Individual-level analysis: mixed effects models

Part of the final project for AQMSS II

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Mixed effects models

Nested Logit

```
source(here::here("utilities", "check_packages.R"))
source(here::here("utilities", "functions.R"))
```

```
ep_raw_dep <- read_rds(here("data", "data_built", "ep_raw_dep.rds"))
data_country <- read_rds(here("data", "data_built", "data_country.rds"))
```

```
load(here("scripts", "models", "feme_bobyqa.RData"))
load(here("scripts", "models", "nlme_bobyqa.RData"))
load(here("scripts", "models", "me_allfit.RData"))
load(here("scripts", "models", "nl_fe.RData"))
```

```
# Recode no data back to native NA
model_data <- ep_raw_dep |>
  mutate(across(c(sex, age_bin, time_to_vs.less_than_hour,
                  time_to_vs.less_than_hour, out_of_Russia_time,
                  result_trust_bin),
                ~ if_else(. %in% c("No Data", "Declined to answer"), NA, .)),
         vote = relevel(as.factor(vote), ref = "Putin"),
         sex = relevel(as.factor(sex), ref = "Male"),
         age_bin = relevel(as.factor(age_bin), ref = "25-44"),
         out_of_Russia_time = relevel(as.factor(out_of_Russia_time), ref = "Before annexation"),
         result_trust_bin = relevel(as.factor(result_trust_bin), ref = "Yes")) |>
  filter(!countryname_en %in% c("New Zealand", "Australia"))
```

```
# Drop Australia and New Zealand for this because they have very skewed and low
# n observations. Might also help with convergence
nested_me_data <- model_data |>
  filter(vote != "Tore up/took", !countryname_en %in% c("Australia",
                                                        "New Zealand")) |>
```

```
  mutate(non_answer = if_else(vote == "Declined to answer", 1, 0),
         putin_else = case_when(vote == "Putin" ~ 1,
                                vote %in% c("Davankov", "Spoiled ballot",
                                            "Slutsky", "Haritonov") ~ 0,
                                .default = NA),
         nonsys_sys = case_when(vote %in% c("Davankov", "Spoiled ballot") ~ 1,
                                vote %in% c("Slutsky", "Haritonov") ~ 0,
                                .default = NA),
         davankov_spoiled = case_when(vote == "Davankov" ~ 1,
                                      vote == "Spoiled ballot" ~ 0,
                                      .default = NA),
         slutsky_haritonov = case_when(vote == "Slutsky" ~ 1,
                                       vote == "Haritonov" ~ 0,
                                       .default = NA)) |>
  left_join(select(data_country,
                   -countryname_en),
            by = c("countrycode_n", "countrycode_c"))
```

We fit the model consecutively for each dichotomy this time separating data by hand in the same way as the `nestedLogit` package does.

For some models we get non-convergence. We diagnose which optimizers work best in those case and update the model to achieve convergence.

```
# Answer (1) vs non-answer (0)
m4a.nested <- glmer(non_answer ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa"))
```

Not answer v answer

```
# Use bobyqa
m5a.nested <- glmer(non_answer ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + orthodox_share + vdem_polyarchy_2022
                    + log(mad_gdppc_2018) + obl_type + export_share
                    + import_share + friendly_status + help + military_dummy
                    + log(dist) + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa",
                                           optCtrl = list(maxfun = 1e9)))

# Doesn't converge


# Fit with all optimizers
m5a.allfit <- allFit(m5a.nested, maxfun = 1e9)
```

```
bobyqa : [OK]
```

```
Nelder_Mead : [OK]
nlminbwrap : [OK]
optimx.L-BFGS-B : [OK]
nloptwrap.NLOPT_LN_NELDERMEAD : [OK]
nloptwrap.NLOPT_LN_BOBYQA : [OK]
```

```
# Convergence results

  ## Export models
  m5a.allfit_OK <- m5a.allfit[sapply(m5a.allfit, is, "merMod")]

  ## Generate warnings encountered
  data.frame(lapply(m5a.allfit_OK, function(x) x@optinfo$conv$lme4$messages)) |>
    pivot_longer(everything(), names_to = "Method",
                 values_to = "Estimation result") |>
    arrange(`Method`, `Estimation result`) |>
    distinct() |>
    mutate(`Method` = if_else(lag(`Method`) != `Method` | is.na(lag(`Method`)),
                              `Method`, ""),
           `Estimation result` = str_replace_all(`Estimation result`,
                                                 "|", " ")) |>
    kable(booktabs = T,
          caption = paste("Convergence results for Answer/non-Answer dichotomy,",
                          "ME with level 2 variables and all optimizers")) |>
    column_spec(1, width = "7cm") |>
    kable_styling(latex_options = c("scale_down"))
```

Table 1: Convergence results for Answer/non-Answer dichotomy and all optimizers

Method	Estimation result
Nelder_Mead	M o d e l f a i l e d t o c o n v e r g e w i t h m a x	g r a
bobyqa	M o d e l f a i l e d t o c o n v e r g e w i t h m a x	g r a
nlminbwrap	M o d e l f a i l e d t o c o n v e r g e w i t h m a x	g r a
nloptwrap.NLOPT_LN_BOBYQA	M o d e l f a i l e d t o c o n v e r g e w i t h m a x	g r a
nloptwrap.NLOPT_LN_NELDERMEAD	M o d e l f a i l e d t o c o n v e r g e : d e g e n e r a t e H e s s u n a b l e t o e v a l u a t e s c a l e d g r a d i e n t
optimx.L.BFGS.B	M o d e l f a i l e d t o c o n v e r g e : d e g e n e r a t e H e s s u n a b l e t o e v a l u a t e s c a l e d g r a d i e n t

```
# Log-Likelihoods
(lliks <- sort(sapply(m5a.allfit_OK, logLik))) |>
  kable(col.names = "Log-likelihood", booktabs = T, digits = 3)
```

