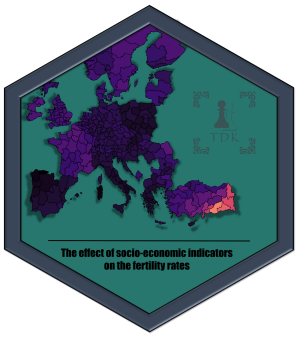

The effect of socio-economic indicators on the fertilty rates

An empirical analysis of fertility rates amoung the regions of Europe

Marcell Granát

March 21, 2021

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Abstract

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4. saját eredmény röviden
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6. módszertan mögötti indoklás
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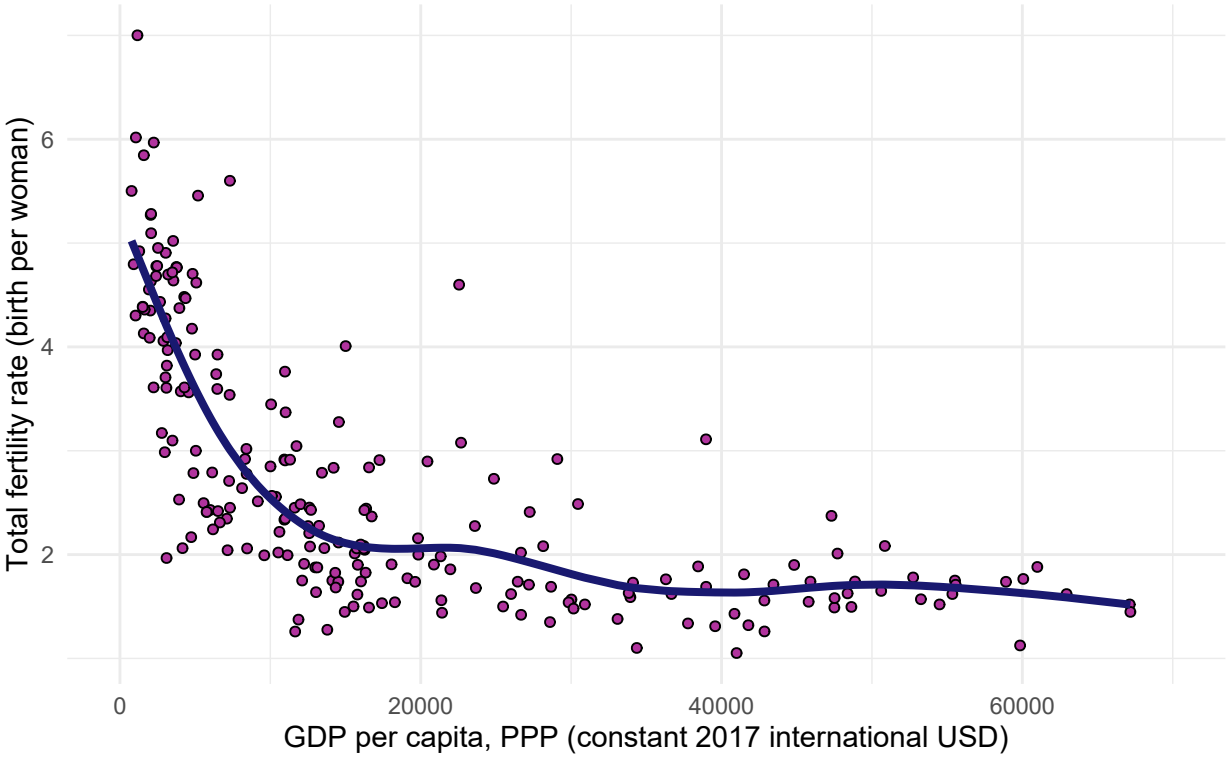


Own editing based on the Figure 5-2. from Kreiszné Hudák (2019).
The trend is drawn via splines.
Source of the data: World Bank.

Figure 1: Seemingly negative effect of gross domestic product on fertility rates based on nation level observations (2017)

Data

Total fertility rates

Human development

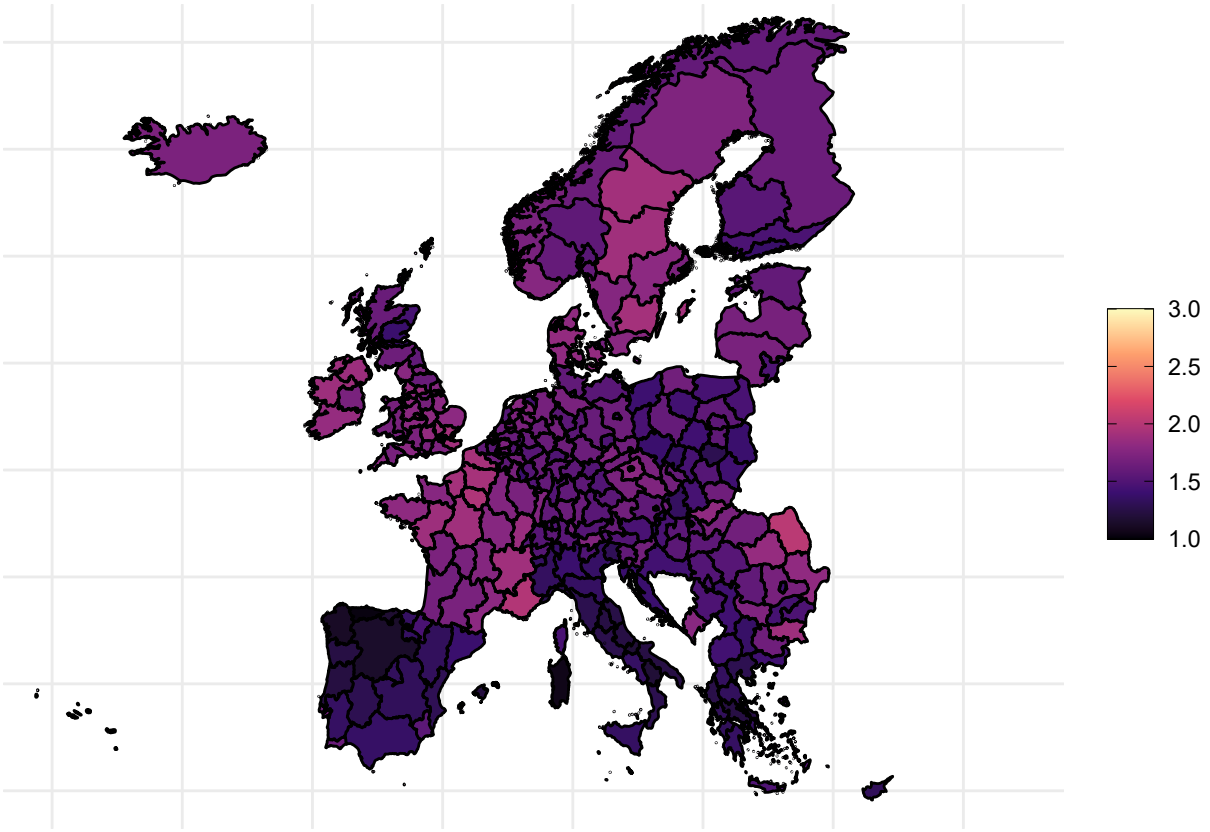


Figure 2: Total fertility rates through Europe in 2017

Table 1: Indicators of similiarity between the Human Development Indices provided by UNDP and GDL

Indicator	Value
R^2	99.76%
Spearman R^2	99.71%
Mean absolute deviation	0.007
Mean absolute percentage deviation	1.20%

Figure 3: HDI and its components based on the dataset from Global Data Lab (2017)

A decent standard of living

Table 2: Indicators of similiarity between the income component of the Human Development Indices provided by GDL and the estimation based on regional GDP

Indicator	Value
R^2	92.20%
Spearman R^2	94.18%
Mean absolute deviation	0.0520
Mean absolute percentage deviation	6.62%

Long and healthy life

Table 3: Indicators of similiarity between the health component of the Human Development Indices provided by GDL and the estimation based on regional life expectency

Indicator	Value
R^2	98.24%
Spearman R^2	98.38%
Mean absolute deviation	0.0041
Mean absolute percentage deviation	0.45%

Knowledge

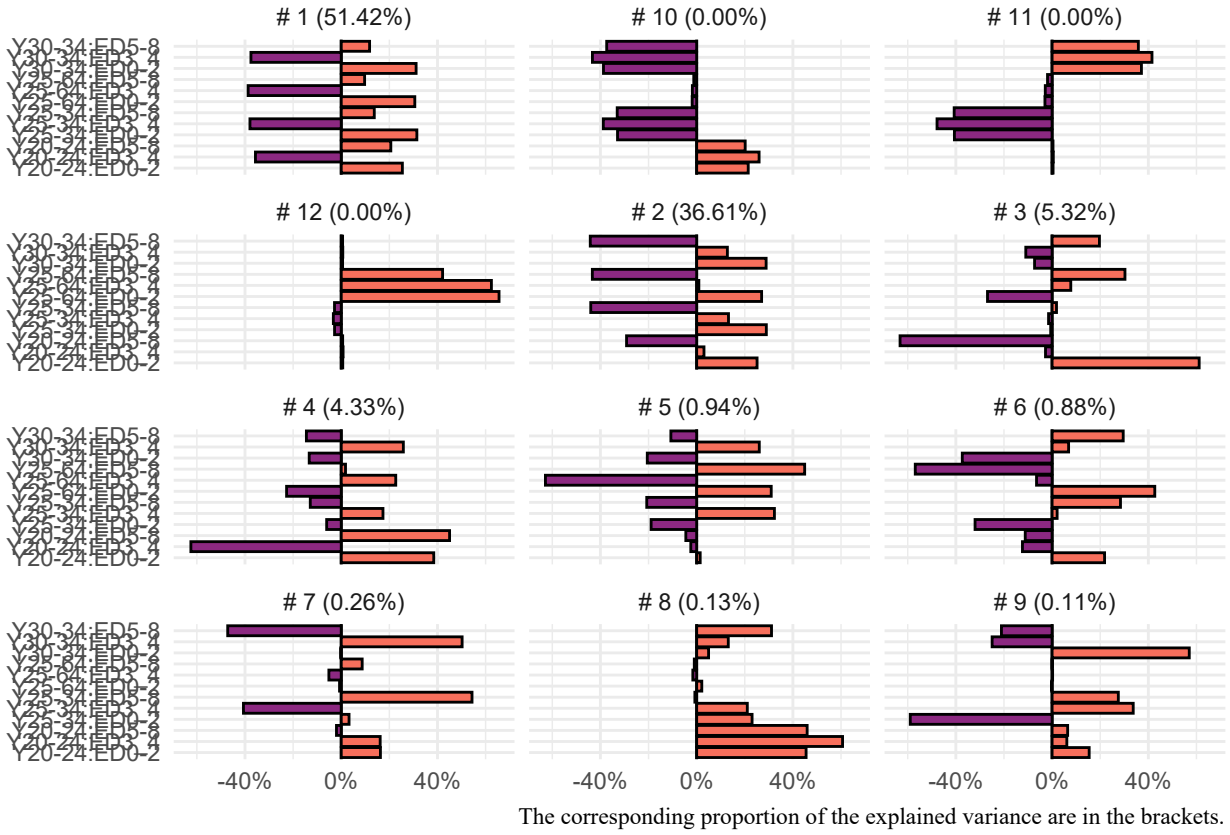


Figure 4: PCAs and the explained variance

Table 4: Indicators of similiarity between the knowledge component of Human Development Indices provided by UNDP and the calculated principal components using educational attainment level

