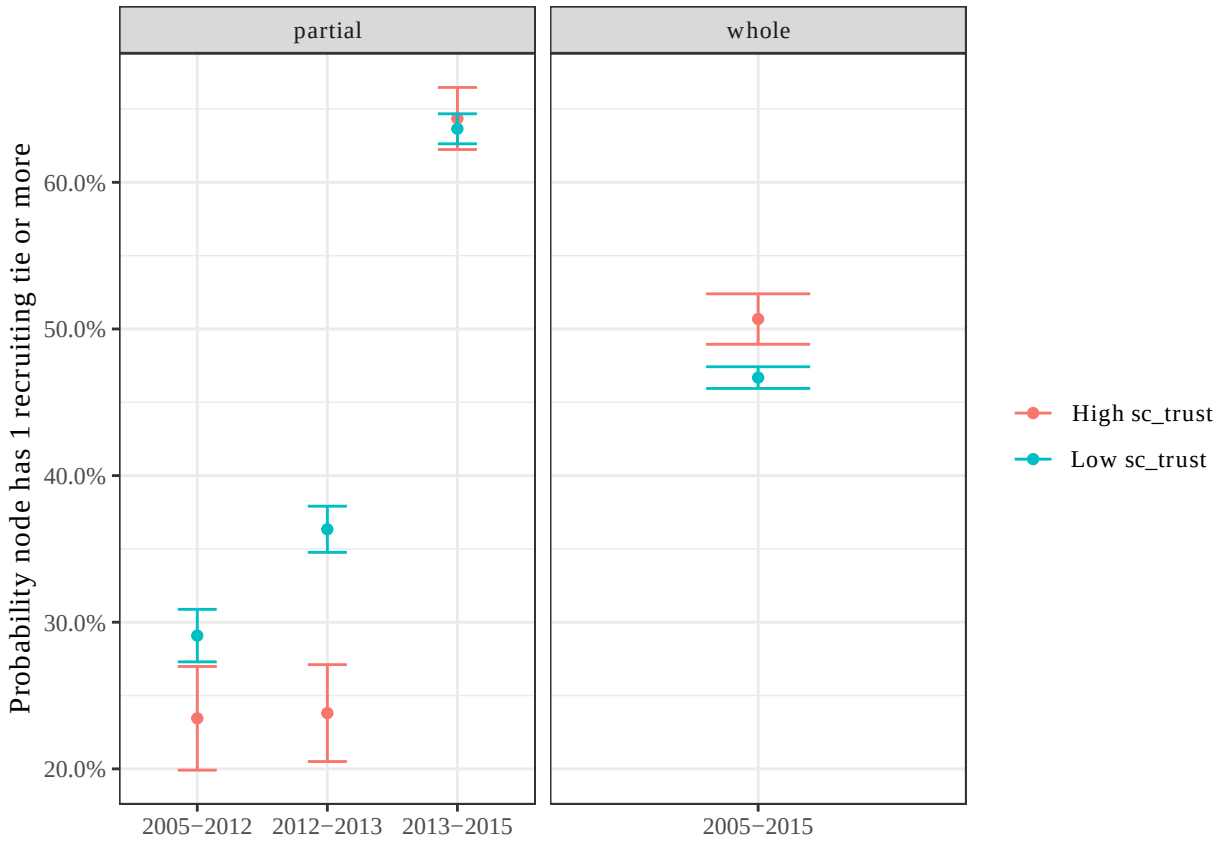



```
pr_df_net <- pr_df
pr_df_net$what <- 'sc_net'
```

Only sc_trust varies

```
newdata <-
  data.frame(gender =
               'male',
             pre_active_buff_20km = mean(g_recruitment_df$pre_active_buff_20km, na.rm = T),
             sc_trust =
               c(mean(g_recruitment_df$sc_trust[
                 g_recruitment_df$DEN_REG %in% 'Veneto']),
                 mean(g_recruitment_df$sc_trust[
                   g_recruitment_df$DEN_REG %in% 'Calabria'])),
             sc_net =
               median(g_recruitment_df$sc_net, na.rm = T),
             north_south_num = 1.5)

pr1 <-
  predict(log_mod1,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr2 <-
  predict(log_mod2,
          newdata = newdata,
          type="response", se.fit = TRUE)
```

```r
pr3 <-
  predict(log_mod3,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr0 <-
  predict(log_mod0,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr_df <-
  data.frame(where = rep(c('High sc_trust','Low sc_trust'), 4),
             time = c(rep("2005-2012", 2),
                      rep("2012-2013", 2),
                      rep("2013-2015", 2),
                      rep("2005-2015", 2)),
             fit = c(pr1$fit, pr2$fit, pr3$fit, pr0$fit),
             se.fit = c(pr1$se.fit, pr2$se.fit, pr3$se.fit, pr0$se.fit),
             stringsAsFactors = F)

pr_df$time <-
  factor(pr_df$time,
         levels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"))

pr_df$panel <-
  factor(ifelse(pr_df$time == "2005-2015", "whole", "partial"),
         levels = c("partial","whole"))

ggplot(pr_df, aes(colour = where, y = fit, x = time)) +
  geom_point() +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .3) +
  theme_bw() +
  labs(x = NULL, y = "Probability node has 1 recruiting tie or more", colour = NULL) +