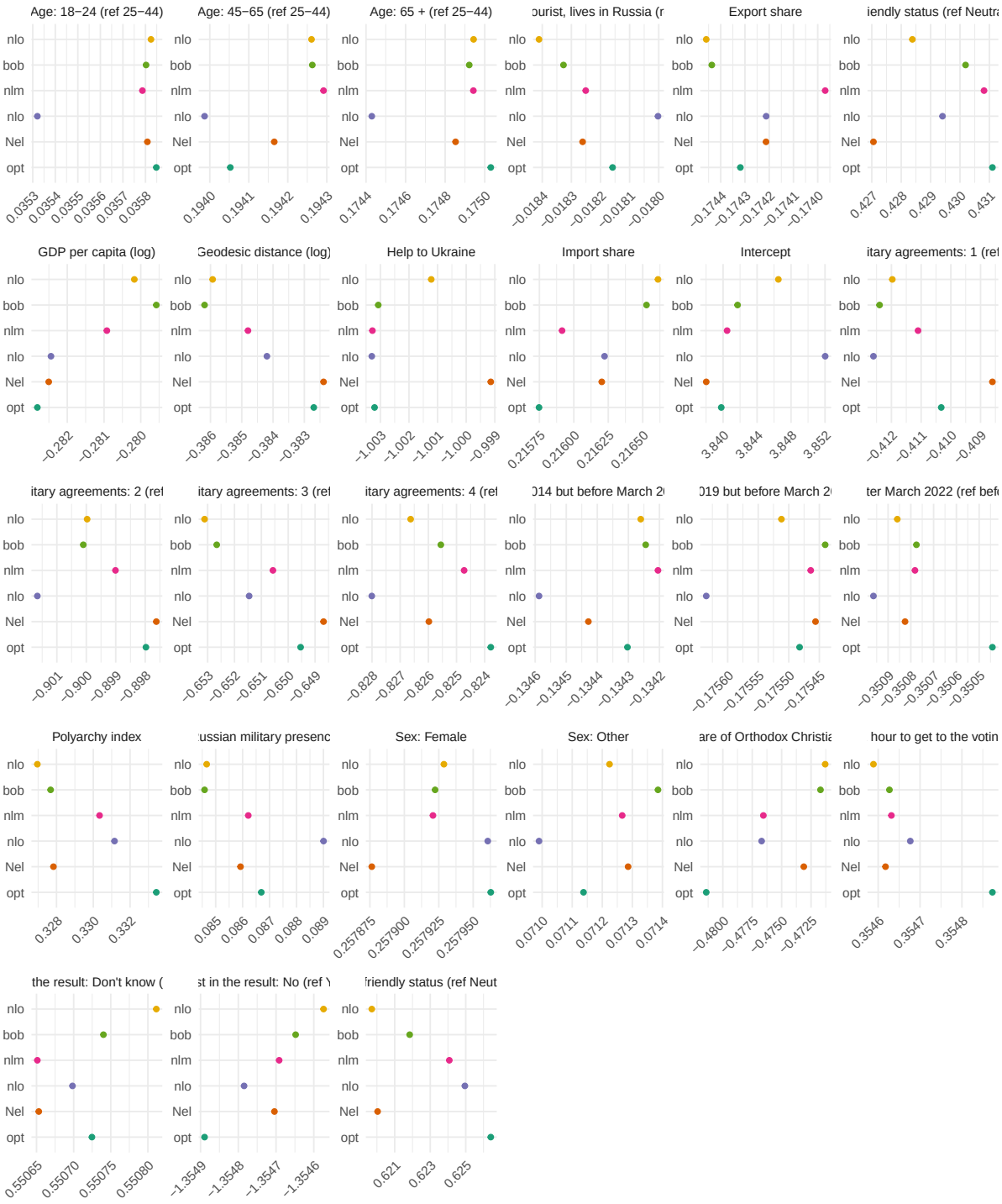
	Log-likelihood
optimx.L-BFGS-B	-8472.303
Nelder_Mead	-8472.302
nloptwrap.NLOPT_LN_BOBYQA	-8472.302
nlminbwrap	-8472.302
bobyqa	-8472.302
nloptwrap.NLOPT_LN_NELDERMEAD	-8472.302

```
# Coefficients from different optimizers

  ## Export fixef and melt into single dataframe
  models <- levels(melt(t(sapply(m5a.allfit_OK, fixef)))$Var1)
  m5a.allfit.fixef.m <- transform(melt(t(sapply(m5a.allfit_OK, fixef))),
                                  Var1 = factor(Var1, levels = names(lliks))) |>
    transmute(`Method` = Var1,
              `Coefficient` = value,
              `Variable` = case_when(
                Var2 == "(Intercept)" ~ "Intercept",
                Var2 == "sexFemale" ~ "Sex: Female",
                Var2 == "sexOther" ~ "Sex: Other",
                Var2 == "age_bin18-24" ~ "Age: 18-24 (ref 25-44)",
                Var2 == "age_bin45-64" ~ "Age: 45-65 (ref 25-44)",
                Var2 == "age_bin65+" ~ "Age: 65 + (ref 25-44)",
                Var2 == "time_to_vs.less_than_hourYes" ~
                  "Took < 1 hour to get to the voting station",
                Var2 == "out_of_Russia_timeAfter invasion" ~
                  "Moved after March 2022 (ref before 2014)",
                Var2 == "out_of_Russia_time2 - 5 years" ~
                  paste("Moved after March 2019 but before",
                        "March 2022 (ref before 2014)"),
                Var2 == "out_of_Russia_timeAfter annexation" ~
                  paste("Moved after March 2014 but before",
                        "March 2019 (ref before 2014)"),
                Var2 == "out_of_Russia_timeTourist (lives in Russia)" ~
                  paste("Didn't move - tourist, lives",
                        "in Russia (ref before 2014)"),
                Var2 == "result_trust_binDon't know" ~
                  "Trust in the result: Don't know (ref Yes)",
                Var2 == "result_trust_binNo" ~
                  "Trust in the result: No (ref Yes)",
                Var2 == "orthodox_share" ~ "Share of Orthodox Christians",
                Var2 == "vdem_polyarchy_2022" ~ "Polyarchy index",
                Var2 == "log(mad_gdppc_2018)" ~ "GDP per capita (log)",
                Var2 == "obl_type1" ~ "Military agreements: 1 (ref 0)",
                Var2 == "obl_type2" ~ "Military agreements: 2 (ref 0)",
                Var2 == "obl_type3" ~ "Military agreements: 3 (ref 0)",
                Var2 == "obl_type4" ~ "Military agreements: 4 (ref 0)",
                Var2 == "export_share" ~ "Export share",
                Var2 == "import_share" ~ "Import share",
                Var2 == "friendly_statusUnfriendly" ~
                  "Unfriendly status (ref Neutral)",
                Var2 == "friendly_statusFriendly" ~
                  "Friendly status (ref Neutral)",
                Var2 == "help" ~ "Help to Ukraine",
                Var2 == "military_dummy" ~ "Russian military presence",
                Var2 == "log(dist)" ~ "Geodesic distance (log)"),
```

```
            )

## Plot
ggplot(m5a.allfit.fixef.m,
         aes(x = `Coefficient`, y = `Method`, colour = `Method`)) +
    geom_point() +
    facet_wrap(~ `Variable`, scale = "free") +
    scale_colour_brewer(palette = "Dark2") +
    scale_y_discrete(breaks = models,
                     labels = substr(models, 1, 3)) +
    labs(x = "", y = "") +
    theme_minimal() +
    theme(legend.position = "none",
          axis.text.x = element_text(angle = 45, hjust = 1))
```




```
# So judging by this I leave the model alone - the coefficients seem to be okay
# between different optimizers and since bobyqa comes close to the tolerance
# threshold, I will use it.
```

```
# Check m5a-specific diagnostics

# Gradient 1
  derivs1 <- m5a.nested@optinfo$derivs
  sc_grad1 <- with(derivs1, solve(Hessian, gradient))
  max(abs(sc_grad1))
```

```
[1] 0.005623852
```

```
  kable(max(pmin(abs(sc_grad1), abs(derivs1$gradient))),
        col.names = "Gradient, method 1", booktabs = T)
```

Gradient, method 1
0.0024041

```
# Gradient 2
  dd <- update(m5a.nested, devFunOnly = TRUE)
  pars <- unlist(getME(m5a.nested, c("theta", "fixef")))
  grad2 <- grad(dd, pars)
  hess2 <- hessian(dd, pars)
  sc_grad2 <- solve(hess2, grad2)
  kable(max(pmin(abs(sc_grad2), abs(grad2))),
        col.names = "Gradient, method 2", booktabs = T)
```

Gradient, method 2
0.0024301

```
  ## The gradient cutoffs for Nelder Mead (nlopt), bobyqa and nlminwrap seem to
  ## be close to what I am getting.

# Check for singular fit
kable(isSingular(m5a.nested), col.names = "Singular fit?")
```

Singular fit?
FALSE

The model doesn't converge.