Indicator	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Comp 7	Comp 8	Comp 9
R^2	9.11%	47.66%	15.03%	0.15%	0.32%	2.40%	0.14%	0.00%	0.05%
Spearman R^2	5.47%	45.55%	14.28%	0.12%	0.38%	2.19%	1.01%	7.87%	0.03%

Family benefits

Youth unemployment

Explore data

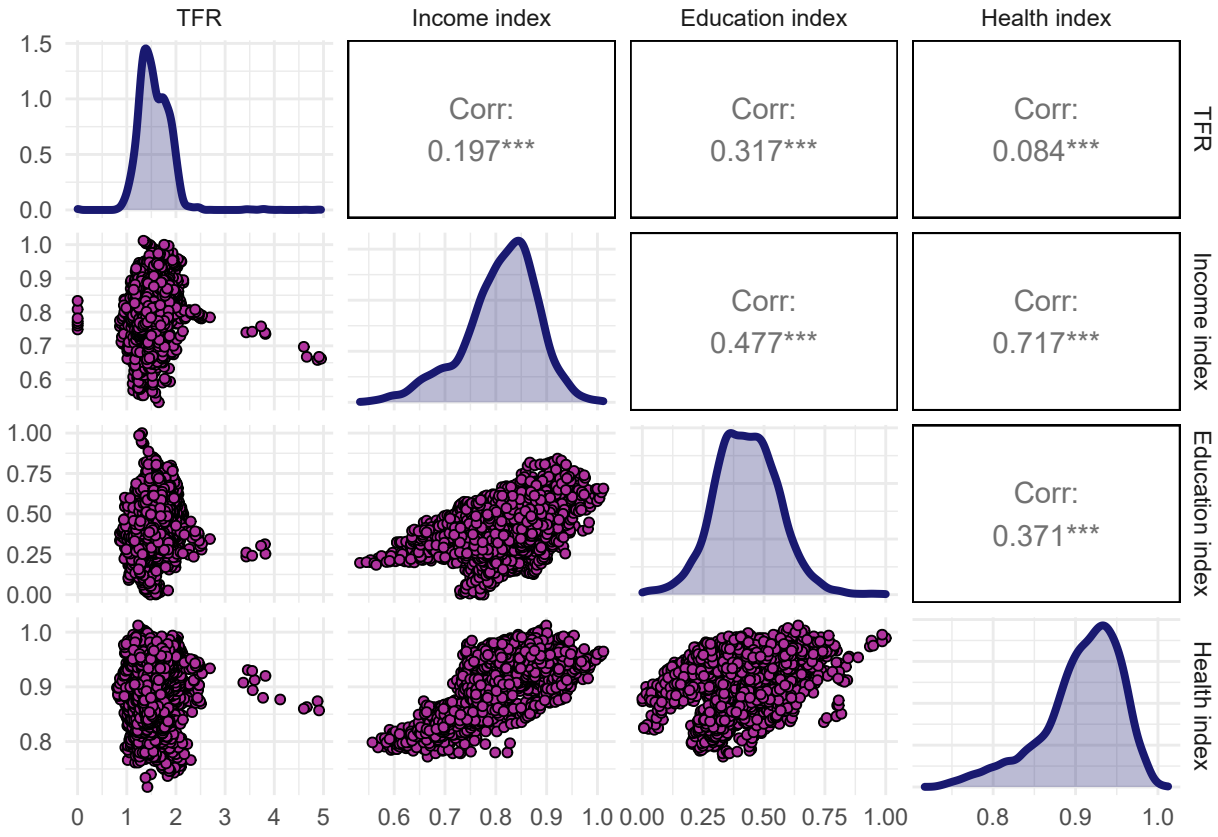


Figure 5: Pairwise correlation among TFR and calculation human development indices

Model building

Table 5: Models

Indicator	Model I.	Model II.
Pooltest	0.00%	0.00%
Phtest	0.00%	0.00%
Adjusted R^2	20.19%	29.05%
Observations	91	246