  facet_wrap(~panel, scales = "free_x") + scale_y_continuous(labels = percent) +
  theme(text = element_text(family = "Palatino"))
```



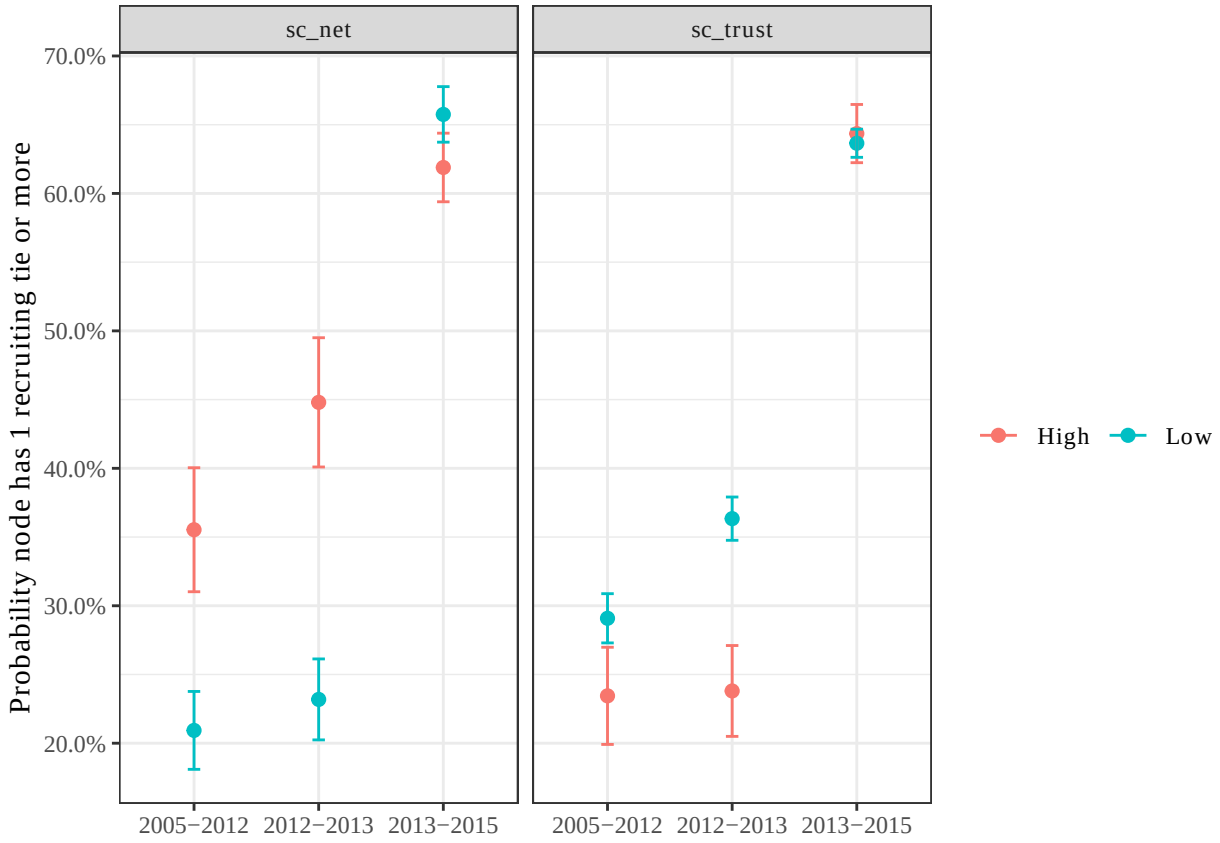

```
pr_df_trust <- pr_df
pr_df_trust$what <- 'sc_trust'
```

Figure 9

```
pr_df <- rbind(pr_df_net, pr_df_trust)

kable(pr_df, digits = 3)
```

where	time	fit	se.fit	panel	what
High sc_net	2005-2012	0.355	0.045	partial	sc_net
Low sc_net	2005-2012	0.209	0.028	partial	sc_net
High sc_net	2012-2013	0.448	0.047	partial	sc_net
Low sc_net	2012-2013	0.232	0.029	partial	sc_net
High sc_net	2013-2015	0.619	0.025	partial	sc_net
Low sc_net	2013-2015	0.657	0.020	partial	sc_net
High sc_net	2005-2015	0.504	0.019	whole	sc_net
Low sc_net	2005-2015	0.446	0.016	whole	sc_net
High sc_trust	2005-2012	0.234	0.035	partial	sc_trust
Low sc_trust	2005-2012	0.291	0.018	partial	sc_trust
High sc_trust	2012-2013	0.238	0.033	partial	sc_trust
Low sc_trust	2012-2013	0.363	0.016	partial	sc_trust
High sc_trust	2013-2015	0.644	0.021	partial	sc_trust
Low sc_trust	2013-2015	0.636	0.010	partial	sc_trust
High sc_trust	2005-2015	0.507	0.017	whole	sc_trust
Low sc_trust	2005-2015	0.467	0.007	whole	sc_trust

```
pr_df$colour <- factor(ifelse(grepl("High", pr_df$where), "High", "Low"), levels = c("High", "Low"))

ggplot(pr_df[pr_df$panel=='partial',], aes(colour = colour, y = fit, x = time)) +
  geom_point(size = 2) +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .1) +
  theme_bw() +
  facet_wrap(~what) +
  scale_shape_manual(values = c(2,6)) +
  scale_y_continuous(labels = percent) +
  guides(colour=guide_legend(ncol=2, title=NULL)) +
  labs(x = NULL, y = "Probability node has 1 recruiting tie or more") +
  theme(text = element_text(family = "Palatino"))
```




```
ggsave("figure/logit-predict-from-sc-net-trust.pdf", width = 8, height = 4,