Putin v everyone else

```r
# Putin (1) vs everyone else (0), declined to answer NA
m4p.nested <- glmer(putin_else ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa"))

# Converges!


m5p.nested <- glmer(putin_else ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + orthodox_share + vdem_polyarchy_2022
                    + log(mad_gdppc_2018) + obl_type + export_share
                    + import_share + friendly_status + help + military_dummy
                    + log(dist) + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa",
                                           optCtrl = list(maxfun = 1e9)))


# Fit with all optimizers (loaded with other models)
m5p.allfit <- allFit(m5p.nested, maxfun = 1e9)
```

```
bobyqa : [OK]
Nelder_Mead : [OK]
nlminbwrap : [OK]
optimx.L-BFGS-B : [OK]
nloptwrap.NLOPT_LN_NELDERMEAD : [OK]
nloptwrap.NLOPT_LN_BOBYQA : [OK]
```

```r
# Convergence results

  ## Export models
  m5p.allfit_OK <- m5p.allfit[sapply(m5p.allfit, is, "merMod")]

  ## Generate warnings encountered
  data.frame(lapply(m5p.allfit_OK, function(x) x@optinfo$conv$lme4$messages)) |>
    pivot_longer(everything(), names_to = "Method",
                 values_to = "Estimation result") |>
    arrange(`Method`, `Estimation result`) |>
    distinct() |>
    mutate(`Method` = if_else(lag(`Method`) != `Method` | is.na(lag(`Method`)),
                              `Method`, "")) |>
    kable(booktabs = T,
          caption = paste("Convergence results for Answer/non-Answer dichotomy,",
                          "ME with level 2 variables and all optimizers")) |>
    column_spec(1, width = "7cm") |>
    kable_styling(latex_options = c("scale_down"))
```

Table 6: Convergence results for Answer/non-Answer dichotomy, ME with level 2 v
and all optimizers

Method	Estimation result
Nelder_Mead	Model failed to converge with max|grad| = 0.04390
bobyqa	Model failed to converge with max|grad| = 0.00486
nlminbwrap	Model failed to converge with max|grad| = 0.01989
nloptwrap.NLOPT_LN_BOBYQA	Model failed to converge with max|grad| = 0.02777
nloptwrap.NLOPT_LN_NELDERMEAD	Model failed to converge with max|grad| = 0.02406
optimx.L.BFGS.B	Model failed to converge with max|grad| = 0.08183

```
# Log-Likelihoods
(lliks <- sort(sapply(m5p.allfit_OK, logLik))) |>
  kable(col.names = "Log-likelihood", booktabs = T, digits = 3)
```

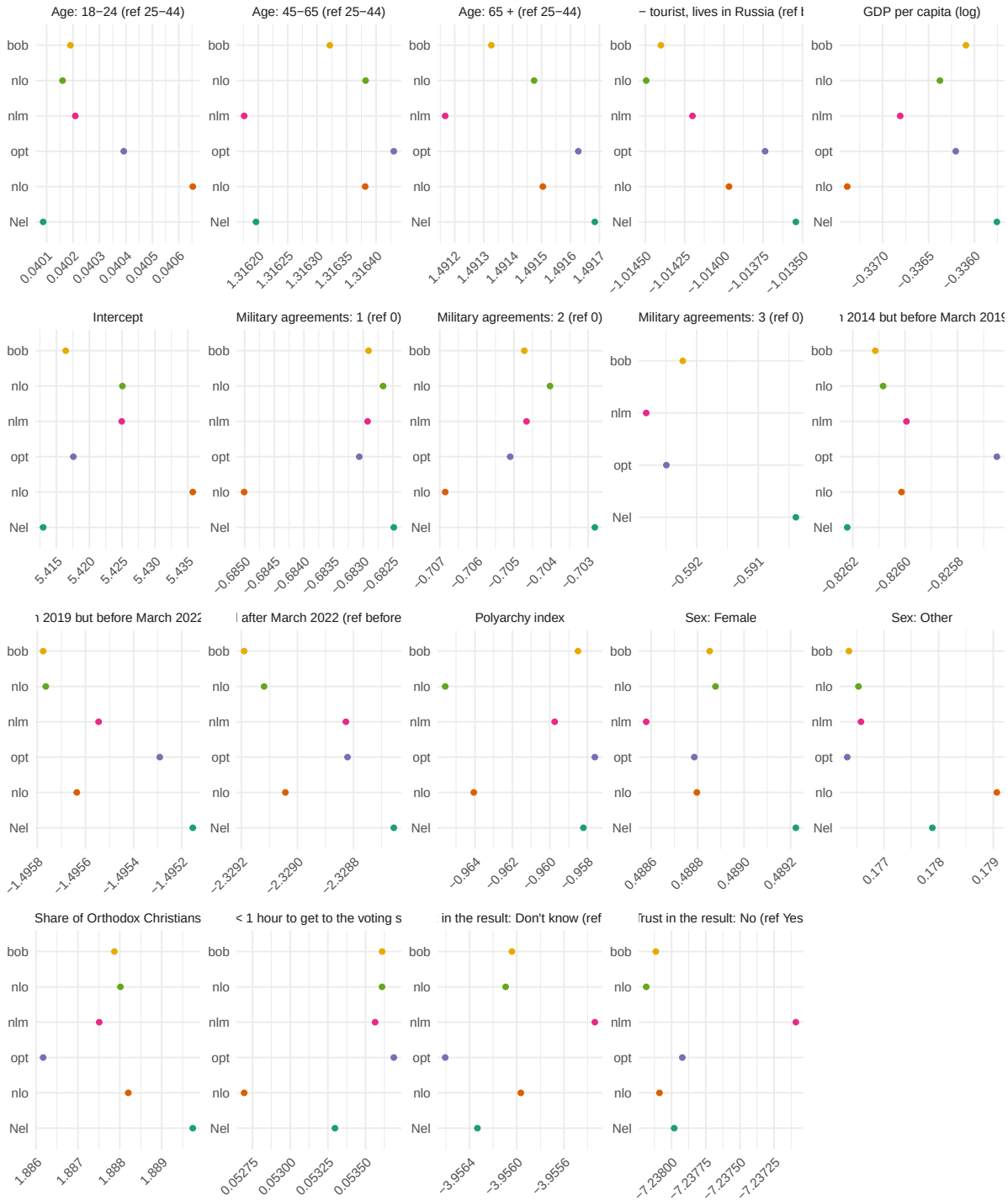
	Log-likelihood
Nelder_Mead	-3178.423
nloptwrap.NLOPT_LN_BOBYQA	-3178.423
optimx.L-BFGS-B	-3178.423
nlminbwrap	-3178.423
nloptwrap.NLOPT_LN_NELDERMEAD	-3178.423
bobyqa	-3178.423

```
# Coefficients from different optimizers

  ## Export fixef and melt into single dataframe
  models <- levels(melt(t(sapply(m5p.allfit_OK, fixef)))$Var1)
  m5p.allfit.fixef.m <- transform(melt(t(sapply(m5p.allfit_OK, fixef))),
                                  Var1 = factor(Var1, levels = names(lliks))) |>
    transmute(`Method` = Var1,
              `Coefficient` = value,
              `Variable` = case_when(
                Var2 == "(Intercept)" ~ "Intercept",
                Var2 == "sexFemale" ~ "Sex: Female",
                Var2 == "sexOther" ~ "Sex: Other",
                Var2 == "age_bin18-24" ~ "Age: 18-24 (ref 25-44)",
                Var2 == "age_bin45-64" ~ "Age: 45-65 (ref 25-44)",
                Var2 == "age_bin65+" ~ "Age: 65 + (ref 25-44)",
                Var2 == "time_to_vs.less_than_hourYes" ~
                  "Took < 1 hour to get to the voting station",
                Var2 == "out_of_Russia_timeAfter invasion" ~
                  "Moved after March 2022 (ref before 2014)",
                Var2 == "out_of_Russia_time2 - 5 years" ~
                  paste("Moved after March 2019 but before",
                        "March 2022 (ref before 2014)"),
                Var2 == "out_of_Russia_timeAfter annexation" ~
                  paste("Moved after March 2014 but before",
```

```
                "March 2019 (ref before 2014)"),
              Var2 == "out_of_Russia_timeTourist (lives in Russia)" ~
                paste("Didn't move - tourist, lives",
                      "in Russia (ref before 2014)"),
              Var2 == "result_trust_binDon't know" ~
                "Trust in the result: Don't know (ref Yes)",
              Var2 == "result_trust_binNo" ~
                "Trust in the result: No (ref Yes)",
              Var2 == "orthodox_share" ~ "Share of Orthodox Christians",
              Var2 == "vdem_polyarchy_2022" ~ "Polyarchy index",
              Var2 == "log(mad_gdppc_2018)" ~ "GDP per capita (log)",
              Var2 == "obl_type1" ~ "Military agreements: 1 (ref 0)",
              Var2 == "obl_type2" ~ "Military agreements: 2 (ref 0)",
              Var2 == "obl_type3" ~ "Military agreements: 3 (ref 0)",
              Var2 == "obl_type4" ~ "Military agreements: 4 (ref 0)",
              Var2 == "export_share" ~ "Export share",
              Var2 == "import_share" ~ "Import share",
              Var2 == "friendly_statusUnfriendly" ~
                "Unfriendly status (ref Neutral)",
              Var2 == "friendly_statusFriendly" ~
                "Friendly status (ref Neutral)",
              Var2 == "help" ~ "Help to Ukraine",
              Var2 == "military_dummy" ~ "Russian military presence",
              Var2 == "log(dist)" ~ "Geodesic distance (log)"),
            )

## Plot
ggplot(m5p.allfit.fixef.m[1:112, ],
         aes(x = `Coefficient`, y = `Method`, colour = `Method`)) +
    geom_point() +
    facet_wrap(~ `Variable`, scale = "free") +
    scale_colour_brewer(palette = "Dark2") +
    scale_y_discrete(breaks = models,
                     labels = substr(models, 1, 3)) +
    labs(x = "", y = "") +
    theme_minimal() +
    theme(legend.position = "none",
          axis.text.x = element_text(angle = 45, hjust = 1))
```




```
# Check m5p-specific diagnostics

# Gradient 1
```

```
  derivs1 <- m5p.nested@optinfo$derivs
  sc_grad1 <- with(derivs1, solve(Hessian, gradient))
  max(abs(sc_grad1))
```

```
[1] 0.02388267
```

```
  kable(max(pmin(abs(sc_grad1), abs(derivs1$gradient))),
        col.names = "Gradient, method 1", booktabs = T)
```