Framework I: with unemployment

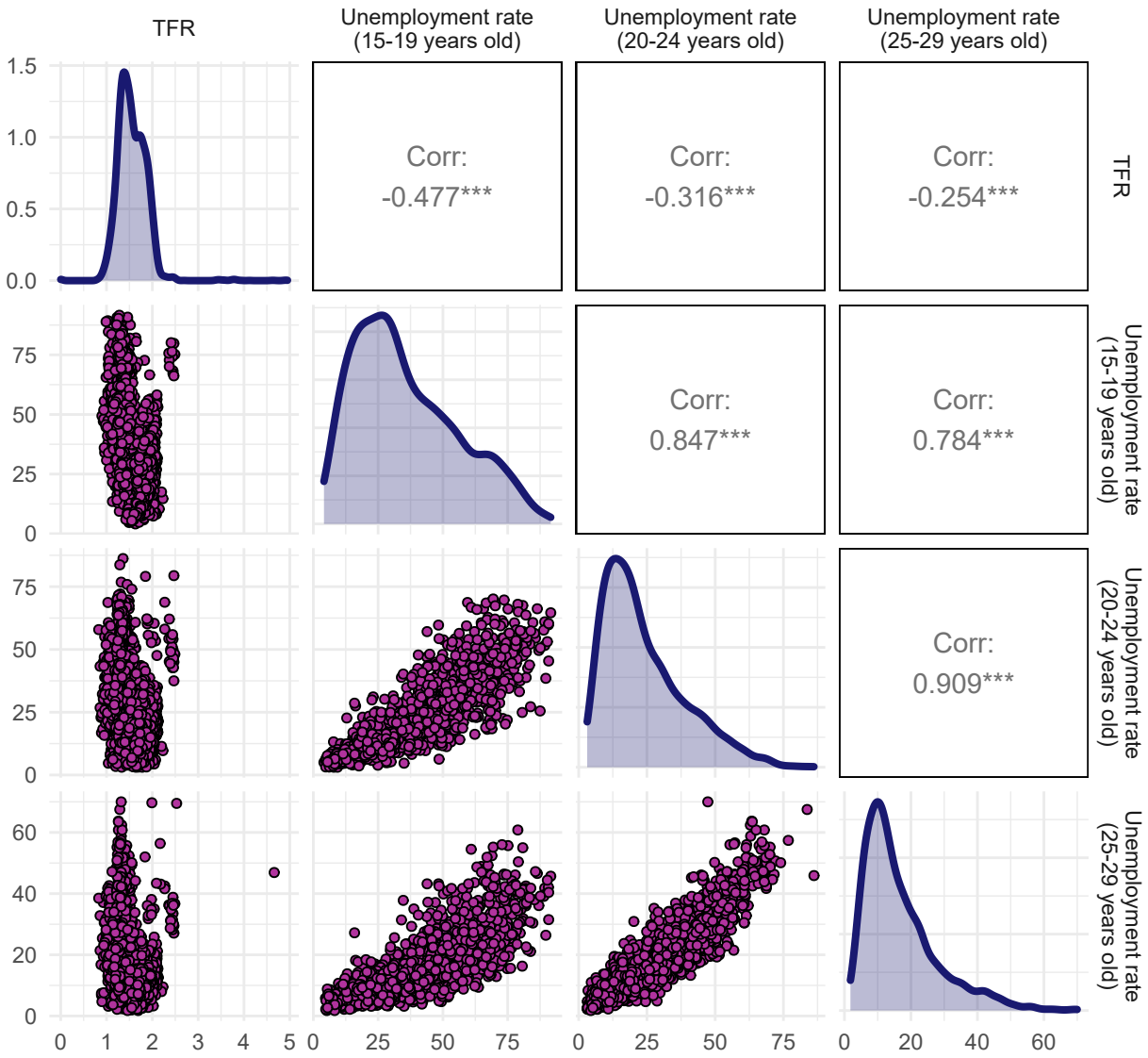


Figure 6: Pairwise correlation among TFR and youth unemployment rates

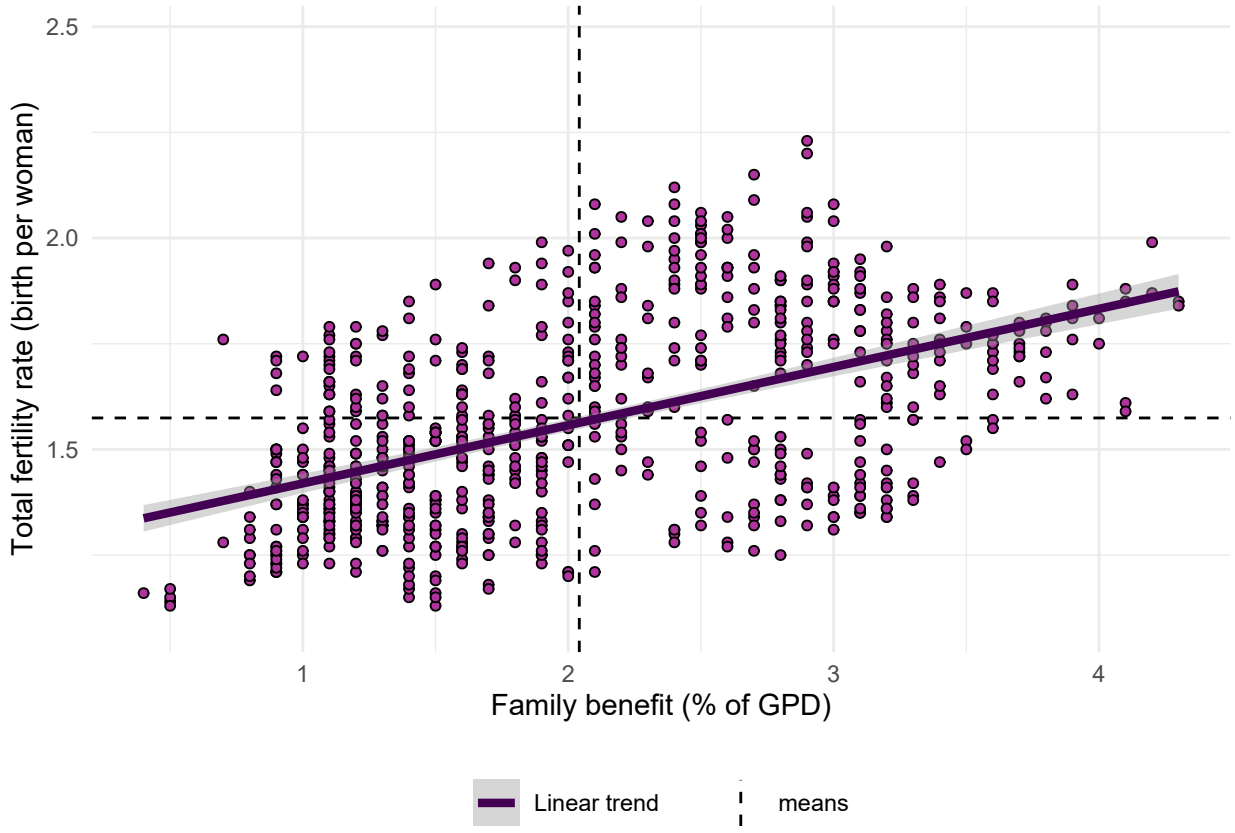


Figure 7: Correlation between TFR and family benefits

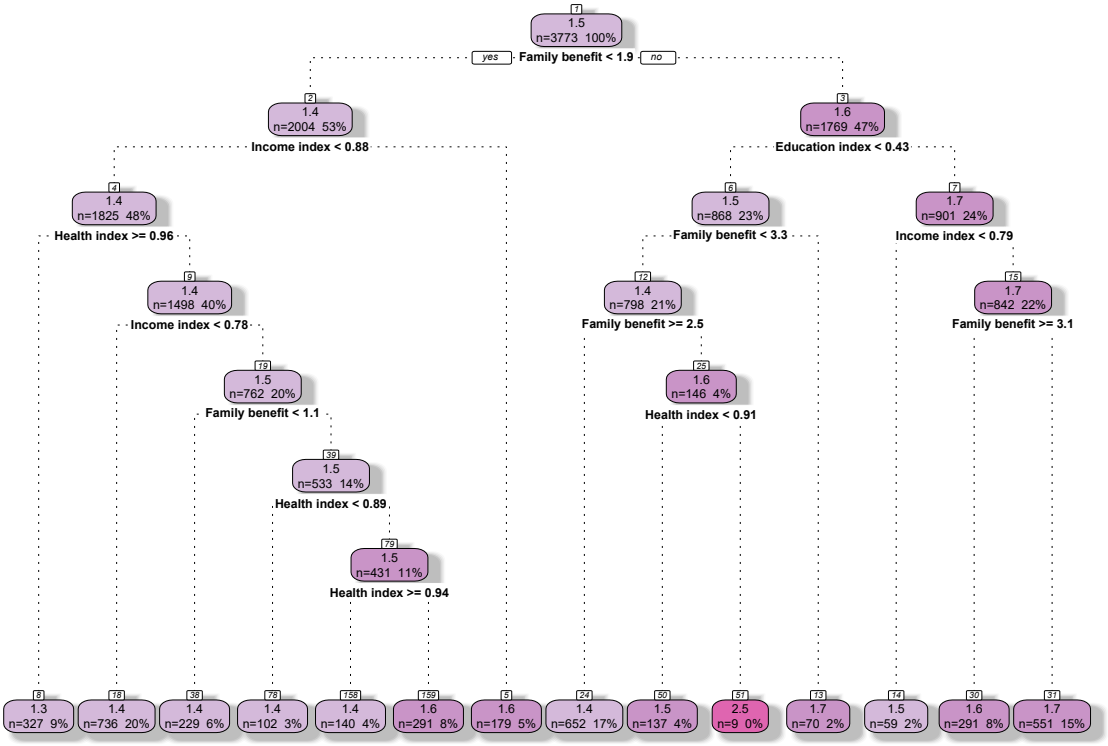


Figure 8: Regression tree explaining the TFR using only the calculated HD indices (cp = 0.01)

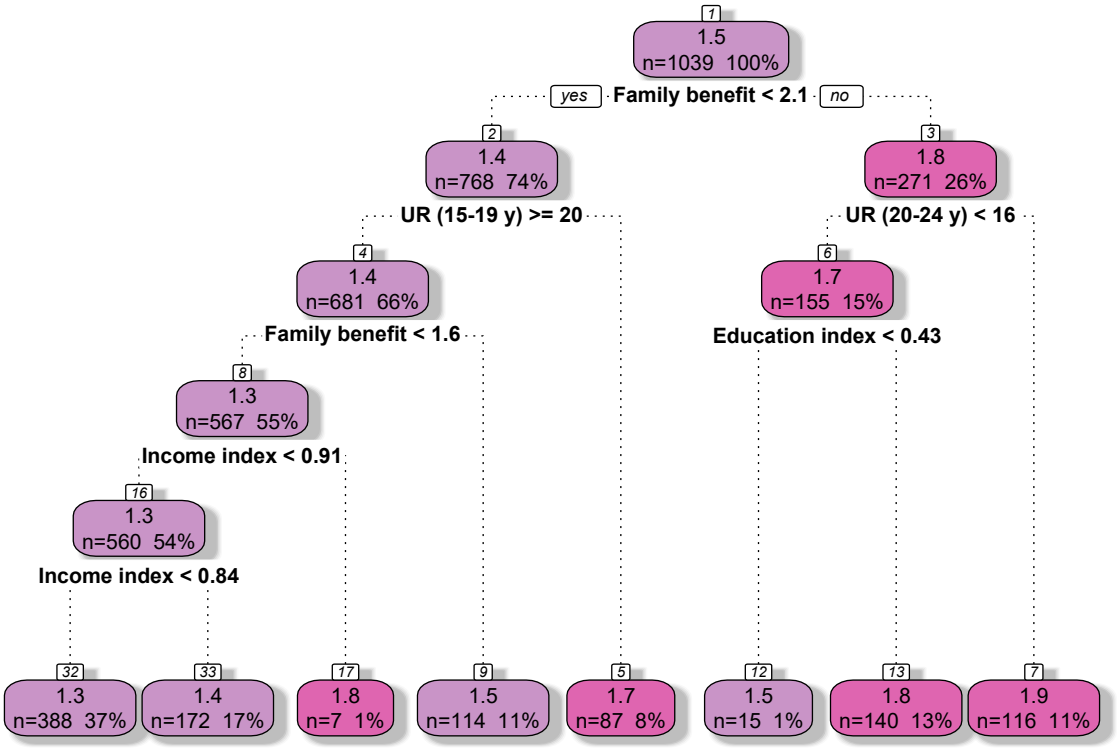


Figure 9: Regression tree explaining the TFR using all the mentioned explanatory variables (cp = 0.01)

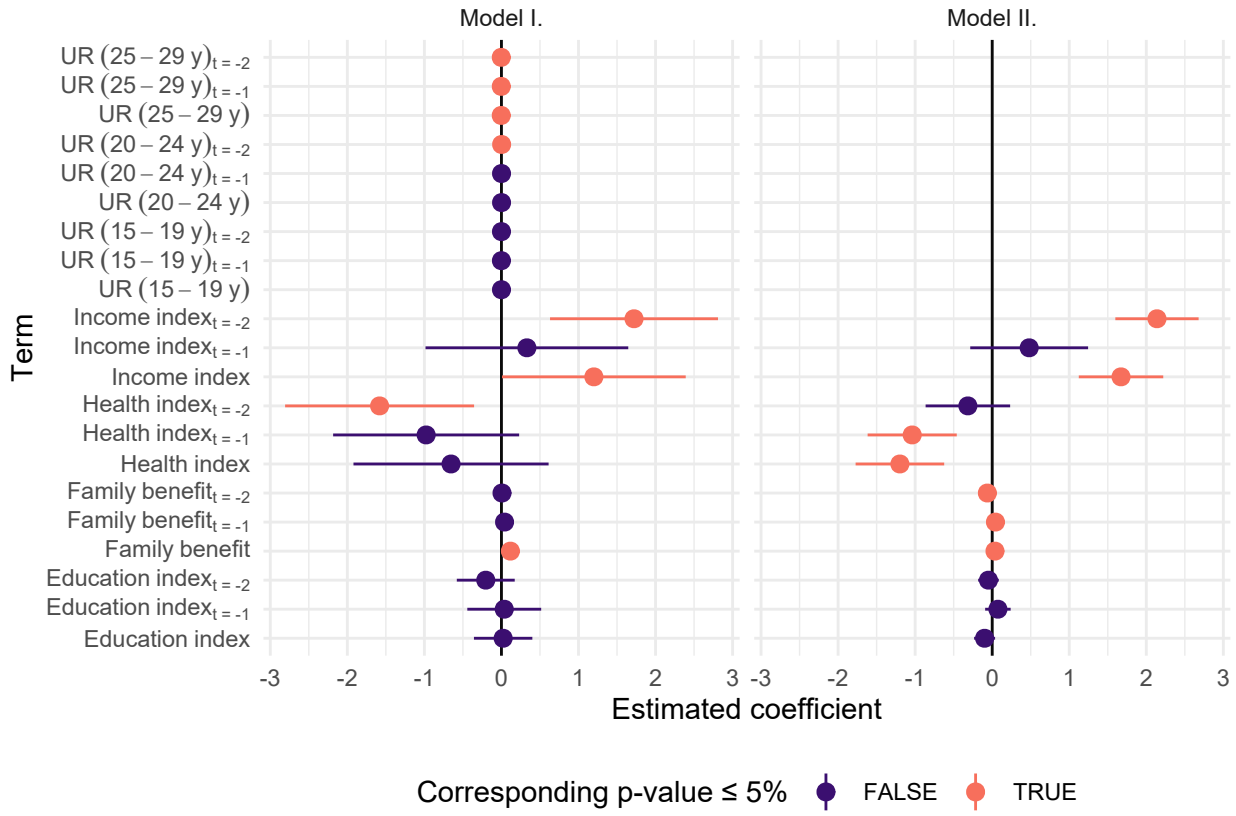


Figure 10: Panel models on the total fertility rates

Table 6: T-tests

Variable	Mean in total sample	Mean in used sample	Number of observations in the total sample	T-statistic	P-value
TFR	1.5575	1.4801	7249	8.0546	0.00%
Education index	0.4246	0.4241	5373	0.0910	92.75%
Health index	0.9089	0.9375	6983	-19.0193	0.00%
Income index	0.8120	0.8298	4291	-7.7143	0.00%
Family benefit	2.0759	1.6302	6155	14.7745	0.00%
UR (15-19 y)	36.6883	44.4313	1713	-8.5191	0.00%
UR (20-24 y)	24.3994	25.5202	2935	-1.7969	7.26%
UR (25-29 y)	17.0107	17.0332	2664	-0.0493	96.07%