       ggplot(pr_df[pr_df$panel=='partial',], aes(colour = colour, y = fit, x = time)) +
         geom_point(size = 2) +
         geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .1) +
         theme_bw() +
         facet_wrap(~what) +
         scale_shape_manual(values = c(2,6)) +
         scale_y_continuous(labels = percent) +
         guides(colour=guide_legend(ncol=2, title=NULL)) +
         labs(x = NULL, y = "Probability node has 1 recruiting tie or more") +
         theme(text = element_text(family = "Palatino")))
```

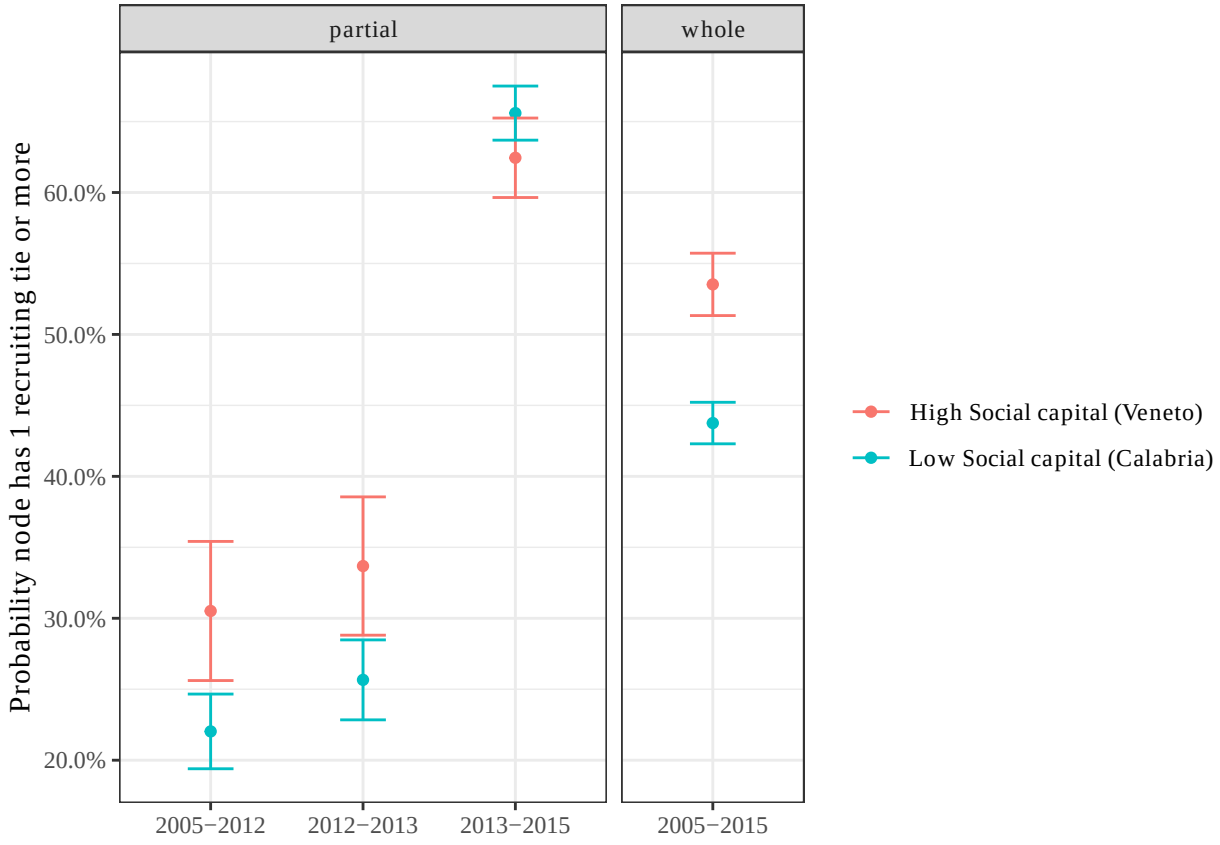
Figure 10

```
newdata <-
  data.frame(gender =
               'male',
             pre_active_buff_20km = mean(g_recruitment_df$pre_active_buff_20km, na.rm = T),
             sc_net =
               c(mean(g_recruitment_df$sc_net[
                 g_recruitment_df$DEN_REG %in% 'Veneto']),
                 mean(g_recruitment_df$sc_net[
                   g_recruitment_df$DEN_REG %in% 'Calabria'])),
             sc_trust =
               c(mean(g_recruitment_df$sc_trust[
                 g_recruitment_df$DEN_REG %in% 'Veneto']),
                 mean(g_recruitment_df$sc_trust[
                   g_recruitment_df$DEN_REG %in% 'Calabria'])),
             north_south_num = 1.5)

pr1 <-
  predict(log_mod1,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr2 <-
  predict(log_mod2,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr3 <-
  predict(log_mod3,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr0 <-
  predict(log_mod0,
          newdata = newdata,
          type="response", se.fit = TRUE)

pr_df <-
  data.frame(where = rep(c('High Social capital (Veneto)','Low Social capital (Calabria)'), 4),
             time = c(rep("2005-2012", 2),
                      rep("2012-2013", 2),
                      rep("2013-2015", 2),
                      rep("2005-2015", 2)),