Gradient, method 1
0.013205

```
# Gradient 2
  dd <- update(m5p.nested, devFunOnly = TRUE)
  pars <- unlist(getME(m5p.nested, c("theta", "fixef")))
  grad2 <- grad(dd, pars)
  hess2 <- hessian(dd, pars)
  sc_grad2 <- solve(hess2, grad2)
  kable(max(pmin(abs(sc_grad2), abs(grad2))),
        col.names = "Gradient, method 2", booktabs = T)
```

Gradient, method 2
0.0131997

```
  ## The gradient cutoffs for Nelder Mead (nlopt), bobyqa and nlminwrap seem to
  ## be close to what I am getting.

# Check for singular fit
kable(isSingular(m5p.nested), col.names = "Singular fit?") # Nope, no singular fit
```

Singular fit?
FALSE

Non-systemic v systemic opposition

```
# Non-systemic - Davankov or Spoiled (1) vs systemic - Haritonov, Slutsky (0)
# opposition, declined to answer and Putin are NA
m4s.nested <- glmer(nonsys_sys ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa"))

# Converges
```

```
m5s.nested <- glmer(nonsys_sys ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + orthodox_share + vdem_polyarchy_2022
                    + log(mad_gdppc_2018) + obl_type + export_share
                    + import_share + friendly_status  + help + military_dummy
                    + log(dist) + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa",
                                           optCtrl = list(maxfun = 1e9)))

# Singular fit!

# The predictors most likely to cause issues are obl_type and friendly_status
# as they are broadly (and correlated between themselves and other variables)
# defined dichotomous predictors. Remove them from the model and try again


m5s.red <- update(m5s.nested, ~ . - obl_type - friendly_status)

# Works great and no issues with convergence either
```

Davankov v spoiled

```
# Davankov (1) vs Spoiled (0) declined to answer, Haritonov, Slutsky and Putin
# are NA
m4d.nested <- glmer(davankov_spoiled ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa"))


m5d.nested <- glmer(davankov_spoiled ~ sex + age_bin + time_to_vs.less_than_hour
                    + out_of_Russia_time + result_trust_bin
                    + orthodox_share + vdem_polyarchy_2022
                    + log(mad_gdppc_2018) + obl_type + export_share
                    + import_share + friendly_status  + help + military_dummy
                    + log(dist) + (1 | countryname_en),
                    data = nested_me_data, family = binomial,
                    control = glmerControl(optimizer = "bobyqa",
                                           optCtrl = list(maxfun = 1e9)))


m5d.allfit <- allFit(m5d.nested, maxfun = 1e9)
```

```
bobyqa : [OK]
Nelder_Mead : [OK]
nlminbwrap : [OK]
optimx.L-BFGS-B : [OK]
nloptwrap.NLOPT_LN_NELDERMEAD : [OK]
nloptwrap.NLOPT_LN_BOBYQA : [OK]
```

```
# Convergence results

  ## Export models
  m5d.allfit_OK <- m5d.allfit[sapply(m5d.allfit, is, "merMod")]

  ## Generate warnings encountered
  data.frame(lapply(m5d.allfit_OK, function(x) x@optinfo$conv$lme4$messages)) |>
    pivot_longer(everything(), names_to = "Method",
                 values_to = "Estimation result") |>
    arrange(`Method`, `Estimation result`) |>
    distinct() |>
    mutate(`Method` = if_else(lag(`Method`) != `Method` | is.na(lag(`Method`)),
                              `Method`, "")) |>
    kable(booktabs = T,
          caption = paste("Convergence results for Answer/non-Answer dichotomy,",
                          "ME with level 2 variables and all optimizers"))|>
    column_spec(1, width = "7cm") |>
    kable_styling(latex_options = c("scale_down"))
```

Table 11: Convergence results for Answer/non-Answer dichotomy, ME with level 2 va and all optimizers