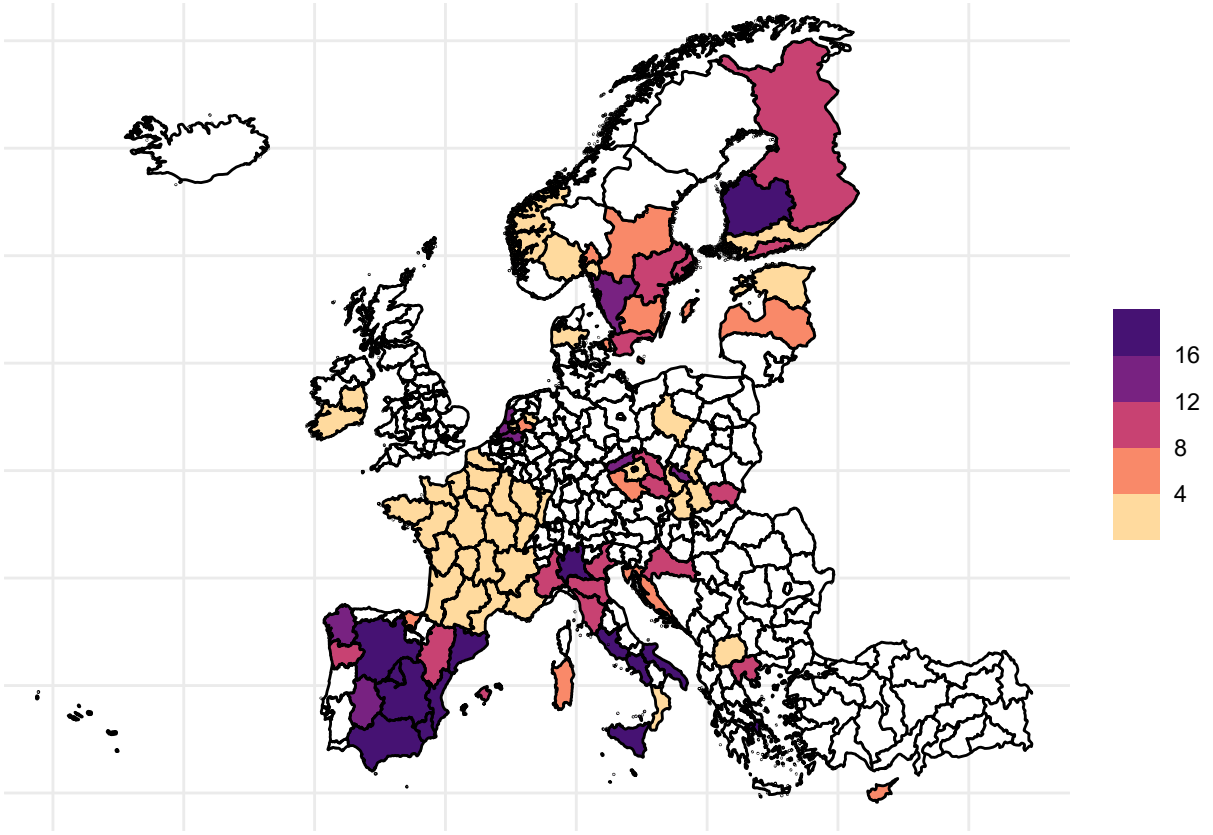
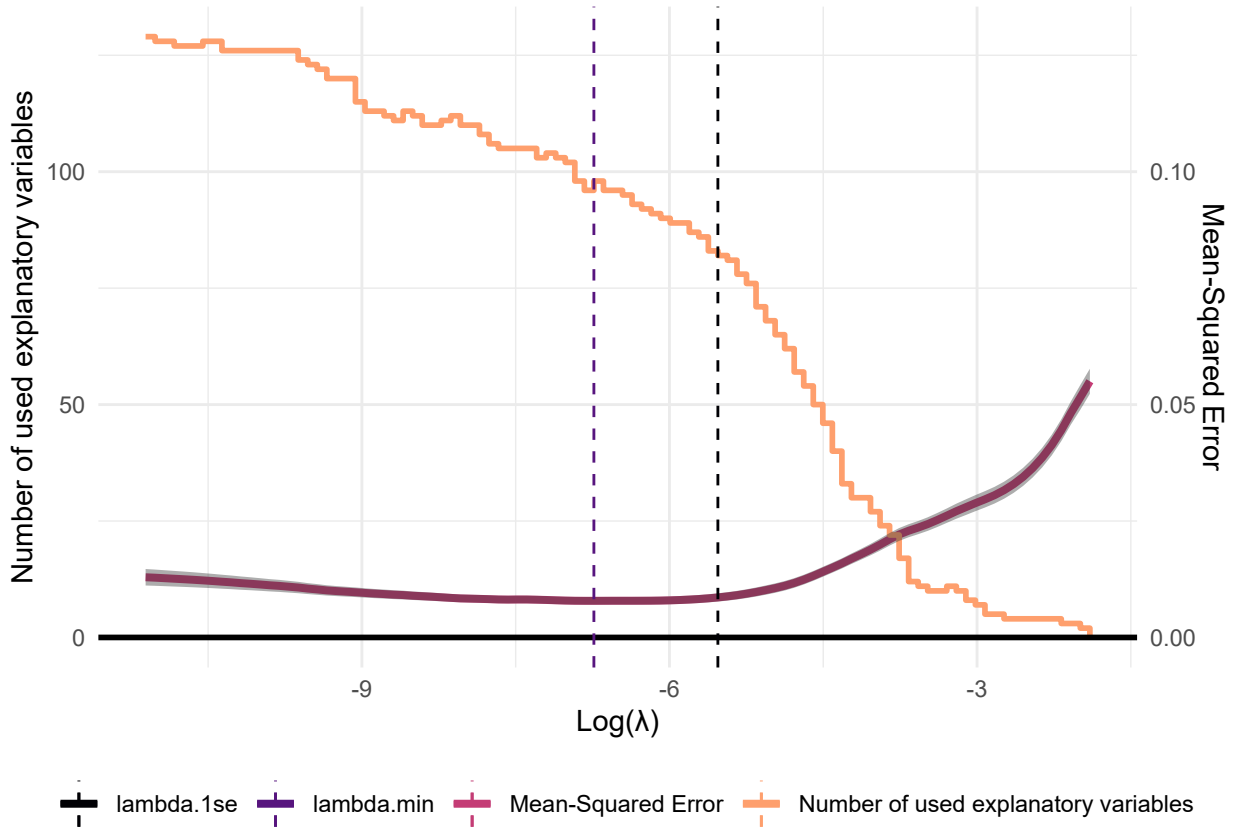


Figure 11: Number of used observations by countries when the model contains youth unemployment



Framework II: without unemployment

Table 7: T-tests

Variable	Mean in total sample	Mean in used sample	Number of observations in total sample	T-statistic	P-value
TFR	1.5575	1.4935	7249	11.7945	0.00%
Education index	0.4246	0.4082	5373	5.8006	0.00%
Health index	0.9089	0.9202	6983	-12.2876	0.00%
Income index	0.8120	0.8228	4291	-7.0235	0.00%
Family benefit	2.0759	1.9699	6155	5.6539	0.00%

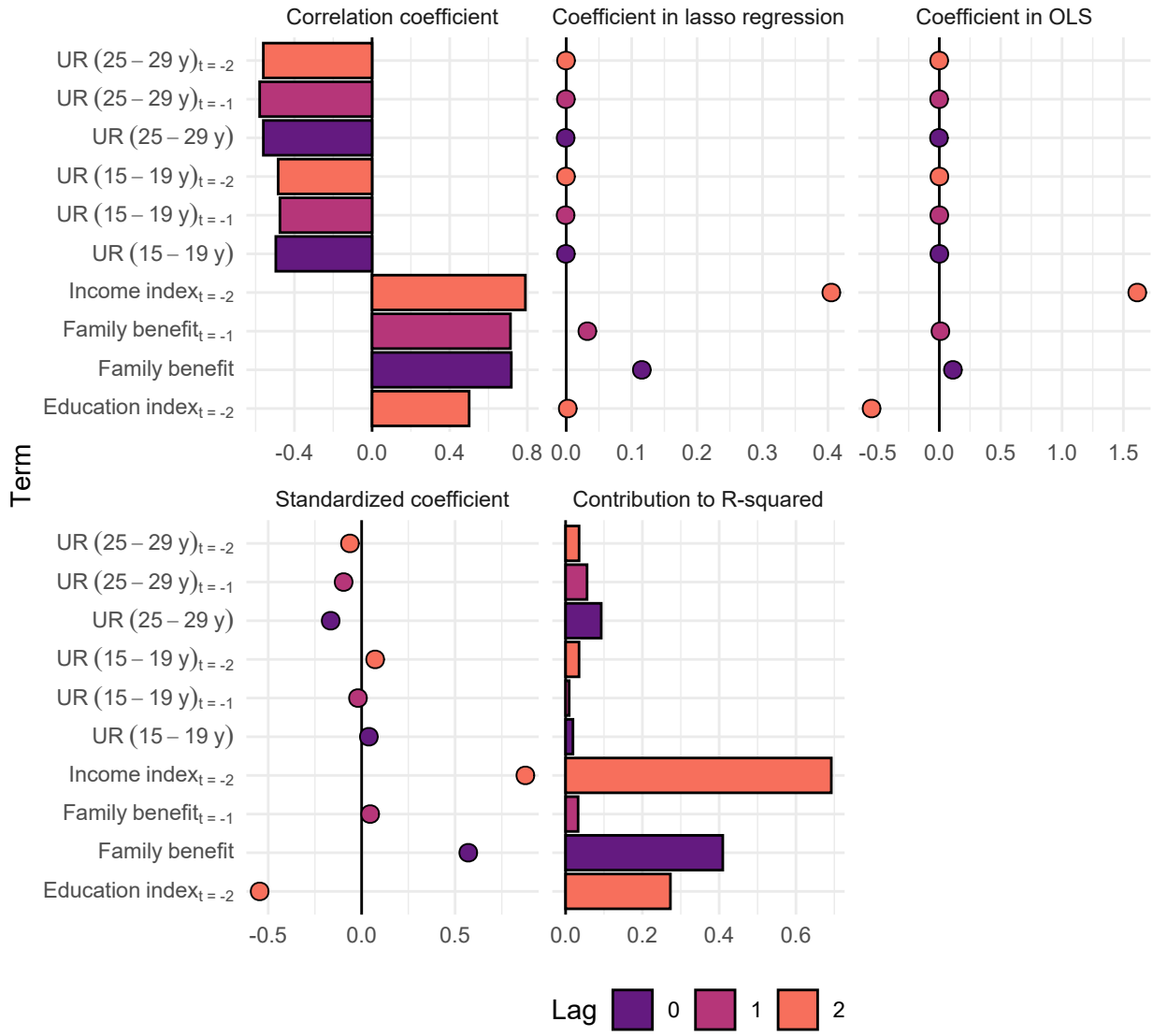


Figure 12: Estimated coefficient of the fixed panel model controlling for youth unemployment indicators