             fit = c(pr1$fit, pr2$fit, pr3$fit, pr0$fit),
             se.fit = c(pr1$se.fit, pr2$se.fit, pr3$se.fit, pr0$se.fit),
             stringsAsFactors = F)

pr_df$time <-
  factor(pr_df$time,
         levels = c("2005-2012", "2012-2013", "2013-2015", "2005-2015"))

pr_df$panel <-
  factor(ifelse(pr_df$time == "2005-2015", "whole", "partial"),
         levels = c("partial","whole"))
```

```
kable(pr_df, digits = 2)
```

where	time	fit	se.fit	panel
High Social capital (Veneto)	2005-2012	0.31	0.05	partial
Low Social capital (Calabria)	2005-2012	0.22	0.03	partial
High Social capital (Veneto)	2012-2013	0.34	0.05	partial
Low Social capital (Calabria)	2012-2013	0.26	0.03	partial
High Social capital (Veneto)	2013-2015	0.62	0.03	partial
Low Social capital (Calabria)	2013-2015	0.66	0.02	partial
High Social capital (Veneto)	2005-2015	0.54	0.02	whole
Low Social capital (Calabria)	2005-2015	0.44	0.01	whole

```
ggplot(pr_df, aes(colour = where, y = fit, x = time)) +
  geom_point() +
  geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .3) +
  theme_bw() +
  labs(x = NULL, y = "Probability node has 1 recruiting tie or more", colour = NULL) +
  facet_grid(.~panel, scales = "free_x", space = "free_x") +
  scale_y_continuous(labels = percent) +
  theme(text = element_text(family = "Palatino"))
```




```
ggsave("figure/logit-predict-from-social-capital.pdf", width = 8, height = 4,
       ggplot(pr_df, aes(colour = where, y = fit, x = time)) +
         geom_point() +
         geom_errorbar(aes(ymin = fit - se.fit, ymax = fit + se.fit), width = .3) +
```

```
        theme_bw() +
        labs(x = NULL, y = "Probability node has 1 recruiting tie or more", colour = NULL) +
        facet_grid(.~panel, scales = "free_x", space = "free_x") +
        scale_y_continuous(labels = percent) +
        theme(text = element_text(family = "Palatino")))
```