Method	Estimation result
Nelder_Mead	Model failed to converge with max|grad| = 0.42524
bobyqa	Model failed to converge with max|grad| = 0.01578
nlminbwrap	Model failed to converge with max|grad| = 1.66793
nloptwrap.NLOPT_LN_BOBYQA	Model failed to converge with max|grad| = 0.06780
nloptwrap.NLOPT_LN_NELDERMEAD	Model failed to converge with max|grad| = 0.08116
optimx.L.BFGS.B	Model failed to converge with max|grad| = 0.06821

```
# Log-Likelihoods
(lliks <- sort(sapply(m5d.allfit_OK, logLik))) |>
  kable(col.names = "Log-likelihood", booktabs = T, digits = 3)
```

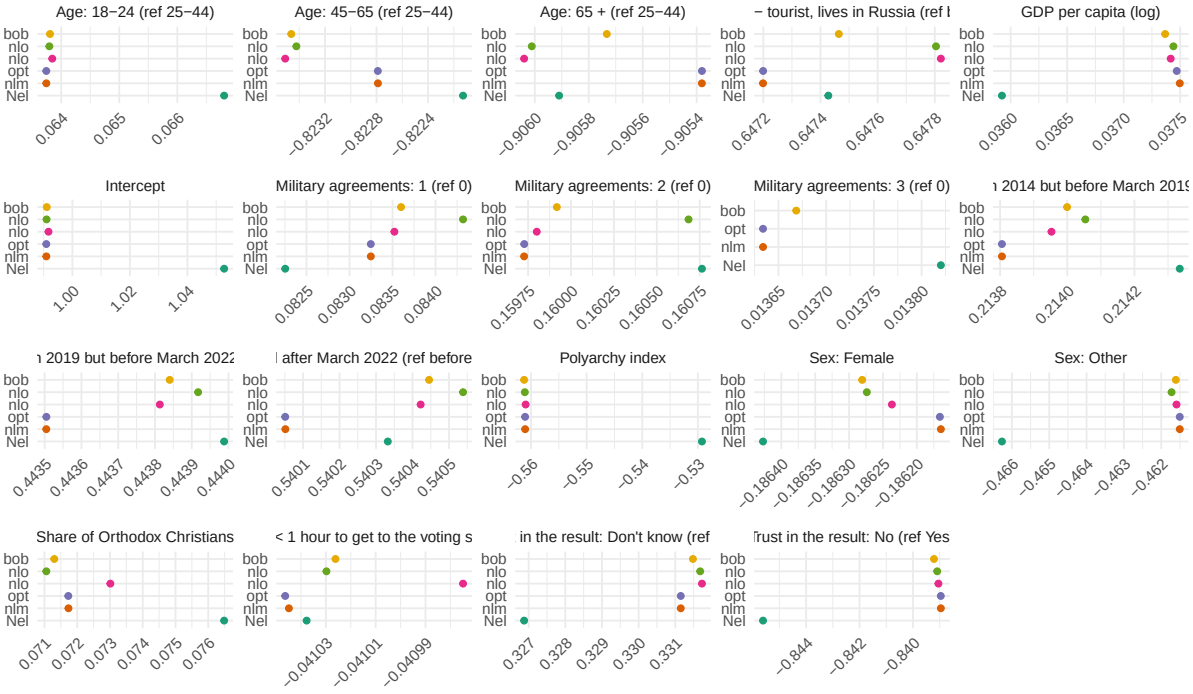
	Log-likelihood
Nelder_Mead	-20537.76
nlminbwrap	-20537.73
optimx.L-BFGS-B	-20537.73
nloptwrap.NLOPT_LN_BOBYQA	-20537.73
nloptwrap.NLOPT_LN_NELDERMEAD	-20537.73
bobyqa	-20537.73

```
# Coefficients from different optimizers

  ## Export fixef and melt into single dataframe
```

```r
models <- levels(melt(t(sapply(m5d.allfit_OK, fixef)))$Var1)
m5d.allfit.fixef.m <- transform(melt(t(sapply(m5d.allfit_OK, fixef))),
                                Var1 = factor(Var1, levels = names(lliks))) |>
  transmute(`Method` = Var1,
            `Coefficient` = value,
            `Variable` = case_when(
              Var2 == "(Intercept)" ~ "Intercept",
              Var2 == "sexFemale" ~ "Sex: Female",
              Var2 == "sexOther" ~ "Sex: Other",
              Var2 == "age_bin18-24" ~ "Age: 18-24 (ref 25-44)",
              Var2 == "age_bin45-64" ~ "Age: 45-65 (ref 25-44)",
              Var2 == "age_bin65+" ~ "Age: 65 + (ref 25-44)",
              Var2 == "time_to_vs.less_than_hourYes" ~
                "Took < 1 hour to get to the voting station",
              Var2 == "out_of_Russia_timeAfter invasion" ~
                "Moved after March 2022 (ref before 2014)",
              Var2 == "out_of_Russia_time2 - 5 years" ~
                paste("Moved after March 2019 but before",
                      "March 2022 (ref before 2014)"),
              Var2 == "out_of_Russia_timeAfter annexation" ~
                paste("Moved after March 2014 but before",
                      "March 2019 (ref before 2014)"),
              Var2 == "out_of_Russia_timeTourist (lives in Russia)" ~
                paste("Didn't move - tourist, lives",
                      "in Russia (ref before 2014)"),
              Var2 == "result_trust_binDon't know" ~
                "Trust in the result: Don't know (ref Yes)",
              Var2 == "result_trust_binNo" ~
                "Trust in the result: No (ref Yes)",
              Var2 == "orthodox_share" ~ "Share of Orthodox Christians",
              Var2 == "vdem_polyarchy_2022" ~ "Polyarchy index",
              Var2 == "log(mad_gdppc_2018)" ~ "GDP per capita (log)",
              Var2 == "obl_type1" ~ "Military agreements: 1 (ref 0)",
              Var2 == "obl_type2" ~ "Military agreements: 2 (ref 0)",
              Var2 == "obl_type3" ~ "Military agreements: 3 (ref 0)",
              Var2 == "obl_type4" ~ "Military agreements: 4 (ref 0)",
              Var2 == "export_share" ~ "Export share",
              Var2 == "import_share" ~ "Import share",
              Var2 == "friendly_statusUnfriendly" ~
                "Unfriendly status (ref Neutral)",
              Var2 == "friendly_statusFriendly" ~
                "Friendly status (ref Neutral)",
              Var2 == "help" ~ "Help to Ukraine",
              Var2 == "military_dummy" ~ "Russian military presence",
              Var2 == "log(dist)" ~ "Geodesic distance (log)"),
            )

## Plot
ggplot(m5d.allfit.fixef.m[1:112, ],
         aes(x = `Coefficient`, y = `Method`, colour = `Method`)) +
    geom_point() +
    facet_wrap(~ `Variable`, scale = "free") +
    scale_colour_brewer(palette = "Dark2") +
    scale_y_discrete(breaks = models,
                     labels = substr(models, 1, 3)) +
    labs(x = "", y = "") +
    theme_minimal() +
    theme(legend.position = "none",
          axis.text.x = element_text(angle = 45, hjust = 1))
```




```
# Check m5d-specific diagnostics

# Gradient 1
  derivs1 <- m5d.nested@optinfo$derivs
  sc_grad1 <- with(derivs1, solve(Hessian, gradient))
  max(abs(sc_grad1))
```

```
[1] 0.004068683
```

```
  kable(max(pmin(abs(sc_grad1), abs(derivs1$gradient))),
        col.names = "Gradient, method 1", booktabs = T)
```