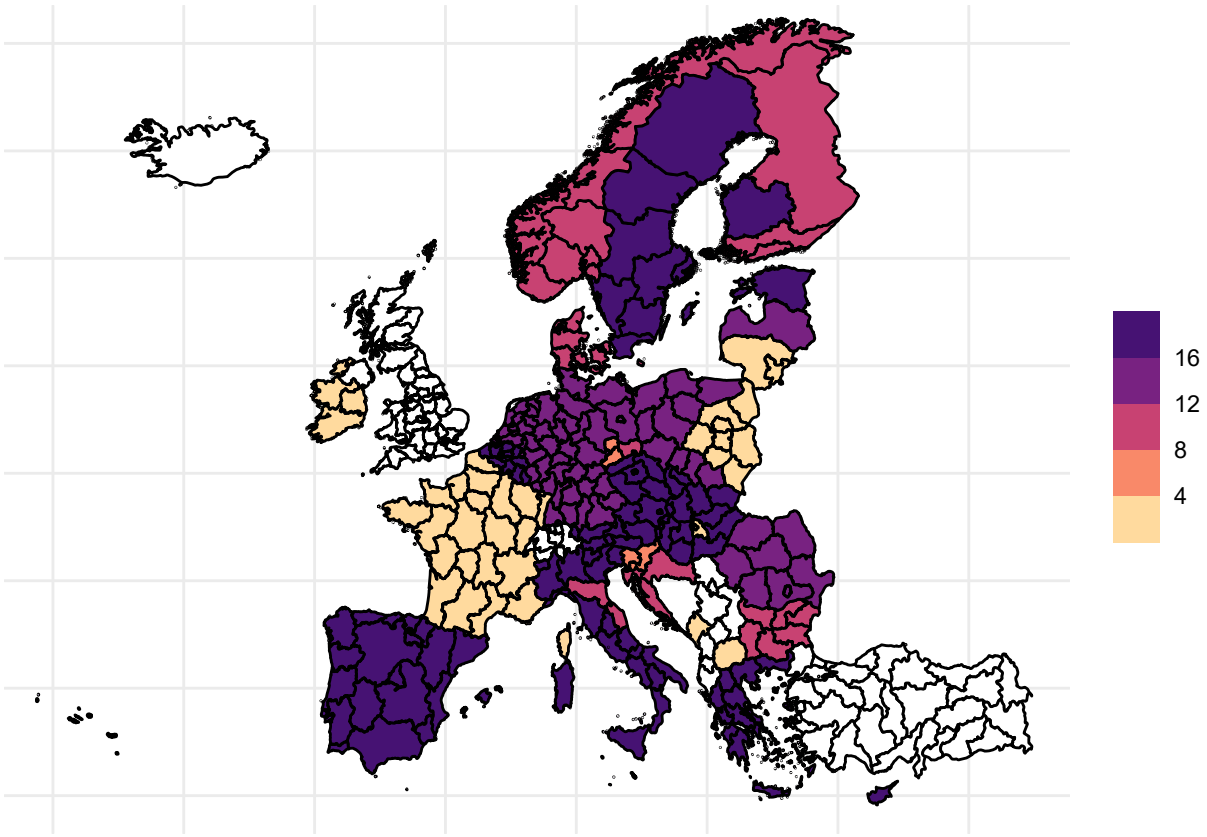


Figure 13: Number of used observations by countries when the model does not contain youth unemployment

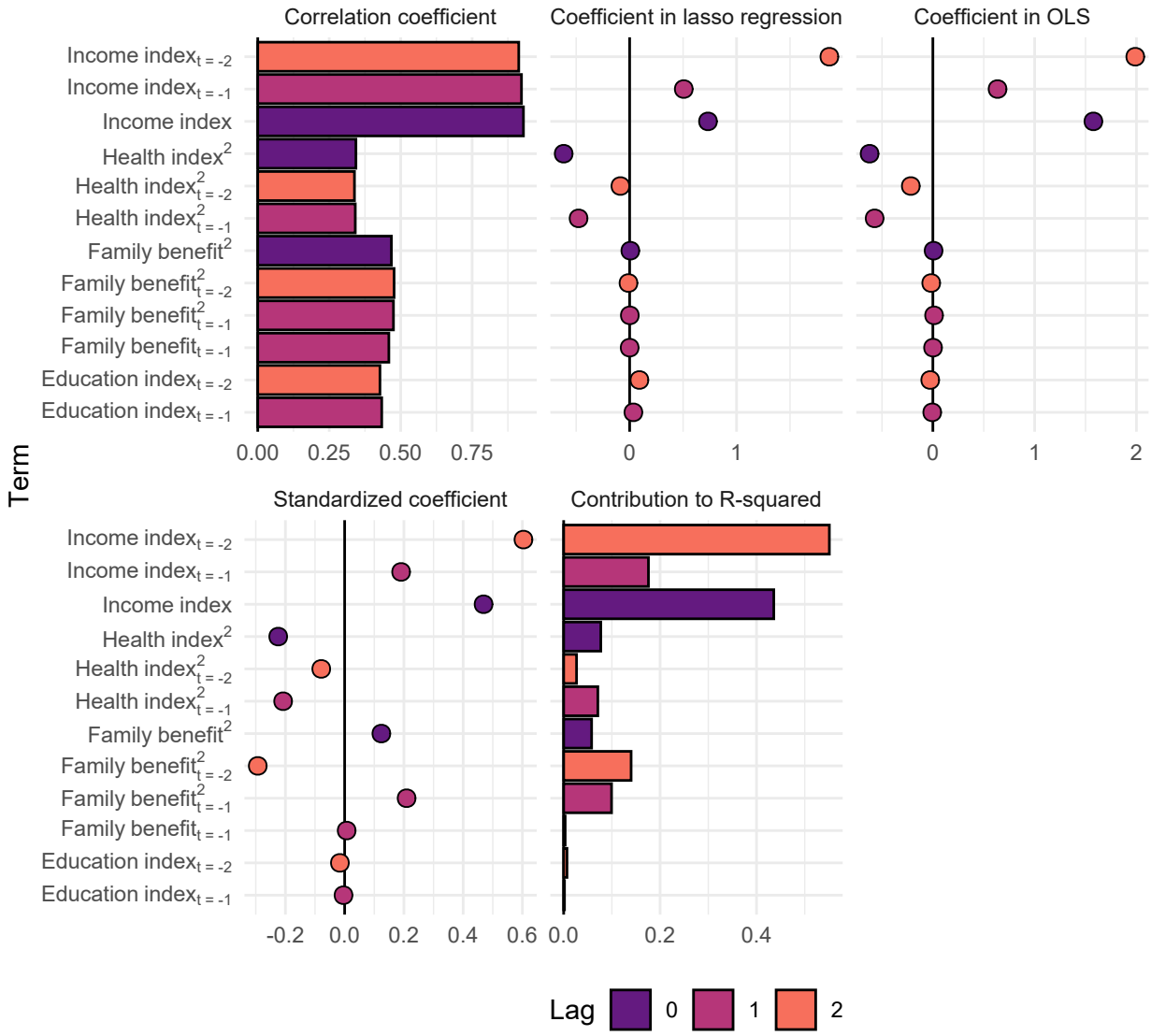


Figure 14: Estimated coefficient of the fixed panel model omitting youth unemployment indicators

Appendix: R codes

```r
# Set up ------------------------------------------------------------------------------

## Packages ==========================================================================

library(tidyverse)
library(patchwork)
library(knitr)
library(broom)
library(eurostat)

## Gg theme ==========================================================================

update_geom_defaults("point", list(fill = "#B1339E",
                                   shape = 21,
                                   color = "black",
                                   size = 1.4))
update_geom_defaults("line",
                     list(color = "midnightblue", size = 1.4))

update_geom_defaults("smooth", list(color = "red4", size = 1.4))

update_geom_defaults("density",
                     list(color = "midnightblue", fill =  "midnightblue", alpha = .3,
                          size = 1.4))

extrafont::loadfonts(device="win")

theme_set(theme_minimal() + theme(
  legend.direction = "vertical",
  # text = element_text(family = "Impact"),
  plot.caption = element_text(family = "serif"),
  legend.key=element_blank()
))

# https://data.worldbank.org/indicator/SP.DYN.TFRT.IN

WB_fertility <- read_csv("WB_fertility.csv", skip = 4)

# https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD

WB_GDP <- read_csv("WB_GDP.csv", skip = 4)

merge(WB_fertility %>%
        select('Country Name', '2017') %>%
        rename(tfr = '2017'),
      WB_GDP %>%
        select('Country Name', '2017') %>%
        rename(GDP = '2017')) %>%
  ggplot(aes(GDP, tfr)) + geom_point() +
  ggformula::geom_spline() +
  scale_x_continuous(limits = c(0, 7e+4)) +
  labs(y = "Total fertility rate (birth per woman)",
```

```
       x = "GDP per capita, PPP (constant 2017 international USD)",
       caption = "Own editing based on the Figure 5-2. from Kreiszné Hudák (2019).
       The trend is drawn via splines.
       Source of the data: World Bank."
  )

plot_NUTS2 <- function(df, viridis_c = T, ..., all.x = F) {
  p <- df %>%
    {merge(eurostat::get_eurostat_geospatial(nuts_level = 2), ., all.x = all.x)} %>%
    ggplot(aes(fill = values)) +
    geom_sf(color = "black") +
    theme(
      axis.text = element_blank()
    ) +
    xlim(c(-30, 44)) +
    ylim(c(35, 70)) +
    labs(fill = NULL)

  if (viridis_c) {
    p <- p + scale_fill_viridis_c(option = "magma", ...,
                                  guide = guide_colorbar(frame.colour = "black",
                                                         ticks.colour = "black"),
                                  na.value = "white")
  }
  p
}

# Data import ------------------------------------------------------------------

# Fertility: source: Eurostat database ===========================================

f_data <- get_eurostat("demo_r_find2", time_format = "num") %>%
  select(geo, time, var = indic_de, values) %>%
  filter(!str_detect(geo, "TR"))

### Map of TFR ##################################################################

f_data %>%
  filter(var == "TOTFERRT" & str_length(geo) == 4 & time == 2017) %>%
  plot_NUTS2(limits = c(1, 3))
# Data from Global Data Labor ====================================================

### Sub-national data ###########################################################

# source of csv files: https://globaldatalab.org/

GDL_import <- function(x) {
  get_eurostat_geospatial(nuts_level = 2) %>%
    data.frame() %>%
    tibble %>%
    mutate(
      ISO_Code = countrycode::countrycode(CNTR_CODE, origin = "iso2c", "iso3c"),
      ISO_Code = ifelse(CNTR_CODE == "UK", "GBR", ISO_Code),
```

```
      ISO_Code = ifelse(CNTR_CODE == "EL", "GRC", ISO_Code),
    ) %>%
    select(ISO_Code, NUTS_NAME, geo) %>%
    merge(read_csv(x), by = "ISO_Code") %>%
    mutate(
      z = stringdist::stringsim(NUTS_NAME, Region)
    ) %>%
    arrange(desc(z)) %>%
    filter(!duplicated(Region)) %>%
    filter(!duplicated(NUTS_NAME)) %>%
    filter((z > .5 | Country %in% c("Greece", "Turkey", 'Romania',
                                    'Malta', 'Italy')) & NUTS_NAME != "Dresden") %>%
    select(geo, '1990':'2018') %>%
    pivot_longer(-1, names_to = "time", values_to = "values") %>%
    mutate(time = as.numeric(time))
}

GDL_subnat <- GDL_import("GDL-Sub-national-HDI-data.csv") %>% rename(HDI = values) %>%
  merge(
    GDL_import("GDL-Educational-index--data.csv") %>% rename(education = values)
  ) %>%
  merge(
    GDL_import("GDL-Health-index-data.csv") %>% rename(health = values)
  ) %>%
  merge(
    GDL_import("GDL-Income-index-data.csv") %>% rename(income = values)
  )

### National data ##############################################################################

GDL_nat <- read_csv("GDL-Sub-national-HDI-data.csv") %>%
  filter(Level == "National") %>%
  select(Country, 6:34) %>% pivot_longer(-1, names_to = "time", values_to = "values") %>%
  mutate(time = as.numeric(time)) %>%
  na.omit()

# Data from UNDP ===============================================================================

# source: http://hdr.undp.org/

HDI_UNDP <- read_csv("Human Development Index (HDI).csv",
                     skip = 5) %>%
  select(!starts_with("X"), - 'HDI Rank') %>%
  mutate_at(-1,
            function(x) {as.numeric(ifelse(x == "..", NA, x))}) %>%
  pivot_longer(-1, names_to = "time", values_to = "values") %>%
  mutate(time = as.numeric(time)) %>%
  na.omit()

merge(GDL_nat %>% rename(GDL = values),
      HDI_UNDP %>% rename(UNDP = values)) %>%
  {
    c(
```

```
      scales::percent(cor(x = .$GDL, y = .$UNDP)^2, accuracy = .01),
      scales::percent(cor(x = .$GDL, y = .$UNDP, method = "spearman")^2, accuracy = .01),
      as.character(format(mean(abs(.$GDL - .$UNDP)), digits = 1)),
      scales::percent(mean(abs(.$GDL - .$UNDP)/.$UNDP), accuracy = .01)
    )
  } %>%
  {tibble(
    Indicator = c("$R^2$", "Spearman $R^2$",
                  "Mean absolute deviation", "Mean absolute percentage deviation"),
    Value = .
  )} %>%
  kable(
    caption = "Indicators of similiarity between the Human Development Indices
    provided by UNDP and GDL"
  )

GDL_subnat %>%
  filter(time == 2017) %>%
  select(-time) %>%
  pivot_longer(-1, names_to = "var", values_to = "values") %>%
  filter(!is.na(var)) %>%
  mutate(
    var = str_to_title(var),
    var = str_replace(var, "Hdi", "HDI"),
    var = factor(var,
                 levels = c("HDI", "Income", "Education", "Health"),
                 ordered = T)
  ) %>%
  plot_NUTS2() + facet_wrap(~ var, ncol = 2) +
  labs(caption = "Source: https://globaldatalab.org")

GDP_index <- get_eurostat("nama_10r_2gdp", time_format = "num") %>%
  filter(unit == "PPS_EU27_2020_HAB") %>%  # Purchasing power standard (PPS) per inhabitant
  select(-unit) %>%
  rename(GDP = values) %>% merge(
    get_eurostat("ert_bil_eur_a", time_format = "num") %>% # EUR/USD annual avg exc r
      filter(currency == "USD" & statinfo == "AVG") %>%
      select(time, e = values)
  ) %>%
  {
    GDP <- .$GDP/.$e # mutate to USD
    mutate(.,
           GDPindex = (log(GDP) - log(100))/
             (log(75000) - log(100))
    )
  }

merge(GDL_subnat, GDP_index) %>%
  {
    c(
      scales::percent(cor(x = .$income, y = .$GDPindex)^2, accuracy = .01),
      scales::percent(cor(x = .$income, y = .$GDPindex, method = "spearman")^2,
                      accuracy = .01),
```

```
      as.character(format(mean(abs(.$income - .$GDPindex)), digits = 1, nsmall = 4)),
      scales::percent(mean(abs(.$income - .$GDPindex)/.$GDPindex), accuracy = .01)
    )
  } %>%
  {tibble(
    Indicator = c("$R^2$", "Spearman $R^2$",
                  "Mean absolute deviation", "Mean absolute percentage deviation"),
    Value = .
  )} %>%
  kable(
    caption = "Indicators of similiarity between the income component of the
    Human Development Indices provided by GDL and the estimation based on regional GDP"
  )

health_index <- get_eurostat("demo_r_mlifexp", time_format = "num") %>%
  filter(age == "Y_LT1" & sex == "T") %>%
  select(geo, time, le = values) %>%
  mutate(
    health_index = (le - 20) / (85 - 20)
  )

merge(GDL_subnat, health_index) %>%
  {
    c(
      scales::percent(cor(x = .$health, y = .$health_index)^2, accuracy = .01),
      scales::percent(cor(x = .$health, y = .$health_index, method = "spearman")^2,
                      accuracy = .01),
      as.character(format(mean(abs(.$health - .$health_index)), digits = 1, nsmall = 4)),
      scales::percent(mean(abs(.$health - .$health_index)/.$health_index), accuracy = .01)
    )
  } %>%
  {tibble(
    Indicator = c("$R^2$", "Spearman $R^2$",
                  "Mean absolute deviation", "Mean absolute percentage deviation"),
    Value = .
  )} %>%
  kable(
    caption = "Indicators of similiarity between the health component of the
    Human Development Indices provided by GDL and the estimation based on regional life
    expectency"
  )

edu_wide <- get_eurostat("edat_lfse_04", time_format = "num") %>%
  filter(sex == "T" & !str_detect(isced11, "GEN") &
           !str_detect(isced11, "VOC") & isced11 != "ED3-8" & !str_detect(geo, "TR")
  ) %>%
  mutate(
    var = str_c(age, ":", isced11)
  ) %>%
  select(geo, time, var, values) %>%
  pivot_wider(names_from = var, values_from = values) %>%
  {
    x <- .
```

```
    names(x) <- letters[1:length(x)]
    x <- cbind(
      .[, 1:2],
      mice::complete(mice::mice(select(x, -a,-b), printFlag = F))
    )
    names(x) <- names(.)
    x
  }

edu_comps <- edu_wide%>%
  select(-time, -geo) %>%
  na.omit() %>%
  {princomp(scale(.))}

edu_comp_vars <- edu_comps %>%
  summary() %>%
  {.$sdev^2/sum(.$sdev^2)} %>%
  scales::percent(accuracy = .01) %>%
  {str_c("# ", 1:length(.), " (", ., ")")}

edu_comps %>%
  .$loadings %>%
  unclass() %>%
  data.frame() %>%
  rownames_to_column() %>%
  pivot_longer(-1) %>%
  mutate(
    name = as.numeric(str_remove(name, 'Comp.')),
  ) %>%
  arrange(name) %>%
  mutate(
    name = edu_comps %>%
      summary() %>%
      {.$sdev^2/sum(.$sdev^2)} %>%