Gradient, method 1
0.0040687

```
# Gradient 2
  dd <- update(m5d.nested, devFunOnly = TRUE)
  pars <- unlist(getME(m5d.nested, c("theta", "fixef")))
  grad2 <- grad(dd, pars)
  hess2 <- hessian(dd, pars)
  sc_grad2 <- solve(hess2, grad2)
  kable(max(pmin(abs(sc_grad2), abs(grad2))),
        col.names = "Gradient, method 2", booktabs = T)
```

Gradient, method 2
0.0039487

```
  ## The gradient cutoffs for Nelder Mead (nlopt), bobyqa and nlminwrap seem to
  ## be close to what I am getting.

# Check for singular fit
kable(isSingular(m5d.nested), col.names = "Singular fit?") # Nope, no singular fit
```

Singular fit?
FALSE

```
save(list = c("m5a.nested", "m5p.nested", "m5s.nested", "m5s.red", "m5d.nested"),
     file = "nlme_bobyqa.RData")

save(list = c("m4a.nested", "m4p.nested", "m4s.nested", "m4d.nested"),
     file = "feme_bobyqa.RData")

save(list = c("m5a.allfit", "m5p.allfit", "m5d.allfit"),
     file = "me_allfit.RData")


resizebox.stargazer(m4a.nested, m4p.nested, m4s.nested, m4d.nested,
          title = "Mixed effects models, level 1", header = F,
          dep.var.labels = c("Declined to answer vs answer",
                             "Putin vs everyone else",
                             "Non-systemic vs systemic opposition",
                             "Davankov vs Spoiled"),
          tab.height = "\\textheight", tab.width= "\\textwidth")



m3.answer <- models(m3.nested.fe, 1)
m3.putin <- models(m3.nested.fe, 2)
m3.nonsys <- models(m3.nested.fe, 3)
m3.davankov <- models(m3.nested.fe, 4)


resizebox.stargazer(m4a.nested, m3.answer, m4p.nested, m3.putin,
          title = "Mixed effects models, comparison I", header = F,
          omit = "as.factor",
          dep.var.labels = c("Declined to answer vs answer",
                             "Declined to answer vs answer",
                             "Putin vs everyone else",
                             "Putin vs everyone else"
                             ),
          tab.height = "\\textheight", tab.width= "\\textwidth")



resizebox.stargazer(m4s.nested, m3.nonsys, m4d.nested, m3.davankov,
          title = "Mixed effects models, comparison II", header = F,
          omit = "as.factor",
```

Table 16: Mixed effects models, level 1

	Dependent variable:			
	Declined to answer vs answer	Putin vs everyone else	Non-systemic vs systemic opposition	Davankov vs Spoiled
	(1)	(2)	(3)	(4)
sexFemale	0.275***	0.482***	0.022	−0.199***
	(0.044)	(0.071)	(0.056)	(0.024)
sexOther	0.064	0.171	−0.375	−0.470***
	(0.237)	(0.368)	(0.296)	(0.144)
age_bin18-24	−0.003	0.026	−0.095	0.062*
	(0.081)	(0.124)	(0.086)	(0.037)
age_bin45-64	0.180***	1.322***	−0.302***	−0.826***
	(0.059)	(0.086)	(0.087)	(0.039)
age_bin65+	0.170**	1.507***	−0.957***	−0.931***
	(0.077)	(0.131)	(0.155)	(0.106)
time_to_vs.less_than_hourYes	0.376***	0.094	−0.099	−0.034
	(0.052)	(0.081)	(0.061)	(0.026)
out_of_Russia_time2 - 5 years	−0.207***	−1.480***	0.409***	0.454***
	(0.075)	(0.109)	(0.091)	(0.042)
out_of_Russia_timeAfter annexation	−0.159**	−0.806***	0.296***	0.219***
	(0.080)	(0.120)	(0.102)	(0.045)
out_of_Russia_timeAfter invasion	−0.359***	−2.330***	0.766***	0.565***
	(0.069)	(0.101)	(0.084)	(0.040)
out_of_Russia_timeTourist (lives in Russia)	−0.039	−0.975***	0.041	0.652***
	(0.096)	(0.143)	(0.144)	(0.087)
result_trust_binDon't know	0.499***	−3.960***	0.718***	0.387***
	(0.082)	(0.109)	(0.127)	(0.139)
result_trust_binNo	−1.328***	−7.218***	1.903***	−0.806***
	(0.060)	(0.101)	(0.094)	(0.105)
Constant	−2.658***	1.992***	1.267***	1.558***
	(0.123)	(0.158)	(0.123)	(0.117)
Observations	53,824	51,202	42,363	40,946
Log Likelihood	−9,143.189	−3,369.086	−5,864.162	−22,658.160
Akaike Inf. Crit.	18,314.380	6,766.172	11,756.320	45,344.320
Bayesian Inf. Crit.	18,438.890	6,889.982	11,877.480	45,465.000

Note: *p<0.1; **p<0.05; ***p<0.01

Table 17: Mixed effects models, comparison I

	Dependent variable:			
	Declined to answer vs answer	Declined to answer vs answer	Putin vs everyone else	Putin vs everyone else
	generalized linear mixed-effects	*logistic*	*generalized linear mixed-effects*	*logistic*
	(1)	(2)	(3)	(4)
sexFemale	0.275***	0.275***	0.482***	0.481***
	(0.044)	(0.044)	(0.071)	(0.072)
sexOther	0.064	0.039	0.171	0.208
	(0.237)	(0.240)	(0.368)	(0.369)
age_bin18-24	−0.003	−0.008	0.026	0.019
	(0.081)	(0.082)	(0.124)	(0.126)
age_bin45-64	0.180***	0.172***	1.322***	1.304***
	(0.059)	(0.059)	(0.086)	(0.087)
age_bin65+	0.170**	0.161**	1.507***	1.501***
	(0.077)	(0.078)	(0.131)	(0.132)
time_to_vs.less_than_hourYes	0.376***	0.310***	0.094	0.071
	(0.052)	(0.055)	(0.081)	(0.085)
out_of_Russia_time2 - 5 years	−0.207***	−0.217***	−1.480***	−1.467***
	(0.075)	(0.075)	(0.109)	(0.110)
out_of_Russia_timeAfter annexation	−0.159**	−0.179**	−0.806***	−0.798***
	(0.080)	(0.081)	(0.120)	(0.121)
out_of_Russia_timeAfter invasion	−0.359***	−0.363***	−2.330***	−2.357***
	(0.069)	(0.069)	(0.101)	(0.103)
out_of_Russia_timeTourist (lives in Russia)	−0.039	−0.002	−0.975***	−0.997***
	(0.096)	(0.098)	(0.143)	(0.146)
result_trust_binDon't know	0.499***	0.521***	−3.960***	−3.955***
	(0.082)	(0.083)	(0.109)	(0.110)
result_trust_binNo	−1.328***	−1.293***	−7.218***	−7.204***
	(0.060)	(0.060)	(0.101)	(0.102)
Constant	−2.658***	−2.146***	1.992***	1.379***
	(0.123)	(0.144)	(0.158)	(0.247)
Observations	53,824	53,824	51,202	51,202
Log Likelihood	−9,143.189	−9,008.215	−3,369.086	−3,287.206
Akaike Inf. Crit.	18,314.380	18,166.430	6,766.172	6,724.412
Bayesian Inf. Crit.	18,438.890		6,889.982	
Note:				*p<0.1; **p<0.05; ***p<0.01

```
          dep.var.labels = c("Non-systemic vs systemic opposition",
                             "Non-systemic vs systemic opposition",
                             "Davankov vs Spoiled",
                             "Davankov vs Spoiled"
                             ),
          tab.height = "\\textheight", tab.width= "\\textwidth")
```