      scales::percent(accuracy = .01) %>%
      {str_c("# ", 1:length(.), " (", ., ")")} %>%
      .[name]
  ) %>%
  ggplot +
  aes(rowname, value, fill = value < 0) +
  geom_hline(yintercept = 0) +
  geom_col(color = 'black') +
  coord_flip() +
  scale_fill_viridis_d(guide = F, option = "magma", begin = .4,
                       end= .7, direction = -1) +
  scale_y_continuous(labels = scales::percent) +
  facet_wrap(~name, ncol = 3) +
  labs(x = NULL, y = NULL, caption =
         "The corresponding proportion of the explained variance are in the brackets.")

edu_comps %>% .$scores %>%
  cbind(edu_wide) %>% merge(GDL_subnat) %>%
  select(3:11, education) %>%
```

```r
  {
    x <- .$education
    apply(select(., -education), 2, function(y) {
      c(
        scales::percent(cor(x = x, y = y)^2, accuracy = .01),
        scales::percent(cor(x = x, y = y, method = "spearman")^2, accuracy = .01)
      )
    })
  } %>%
  data.frame() %>%
  mutate(Indicator = c("$R^2$", "Spearman $R^2$")) %>%
  rename_all(function(x) str_replace(x, "p.", "p ")) %>%
  select(Indicator, 1:9) %>%
  kable(
    caption = "Indicators of similiarity between the knowledge component of Human
    Development Indices provided by UNDP and the calculated principal components using
    educational attainment level"
  )

edu_index <- edu_comps %>%
  .$scores %>%
  data.frame() %>%
  select(2) %>%
  cbind(edu_wide) %>%
  select(geo, time, edu_index = Comp.2) %>%
  mutate(
    edu_index = -edu_index,
    edu_index = edu_index + abs(min(edu_index)),
    edu_index = edu_index/max(edu_index)
  )

dat <- f_data %>%
  pivot_wider(names_from = var, values_from = values) %>%
  merge(edu_index, all = T) %>%
  merge(health_index, all = T) %>%
  merge(GDP_index, all = T) %>%
  filter(!str_detect(geo, "TR"))

FAM_df <- get_eurostat("spr_exp_sum", time_format = "num") %>%
  filter(spdeps == "FAM" & unit == "PC_GDP") %>%
  rename(FAM = values, country = geo) %>%
  select(-(spdeps:unit))

yth_empl_byage <- get_eurostat("yth_empl_110", time_format = "num") %>%
  filter(unit == "PC" & sex == "F") %>%
  filter(age %in% c("Y15-19", "Y20-24", "Y25-29")) %>%
  select(-unit, -sex) %>%
  pivot_wider(names_from = age, values_from = values) %>%
  rename(
    "uY15"  = "Y15-19",
    "uY20"  = "Y20-24",
    "uY25"  = "Y25-29"
  )
```

```r

dat <- dat %>%
  mutate(country = str_sub(geo, end = 2)) %>%
  merge(FAM_df, all.x = T, all.y = F) %>%
  merge(yth_empl_byage, all.x = T, all.y = F) %>%
  filter(!str_detect(geo, "TR"))

f.clean_names <- function(v, Tosparse = F) {
  v <- str_replace_all(v, "GDPindex", "Income index") %>%
    str_replace_all("health_index", "Health index") %>%
    str_replace_all("edu_index", "Education index") %>%
    str_replace_all("TOTFERRT", "TFR") %>%
    str_replace_all("GDPindex", "Income index") %>%
    str_replace_all("FAM", "Family benefit") %>%
    str_replace_all("uY15", "UR (15-19 y)") %>%
    str_replace_all("uY20", "UR (20-24 y)") %>%
    str_replace_all("uY25", "UR (25-29 y)")
  if(Tosparse) v <- str_replace_all(v, " ", "~")
  v
}

# Explore the data ------------------------------------------------------------

# Pairwise correlations ========================================================

dat %>%
  filter(str_length(geo) == 4) %>%
  select(TOTFERRT, GDPindex, edu_index, health_index) %>%
  {set_names(., f.clean_names(names(.)))} %>%
  GGally::ggpairs()

dat %>%
  filter(str_length(geo) == 4) %>%
  select(TOTFERRT, uY15, uY20, uY25) %>%
  set_names("TFR", "Unemployment rate\n(15-19 years old)",
            "Unemployment rate\n(20-24 years old)",
            "Unemployment rate\n(25-29 years old)") %>%
  GGally::ggpairs()

dat %>%
  filter(str_length(geo) == 2) %>%
{ggplot(., aes(FAM, TOTFERRT)) +
  geom_vline(aes(xintercept = mean(.$FAM, na.rm = T), linetype = "means")) +
  geom_hline(yintercept = mean(.$TOTFERRT, na.rm = T), linetype = 2) +
  geom_point() +
  geom_smooth(method = "lm", aes(color = "Linear trend"), size = 1.5) +
  scale_color_viridis_d() +
  scale_linetype_manual(values = c("means" = 2)) +
  labs(y = "Total fertility rate (birth per woman)",
       x = "Family benefit (% of GPD)",
       linetype = NULL, color = NULL
  ) +
    theme(
      legend.position = "bottom"
```

```r
    )
  }

# Regression trees ============================================================

m_part <- dat %>%
  filter(str_length(geo) == 4) %>%
  select(TOTFERRT, GDPindex, edu_index, health_index, FAM) %>%
  {set_names(., f.clean_names(names(.)))} %>%
  na.omit() %>%
  rpart::rpart(formula = TFR ~ ., cp = .01)

m_part %>% rattle::fancyRpartPlot(palettes = 'PuRd', sub = NULL)

m_part %>% summary()

m_part2 <- dat %>%
  filter(str_length(geo) == 4) %>%
  select(TOTFERRT, GDPindex, edu_index, health_index, uY15, uY20, uY25, FAM) %>%
  {set_names(., f.clean_names(names(.)))} %>%
  na.omit() %>%
  rpart::rpart(formula = TFR ~ ., cp = .01)

m_part2 %>% rattle::fancyRpartPlot(palettes = 'PuRd', sub = NULL)

# Model building ----------------------------------------------------------------

# Transform the data for panel modeling ===================================================

dat_plm <- dat %>%
  select(
    geo, time, TOTFERRT, edu_index, health_index, GDPindex, FAM, uY15, uY20, uY25
  ) %>%
  filter(str_length(geo) == 4 & !is.na(TOTFERRT))

dat_plm <- dat_plm %>%
  select(-TOTFERRT) %>%
  mutate(time = time + 1) %>%
  {
    set_names(., ifelse(names(.) == 'geo' | names(.) == 'time', names(.),
                        paste0(names(.), '_l')))
  } %>%
  merge(dat_plm, all.x = F, all.y = T)

dat_plm <- dat_plm %>%
  select(!ends_with("_l")) %>%
  select(-TOTFERRT) %>%
  mutate(time = time + 2) %>%
  {
    set_names(., ifelse(names(.) == 'geo' | names(.) == 'time', names(.),
                        paste0(names(.), '_l_l')))
  } %>%
  merge(dat_plm, all.x = F, all.y = T)
```

```r

dat_plm <- dat_plm %>%
  select(-TOTFERRT) %>%
  mutate_at(-(1:2), function(x) x^2) %>%
  {
    set_names(., ifelse(names(.) == 'geo' | names(.) == 'time', names(.),
                        paste0(names(.), '_2')))
  } %>%
  merge(dat_plm, all.x = F, all.y = T)

## Initial models ==============================================================

library(plm)

m_panels <- c(
  'TOTFERRT ~ edu_index_l_l + health_index_l_l + GDPindex_l_l + FAM_l_l +
  uY15_l_l + uY20_l_l + uY25_l_l + edu_index_l + health_index_l + GDPindex_l + FAM_l +
  uY15_l + uY20_l + uY25_l + edu_index + health_index + GDPindex + FAM + uY15 + uY20 +
  uY25',
  'TOTFERRT ~ edu_index_l_l + health_index_l_l + GDPindex_l_l + FAM_l_l + edu_index_l +
  health_index_l + GDPindex_l + FAM_l + edu_index + health_index + GDPindex + FAM'
) %>%
  lapply(function(formula) {
    pooling <- plm(eval(formula), data = dat_plm, model = "pooling")
    within <- plm(eval(formula), data = dat_plm, model = "within")
    random <- plm(eval(formula), data = dat_plm, model = "random")

    list(
      tests = c(
        pooltest(pooling, within)$p.value,
        phtest(within, random)$p.value,
        plm::r.squared(within, dfcor = T)),
      model = within,
      OLS = formula %>%
  str_replace_all('\\~', ',') %>%
  str_replace_all('\\+', ',') %>%
  str_split(',') %>%
  .[[1]] %>%
  trimws() %>%
  {c(., 'geo')} %>%
  {select(dat_plm, .)} %>%
  na.omit() %>%
  group_by(geo) %>%
  summarise_all(.funs = function(x) mean(x)) %>%
  merge(
    plm::fixef(within) %>%
      {tibble(geo = names(.), a = .)}
  ) %>%
  mutate(
    TOTFERRT = TOTFERRT - a
  ) %>%
  lm(formula = formula)
    )
  })
```

```
532
533 ### Plot coefficients ##############################################################################
534
535 m_panels %>%
536   lapply(function(output) {
537     output$model %>% broom::tidy(conf.int = T) %>%
538       rownames_to_column()
539   }) %>%
540   reduce(rbind) %>%
541   mutate(
542     rowname = paste0("Model ", as.roman(cumsum(rowname == 1)), "."),
543     term = f.clean_names(term, Tosparse = T),
544     term = gsub("_2", "^2", term),
545     term = gsub("_l_l", '["t = -2"]', term),
546     term = gsub("_l", '["t = -1"]', term),
547   ) %>%
548   ggplot() +
549   aes(estimate, term, color = p.value <= .05) +
550   geom_vline(xintercept = 0, color = "gray4") +
551   geom_point() +
552   geom_pointrange(aes(xmin = conf.low, xmax = conf.high)) +
553   facet_wrap(~rowname, nrow = 1) +
554   labs(x = "Estimated coefficient", y = "Term", color = "Corresponding p-value \u2264 5%") +
555   scale_color_viridis_d(option = "magma", begin = .2, end = .7) +
556   scale_y_discrete(labels=scales::parse_format()) +
557   theme(
558     legend.position = "bottom",
559     legend.direction = "horizontal"
560   )
561
562 ### Model descriptions ##############################################################################
563
564 m_panels %>%
565   lapply(function(output) {
566     c(output$tests, nrow(augment(output$OLS)))
567   }) %>%
568   reduce(rbind) %>%
569   t() %>%
570   data.frame() %>%
571   mutate_all(function(x) c(scales::percent(x[1:3], accuracy = .01),
572                            as.character(x[4]))) %>%
573   {set_names(., paste0("Model ", as.roman(1:ncol(.)), "."))  } %>%
574   mutate(
575     Indicator = c("Pooltest", "Phtest", "Adjusted $R^2$", "Observations")
576   ) %>%
577   select(Indicator, everything()) %>%
578   knitr::kable(caption = "Models", align = c("l", "c", "c", "c"))
579
580 # Framework I. ========================================================================================
581
582 ## Bias of framework ################################################################################
583
584 names(dat_plm) %>%
585   { ifelse(
```

```
    . %in% c("geo", "time") | str_detect(., "_l") | str_detect(., "_2"), NA, .
  )} %>%
  na.omit() %>%
  lapply(function(variable){
    x <- pull(dat_plm, variable) %>% na.omit()
    y <- pull(na.omit(dat_plm), variable)
    t <- t.test(x, y)
    tibble(
      Variable = f.clean_names(variable),
      'Mean in total sample' = mean(x),