Table 18: Mixed effects models, comparison II

	Dependent variable:			
	Non-systemic vs systemic opposition	Non-systemic vs systemic opposition	Davankov vs Spoiled	Davankov vs Spoiled
	generalized linear mixed-effects	*logistic*	*generalized linear mixed-effects*	*logistic*
	(1)	(2)	(3)	(4)
sexFemale	0.022	0.019	−0.199***	−0.195***
	(0.056)	(0.057)	(0.024)	(0.024)
sexOther	−0.375	−0.371	−0.470***	−0.455***
	(0.296)	(0.301)	(0.144)	(0.146)
age_bin18-24	−0.095	−0.114	0.062*	0.072*
	(0.086)	(0.088)	(0.037)	(0.037)
age_bin45-64	−0.302***	−0.294***	−0.826***	−0.827***
	(0.087)	(0.088)	(0.039)	(0.039)
age_bin65+	−0.957***	−0.994***	−0.931***	−0.952***
	(0.155)	(0.159)	(0.106)	(0.107)
time_to_vs.less_than_hourYes	−0.099	−0.086	−0.034	−0.028
	(0.061)	(0.067)	(0.026)	(0.027)
out_of_Russia_time2 - 5 years	0.409***	0.419***	0.454***	0.438***
	(0.091)	(0.093)	(0.042)	(0.042)
out_of_Russia_timeAfter annexation	0.296***	0.299***	0.219***	0.213***
	(0.102)	(0.103)	(0.045)	(0.046)
out_of_Russia_timeAfter invasion	0.766***	0.820***	0.565***	0.539***
	(0.084)	(0.090)	(0.040)	(0.040)
out_of_Russia_timeTourist (lives in Russia)	0.041	0.134	0.652***	0.633***
	(0.144)	(0.150)	(0.087)	(0.088)
result_trust_binDon't know	0.718***	0.716***	0.387***	0.392***
	(0.127)	(0.129)	(0.139)	(0.141)
result_trust_binNo	1.903***	1.891***	−0.806***	−0.804***
	(0.094)	(0.095)	(0.105)	(0.106)
Constant	1.267***	1.223***	1.558***	1.401***
	(0.123)	(0.198)	(0.117)	(0.130)
Observations	42,363	42,363	40,946	40,946
Log Likelihood	−5,864.162	−5,809.709	−22,658.160	−22,553.850
Akaike Inf. Crit.	11,756.320	11,769.420	45,344.320	45,257.690
Bayesian Inf. Crit.	11,877.480		45,465.000	
Note:				*p<0.1; **p<0.05; ***p<0.01

```
resizebox.stargazer(m5a.nested, m5p.nested, m5s.red, m5d.nested,
          title = "Mixed effects models with level 2", header = F,
          omit = "as.factor",
          dep.var.labels = c("Declined to answer vs answer",
                             "Putin vs everyone else",
                             "Non-systemic vs systemic opposition",
                             "Davankov vs Spoiled"
```

```
                        ),
          tab.height = "\\textheight", tab.width= "\\textwidth")


resizebox.stargazer(m4a.nested, m5a.nested, m4p.nested, m5p.nested,
          title = "Mixed effects models with level 2, comparison I", header = F,
          omit = "as.factor",
          dep.var.labels = c("Declined to answer vs answer",
                             "Declined to answer vs answer",
                             "Putin vs everyone else",
                             "Putin vs everyone else"
                             ),
          tab.height = "\\textheight", tab.width= "\\textwidth")


resizebox.stargazer(m4s.nested, m5s.red, m4d.nested, m5d.nested,
          title = "Mixed effects models with level 2, comparison II", header = F,
          omit = "as.factor",
          dep.var.labels = c("Non-systemic vs systemic opposition",
                             "Non-systemic vs systemic opposition",
                             "Davankov vs Spoiled",
                             "Davankov vs Spoiled"
                             ),
          tab.height = "\\textheight", tab.width = "\\textwidth")
```

Table 19: Mixed effects models with level 2

	Dependent variable:			
	Declined to answer vs answer	Putin vs everyone else	Non-systemic vs systemic opposition	Davankov vs Spoiled
	(1)	(2)	(3)	(4)
sexFemale	0.258***	0.489***	0.015	−0.186***
	(0.045)	(0.073)	(0.059)	(0.025)
sexOther	0.071	0.176	−0.232	−0.462***
	(0.240)	(0.376)	(0.328)	(0.148)
age_bin18-24	0.036	0.040	−0.117	0.064*
	(0.083)	(0.125)	(0.088)	(0.038)
age_bin45-64	0.194***	1.316***	−0.299***	−0.823***
	(0.060)	(0.089)	(0.090)	(0.040)
age_bin65+	0.175**	1.491***	−0.930***	−0.906***
	(0.078)	(0.134)	(0.159)	(0.108)
time_to_vs.less_than_hourYes	0.355***	0.054	−0.081	−0.041
	(0.054)	(0.084)	(0.065)	(0.027)
out_of_Russia_time2 - 5 years	−0.175**	−1.496***	0.402***	0.444***
	(0.076)	(0.111)	(0.093)	(0.042)
out_of_Russia_timeAfter annexation	−0.134*	−0.826***	0.318***	0.214***
	(0.081)	(0.121)	(0.103)	(0.045)
out_of_Russia_timeAfter invasion	−0.351***	−2.329***	0.817***	0.540***
	(0.071)	(0.103)	(0.090)	(0.040)
out_of_Russia_timeTourist (lives in Russia)	−0.018	−1.014***	0.148	0.647***
	(0.099)	(0.148)	(0.153)	(0.090)
result_trust_binDon't know	0.551***	−3.956***	0.700***	0.331**
	(0.084)	(0.111)	(0.133)	(0.146)
result_trust_binNo	−1.355***	−7.238***	1.910***	−0.839***
	(0.062)	(0.103)	(0.098)	(0.111)
orthodox_share	−0.472	1.888***	−0.360**	0.071
	(0.468)	(0.412)	(0.142)	(0.163)
vdem_polyarchy_2022	0.328	−0.959	0.532**	−0.561**
	(0.668)	(0.674)	(0.250)	(0.233)
log(mad_gdppc_2018)	−0.280	−0.336*	0.036	0.037
	(0.174)	(0.176)	(0.088)	(0.072)
obl_type1	−0.412	−0.683		0.084
	(0.471)	(0.454)		(0.162)
obl_type2	−0.900*	−0.705		0.160
	(0.507)	(0.485)		(0.171)
obl_type3	−0.653	−0.592		0.014
	(0.463)	(0.427)		(0.162)
obl_type4	−0.826	0.149		−0.132
	(0.814)	(0.739)		(0.278)
export_share	−0.174***	−0.061	0.030	0.018
	(0.062)	(0.058)	(0.024)	(0.016)
import_share	0.217***	0.123**	−0.020	−0.018
	(0.063)	(0.056)	(0.020)	(0.018)
friendly_statusUnfriendly	0.622	0.103		0.149
	(0.819)	(0.794)		(0.284)
friendly_statusFriendly	0.430	−0.279		0.264
	(0.480)	(0.466)		(0.183)
help	−1.003**	−0.599	−0.124	−0.255
	(0.476)	(0.532)	(0.194)	(0.196)
military_dummy	0.085	−1.367**	0.224	0.254
	(0.728)	(0.678)	(0.195)	(0.264)
log(dist)	−0.386**	0.212	−0.150***	0.074
	(0.151)	(0.144)	(0.057)	(0.050)
Constant	3.842*	5.416***	1.739*	0.991
	(1.965)	(2.091)	(1.051)	(0.907)
Observations	48,964	46,494	37,827	36,523
Log Likelihood	−8,472.302	−3,178.423	−5,342.410	−20,537.730
Akaike Inf. Crit.	17,000.600	6,412.846	10,728.820	41,131.460
Bayesian Inf. Crit.	17,246.970	6,657.764	10,916.720	41,369.610