      'Mean in used sample' = mean(y),
      'Number of observations in the total sample' = length(x),
      'T-statistic' = t$statistic,
      'P-value' = scales::percent(t$p.value, accuracy = .01)
    )
  }
  ) %>% reduce(rbind) %>%
  knitr::kable(caption = 'T-tests', digits = 4,
               align = c('l', 'c', 'c', 'c', 'c', 'c', 'c'))

dat_plm %>%
  na.omit() %>%
  group_by(geo) %>%
  summarise(
    values = n()
  ) %>%
  plot_NUTS2(all.x = T) +
  scale_fill_viridis_b(option = "magma", direction = -1, begin = .2,
                                  na.value = "white")

### Run lasso regression ##########################################################

library(glmnet)

y <- na.omit(dat_plm)$TOTFERRT
X <- model.matrix(TOTFERRT ~ ., data = select(na.omit(dat_plm), -time))
LASSO <- cv.glmnet(X, y)

tidy(LASSO) %>%
  ggplot() +
  aes(log(lambda), ymin = conf.low*1000, ymax = conf.high*1000) +
  geom_line(aes(log(lambda), estimate*1000, color = "Mean-Squared Error")) +
  geom_step(aes(y = nzero, color = "Number of used explanatory variables"),
            size = 1) +
  geom_ribbon(alpha = .4) +
  geom_hline(yintercept = 0, size = 1) +
  geom_vline(aes(xintercept = log(LASSO$lambda.1se), color = "lambda.1se"),
             # TODO name the line
             linetype = 2) +
  geom_vline(aes(xintercept = log(LASSO$lambda.min), color = "lambda.min"),
             linetype = 2) +
  scale_y_continuous(
    name = "Number of used explanatory variables",
```

```
    sec.axis = sec_axis( trans=~./1000, name = "Mean-Squared Error")
  ) +
  labs(y = "Mean-Squared Error", x = "Log(\u03BB)", color = NULL) +
  scale_color_viridis_d(option = "magma", end = .8) +
  theme(legend.position = "bottom", legend.direction = "horizontal")

lasso_coefs <- capture.output(
  coef(LASSO, LASSO$lambda.1se)
) %>%
  .[-(1:2)] %>%
  {tibble(x = .)} %>%
  mutate(term = gsub(" .*", "", x), coef = gsub(".* ", "", x)) %>%
  select(-x) %>%
  filter(!str_detect(term, "geo") & coef != "" & term != "(Intercept)")

m_panels2 <- paste("TOTFERRT ~", paste(lasso_coefs$term, collapse = " + ")) %>%
  lapply(function(formula) {
    pooling <- plm(eval(formula), data = dat_plm, model = "pooling")
    within <- plm(eval(formula), data = dat_plm, model = "within")
    random <- plm(eval(formula), data = dat_plm, model = "random")
    list(
      tests = c(
        pooltest(pooling, within)$p.value,
        phtest(within, random)$p.value,
        plm::r.squared(within, dfcor = T)),
      model = within,
      OLS = formula %>%
  str_replace_all('\\~', ',') %>%
  str_replace_all('\\+', ',') %>%
  str_split(',') %>%
  .[[1]] %>%
  trimws() %>%
  {c(., 'geo')} %>%
  {select(dat_plm, .)} %>%
  na.omit() %>%
  group_by(geo) %>%
  summarise_all(.funs = function(x) mean(x)) %>%
  merge(
    plm::fixef(within) %>%
      {tibble(geo = names(.), a = .)}
  ) %>%
  mutate(
    TOTFERRT = TOTFERRT - a
  ) %>%
  lm(formula = formula)
    )
  }
  )

m_panels2 %>%
  lapply(function(output) {
    output$tests
  })
```

```r

standard_beta <- m_panels2[[1]]$OLS %>%
  QuantPsyc::lm.beta() %>%
  {tibble(term = names(.), beta = .)} %>%
  filter(!str_detect(term, "geo"))

standard_beta <- augment(m_panels2[[1]]$OLS) %>%
  select(TOTFERRT:.fitted) %>%
  select(-.fitted) %>%
  cor() %>%
  data.frame() %>%
  select(1) %>%
  rownames_to_column() %>%
  rename(term = rowname) %>%
  merge(standard_beta) %>%
  mutate(explain = abs(TOTFERRT*beta)) %>%
  select(term, cor = TOTFERRT, standard_beta = beta, explain)

lasso_coefs %>%
  rename(lasso = coef) %>%
  merge(tidy(m_panels2[[1]]$OLS, conf.int = T)) %>%
  merge(standard_beta) %>%
  mutate_at(-1, function(x) as.numeric(x)) %>%
  pivot_longer(c(lasso:estimate, cor:explain)) %>%
  mutate(
    conf.low = ifelse(name != "estimate", NA, conf.low),
    conf.high = ifelse(name != "estimate", NA, conf.high),
    lag = ifelse(str_detect(term, "_l"),
                 ifelse(str_detect(term, "_l_l"), 2, 1), 0),
    bar = ifelse(name %in% c("cor", "explain"), value, NA),
    value = ifelse(!(name %in% c("cor", "explain")), value, NA),
    term = f.clean_names(term, Tosparse = T),
    term = gsub("_2", "^2", term),
    term = gsub("_l_l", '["t = -2"]', term),
    term = gsub("_l", '["t = -1"]', term),
    name = case_when(
      name == "cor" ~ 'Correlation coefficient',
      name == "estimate" ~ 'Coefficient in OLS',
      name == "lasso" ~ 'Coefficient in lasso regression',
      name == "standard_beta" ~ 'Standardized coefficient',
      name == "explain" ~ 'Contribution to R-squared'
    ),
    name = factor(
      name, levels = c(
        'Correlation coefficient',
        'Coefficient in lasso regression',
        'Coefficient in OLS',
        'Standardized coefficient',
        'Contribution to R-squared'
      )
    ),
  ) %>%
  {
    ggplot(.) +
```

```r
      geom_vline(xintercept = 0) +
      geom_point(aes(value, term, fill = factor(lag)), size = 3) +
      geom_col(aes(bar, term, fill = factor(lag)), color = "black") +
      scale_fill_viridis_d(option = "magma", begin = .3, end = .7) +
      scale_y_discrete(labels=scales::parse_format()) +
      facet_wrap(~ name, scales = "free_x") +
      labs(x = NULL, y = "Term", fill = "Lag") +
      theme(legend.position = "bottom", legend.direction = "horizontal")
  }

dat_plm <- dat_plm %>%
  select(!starts_with("uY"))

LASSO <- cv.glmnet(model.matrix(TOTFERRT ~ ., data = select(na.omit(dat_plm), -time)),
                   na.omit(dat_plm)$TOTFERRT)

names(dat_plm) %>%
  {ifelse(
    . %in% c("geo", "time") | str_detect(., "_1") | str_detect(., "_2"), NA, .
  )} %>%
  na.omit() %>%
  lapply(function(variable){
    x <- pull(dat_plm, variable) %>% na.omit()
    y <- pull(na.omit(dat_plm), variable)
    t <- t.test(x, y)
    tibble(
      Variable = f.clean_names(variable),
      'Mean in total sample' = mean(x),
      'Mean in used sample' = mean(y),
      'Number of observations in total sample' = length(x),
      'T-statistic' = t$statistic,
      'P-value' = scales::percent(t$p.value, accuracy = .01)
    )
  }
  ) %>% reduce(rbind) %>%
  knitr::kable(caption = 'T-tests', digits = 4,
               align = c('l', 'c', 'c', 'c', 'c', 'c', 'c'))

dat_plm %>%
  na.omit() %>%
  group_by(geo) %>%
  summarise(
    values = n()
  ) %>%
  plot_NUTS2(all.x = T) +
  scale_fill_viridis_b(option = "magma", direction = -1, begin = .2,
                                  na.value = "white")

lasso_coefs <- capture.output(
  coef(LASSO, LASSO$lambda.1se)
) %>%
  .[-(1:2)] %>%
  {tibble(x = .)} %>%
```

```r
  mutate(term = gsub(" .*", "", x), coef = gsub(".* ", "", x)) %>%
  select(-x) %>%
  filter(!str_detect(term, "geo") & coef != "" & term != "(Intercept)")

m_panels2 <- paste("TOTFERRT ~", paste(lasso_coefs$term, collapse = " + ")) %>%
  lapply(function(formula) {
    pooling <- plm(eval(formula), data = dat_plm, model = "pooling")
    within <- plm(eval(formula), data = dat_plm, model = "within")
    random <- plm(eval(formula), data = dat_plm, model = "random")
    list(
      tests = c(
        pooltest(pooling, within)$p.value,
        phtest(within, random)$p.value,
        plm::r.squared(within, dfcor = T)),
      model = within,
      OLS = formula %>%
  str_replace_all('\\~', ',') %>%
  str_replace_all('\\+', ',') %>%
  str_split(',') %>%
  .[[1]] %>%
  trimws() %>%
  {c(., 'geo')} %>%
  {select(dat_plm, .)} %>%
  na.omit() %>%
  group_by(geo) %>%
  summarise_all(.funs = function(x) mean(x)) %>%
  merge(
    plm::fixef(within) %>%
      {tibble(geo = names(.), a = .)}
  ) %>%
  mutate(
    TOTFERRT = TOTFERRT - a
  ) %>%
  lm(formula = formula)
    )
  }
  )

m_panels2 %>%
  lapply(function(output) {
    output$tests
  })

standard_beta <- m_panels2[[1]]$OLS %>%
  QuantPsyc::lm.beta() %>%
  {tibble(term = names(.), beta = .)} %>%
  filter(!str_detect(term, "geo"))

standard_beta <- augment(m_panels2[[1]]$OLS) %>%
  select(TOTFERRT:.fitted) %>%
  select(-.fitted) %>%
  cor() %>%
  data.frame() %>%
```

```r
  select(1) %>%
  rownames_to_column() %>%
  rename(term = rowname) %>%
  merge(standard_beta) %>%
  mutate(explain = abs(TOTFERRT*beta)) %>%
  select(term, cor = TOTFERRT, standard_beta = beta, explain)

lasso_coefs %>%
  rename(lasso = coef) %>%
  merge(tidy(m_panels2[[1]]$OLS, conf.int = T)) %>%
  merge(standard_beta) %>%
  mutate_at(-1, function(x) as.numeric(x)) %>%
  pivot_longer(c(lasso:estimate, cor:explain)) %>%
  mutate(
    conf.low = ifelse(name != "estimate", NA, conf.low),
    conf.high = ifelse(name != "estimate", NA, conf.high),
    lag = ifelse(str_detect(term, "_l"),
                 ifelse(str_detect(term, "_l_l"), 2, 1), 0),
    bar = ifelse(name %in% c("cor", "explain"), value, NA),
    value = ifelse(!(name %in% c("cor", "explain")), value, NA),
    term = f.clean_names(term, Tosparse = T),
    term = gsub("_2", "^2", term),
    term = gsub("_l_l", '["t = -2"]', term),
    term = gsub("_l", '["t = -1"]', term),
    name = case_when(
      name == "cor" ~ 'Correlation coefficient',
      name == "estimate" ~ 'Coefficient in OLS',
      name == "lasso" ~ 'Coefficient in lasso regression',
      name == "standard_beta" ~ 'Standardized coefficient',
      name == "explain" ~ 'Contribution to R-squared'
    ),
    name = factor(
      name, levels = c(
        'Correlation coefficient',
        'Coefficient in lasso regression',
        'Coefficient in OLS',
        'Standardized coefficient',
        'Contribution to R-squared'
      )
    )
  ) %>%
  {
    ggplot(.) +
      geom_vline(xintercept = 0) +
      geom_point(aes(value, term, fill = factor(lag)), size = 3) +
      geom_col(aes(bar, term, fill = factor(lag)), color = "black") +
      scale_fill_viridis_d(option = "magma", begin = .3, end = .7) +
      scale_y_discrete(labels=scales::parse_format()) +
      facet_wrap(~ name, scales = "free_x") +
      labs(x = NULL, y = "Term", fill = "Lag") +
      theme(legend.position = "bottom", legend.direction = "horizontal")
  }
```