Note: *p<0.1; **p<0.05; ***p<0.01

Table 20: Mixed effects models with level 2, comparison I

	Dependent variable:			
	Declined to answer vs answer		Declined to answer vs answer	
	(1)	(2)	(3)	(4)
sexFemale	0.275***	0.258***	0.482***	0.489***
	(0.044)	(0.045)	(0.071)	(0.073)
sexOther	0.064	0.071	0.171	0.176
	(0.237)	(0.240)	(0.368)	(0.376)
age_bin18-24	−0.003	0.036	0.026	0.040
	(0.081)	(0.083)	(0.124)	(0.125)
age_bin45-64	0.180***	0.194***	1.322***	1.316***
	(0.059)	(0.060)	(0.086)	(0.089)
age_bin65+	0.170**	0.175**	1.507***	1.491***
	(0.077)	(0.078)	(0.131)	(0.134)
time_to_vs.less_than_hourYes	0.376***	0.355***	0.094	0.054
	(0.052)	(0.054)	(0.081)	(0.084)
out_of_Russia_time2 - 5 years	−0.207***	−0.175**	−1.480***	−1.496***
	(0.075)	(0.076)	(0.109)	(0.111)
out_of_Russia_timeAfter annexation	−0.159**	−0.134*	−0.806***	−0.826***
	(0.080)	(0.081)	(0.120)	(0.121)
out_of_Russia_timeAfter invasion	−0.359***	−0.351***	−2.330***	−2.329***
	(0.069)	(0.071)	(0.101)	(0.103)
out_of_Russia_timeTourist (lives in Russia)	−0.039	−0.018	−0.975***	−1.014***
	(0.096)	(0.099)	(0.143)	(0.148)
result_trust_binDon't know	0.499***	0.551***	−3.960***	−3.956***
	(0.082)	(0.084)	(0.109)	(0.111)
result_trust_binNo	−1.328***	−1.355***	−7.218***	−7.238***
	(0.060)	(0.062)	(0.101)	(0.103)
orthodox_share		−0.472		1.888***
		(0.468)		(0.412)
vdem_polyarchy_2022		0.328		−0.959
		(0.668)		(0.674)
log(mad_gdppc_2018)		−0.280		−0.336*
		(0.174)		(0.176)
obl_type1		−0.412		−0.683
		(0.471)		(0.454)
obl_type2		−0.900*		−0.705
		(0.507)		(0.485)
obl_type3		−0.653		−0.592
		(0.463)		(0.427)
obl_type4		−0.826		0.149
		(0.814)		(0.739)
export_share		−0.174***		−0.061
		(0.062)		(0.058)
import_share		0.217***		0.123**
		(0.063)		(0.056)
friendly_statusUnfriendly		0.622		0.103
		(0.819)		(0.794)
friendly_statusFriendly		0.430		−0.279
		(0.480)		(0.466)
help		−1.003**		−0.599
		(0.476)		(0.532)
military_dummy		0.085		−1.367**
		(0.728)		(0.678)
log(dist)		−0.386**		0.212
		(0.151)		(0.144)
Constant	−2.658***	3.842*	1.992***	5.416***
	(0.123)	(1.965)	(0.158)	(2.091)
Observations	53,824	48,964	51,202	46,494
Log Likelihood	−9,143.189	−8,472.302	−3,369.086	−3,178.423
Akaike Inf. Crit.	18,314.380	17,000.600	6,766.172	6,412.846
Bayesian Inf. Crit.	18,438.890	17,246.970	6,889.982	6,657.764
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 21: Mixed effects models with level 2, comparison II

	Dependent variable:			
	Non-systemic vs systemic opposition		Non-systemic vs systemic opposition	
	(1)	(2)	(3)	(4)
sexFemale	0.022	0.015	−0.199***	−0.186***
	(0.056)	(0.059)	(0.024)	(0.025)
sexOther	−0.375	−0.232	−0.470***	−0.462***
	(0.296)	(0.328)	(0.144)	(0.148)
age_bin18-24	−0.095	−0.117	0.062*	0.064*
	(0.086)	(0.088)	(0.037)	(0.038)
age_bin45-64	−0.302***	−0.299***	−0.826***	−0.823***
	(0.087)	(0.090)	(0.039)	(0.040)
age_bin65+	−0.957***	−0.930***	−0.931***	−0.906***
	(0.155)	(0.159)	(0.106)	(0.108)
time_to_vs.less_than_hourYes	−0.099	−0.081	−0.034	−0.041
	(0.061)	(0.065)	(0.026)	(0.027)
out_of_Russia_time2 - 5 years	0.409***	0.402***	0.454***	0.444***
	(0.091)	(0.093)	(0.042)	(0.042)
out_of_Russia_timeAfter annexation	0.296***	0.318***	0.219***	0.214***
	(0.102)	(0.103)	(0.045)	(0.045)
out_of_Russia_timeAfter invasion	0.766***	0.817***	0.565***	0.540***
	(0.084)	(0.090)	(0.040)	(0.040)
out_of_Russia_timeTourist (lives in Russia)	0.041	0.148	0.652***	0.647***
	(0.144)	(0.153)	(0.087)	(0.090)
result_trust_binDon't know	0.718***	0.700***	0.387***	0.331**
	(0.127)	(0.133)	(0.139)	(0.146)
result_trust_binNo	1.903***	1.910***	−0.806***	−0.839***
	(0.094)	(0.098)	(0.105)	(0.111)
orthodox_share		−0.360**		0.071
		(0.142)		(0.163)
vdem_polyarchy_2022		0.532**		−0.561**
		(0.250)		(0.233)
log(mad_gdppc_2018)		0.036		0.037
		(0.088)		(0.072)
obl_type1				0.084
				(0.162)
obl_type2				0.160
				(0.171)
obl_type3				0.014
				(0.162)
obl_type4				−0.132
				(0.278)
export_share		0.030		0.018
		(0.024)		(0.016)
import_share		−0.020		−0.018
		(0.020)		(0.018)
friendly_statusUnfriendly				0.149
				(0.284)
friendly_statusFriendly				0.264
				(0.183)
help		−0.124		−0.255
		(0.194)		(0.196)
military_dummy		0.224		0.254
		(0.195)		(0.264)
log(dist)		−0.150***		0.074
		(0.057)		(0.050)
Constant	1.267***	1.739*	1.558***	0.991
	(0.123)	(1.051)	(0.117)	(0.907)
Observations	42,363	37,827	40,946	36,523
Log Likelihood	−5,864.162	−5,342.410	−22,658.160	−20,537.730
Akaike Inf. Crit.	11,756.320	10,728.820	45,344.320	41,131.460
Bayesian Inf. Crit.	11,877.480	10,916.720	45,465.000	41,369.610

Note: *p<0.1; **p<0.05; ***p<0.01