Räumliche & Zeitliche Ausbreitung von Corona

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```
df4 <- read.csv("df4.csv", header = TRUE, sep = ",")
df4_pan<-pdata.frame(df4,index=c("district","week"))
```

Hotspot Variable definiert als: doppelt so hoch wie die Inzidenz zur Vorwoche & doppelt so hoch wie die Inzidenz der Nachbarorte

Hotspotnb Variable deifiniert als: mindestens ein Nachbarort gilt als Hotspot

```
table(df4_pan$hotspot)
```

```
##
## FALSE  TRUE
## 13769   439
```

```
table(df4_pan$hotspotnb)
```

```
##
## FALSE  TRUE
## 13266   942
```

Entscheidung zwischen random effects und fixed effects, mit Hilfe des Hausman-Tests:

```
fe.step0 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
              + I(log(density)*lag(inzidenz, 1))
              + factor(week)
               , data =df4_pan, model = "within")

re.step0 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
    + I(log(density)*lag(inzidenz, 1))
    + factor(week)
    , data =df4_pan, model = "random")

phtest(fe.step0, re.step0)
```

```
##
##  Hausman Test
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## chisq = 117.28, df = 149, p-value = 0.9743
## alternative hypothesis: one model is inconsistent
```

p-value>0.05, deswegen random effects.

Schrittweise Modellselektion mit Hilfe von F-Test für panel-data:

```
re.step0 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1))
                + factor(week)
                , data =df4_pan, model = "random")

#summary(re.step0)

re.step1 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step1, re.step0)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 60.859, df1 = 1, df2 = 13961, p-value = 6.566e-15
## alternative hypothesis: significant effects
```

```
## include: hotspot*inzidenz

re.step1.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  + I(hotspotnb * lag(weightednbinz, 1))
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step1.5, re.step1)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 7.807, df1 = 1, df2 = 13960, p-value = 0.005212
## alternative hypothesis: significant effects
```

```
## include: hotspotnb*inzidenz

re.step2 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1))
                + rate_zweitimpf
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step2, re.step1.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.39688, df1 = 1, df2 = 13959, p-value = 0.5287
## alternative hypothesis: significant effects
```

```
## reject rate_zweitimpf


re.step2.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  + I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step2.5, re.step1.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 4.7866, df1 = 1, df2 = 13959, p-value = 0.0287
## alternative hypothesis: significant effects
```

```
## include rate_zweitimpf * hotspot


re.step3 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step3, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 4.5389, df1 = 1, df2 = 13958, p-value = 0.03315
## alternative hypothesis: significant effects
```

```
## include A60.79.Anteil


re.step4 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil + A35.59.Anteil
                + factor(week)
```

```r
                , data =df4_pan, model = "random")

pFtest(re.step4, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.8603, df1 = 1, df2 = 13957, p-value = 0.1726
## alternative hypothesis: significant effects
```

```r
re.step4.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                  + A35.59.Anteil
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step4.5, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.0067, df1 = 1, df2 = 13958, p-value = 0.3157
## alternative hypothesis: significant effects
```

```r
## reject A35.59.Anteil


re.step5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil + A15.34.Anteil
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step5, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.5696, df1 = 1, df2 = 13957, p-value = 0.2103
## alternative hypothesis: significant effects
```

```r
re.step5.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                  + A15.34.Anteil
                  + factor(week)
```

```r
                  , data =df4_pan, model = "random")

pFtest(re.step5, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 3.0544, df1 = 2, df2 = 13957, p-value = 0.04718
## alternative hypothesis: significant effects
```

```r
## Entweder / oder, beide Variablen sind nicht gleichzeitig signifikant.
## Wir nehmen zunächst A60.79.Anteil als Variable auf


re.step6 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil + A05.14.Anteil
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step6, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.3675, df1 = 1, df2 = 13957, p-value = 0.2423
## alternative hypothesis: significant effects
```

```r
re.step6.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                  + A05.14.Anteil
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step6.5, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.9082, df1 = 1, df2 = 13958, p-value = 0.1672
## alternative hypothesis: significant effects
```

```r
## reject A05.14.Anteil

re.step7 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
```

```r
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil + A00.04.Anteil
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step7, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.10739, df1 = 1, df2 = 13957, p-value = 0.7431
## alternative hypothesis: significant effects
```

```r
re.step7.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                  + A00.04.Anteil
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step7.5, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.1934, df1 = 1, df2 = 13958, p-value = 0.6601
## alternative hypothesis: significant effects
```

```r
## reject A00.04.Anteil

re.step8 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil + A80.Anteil
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step8, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.95362, df1 = 1, df2 = 13957, p-value = 0.3288
## alternative hypothesis: significant effects
```

```r
re.step8.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
```

```
                  + A80.Anteil
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step8.5, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.90693, df1 = 1, df2 = 13958, p-value = 0.3409
## alternative hypothesis: significant effects
```

```
## reject A80.Anteil


re.step9 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                + A60.79.Anteil + F.Anteil
                + factor(week)
                , data =df4_pan, model = "random")

pFtest(re.step9, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.87265, df1 = 1, df2 = 13957, p-value = 0.3502
## alternative hypothesis: significant effects
```

```
re.step9.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                  + M.Anteil
                  + factor(week)
                  , data =df4_pan, model = "random")

pFtest(re.step9.5, re.step2.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.014259, df1 = 1, df2 = 13958, p-value = 0.905
## alternative hypothesis: significant effects
```

```
## reject --- for F.Anteil, for M.Anteil as well
```

```r
re.step10 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil + rate_zweitimpf
                 + factor(week)
                 , data =df4_pan, model = "random")

pFtest(re.step10, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.23774, df1 = 1, df2 = 13957, p-value = 0.6259
## alternative hypothesis: significant effects
```

```r
## reject rate_zweitimpf

re.step11 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil + rate_drittimpf
                 + factor(week)
                 , data =df4_pan, model = "random")
pFtest(re.step11, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.7357, df1 = 1, df2 = 13957, p-value = 0.1877
## alternative hypothesis: significant effects
```

```r
re.step11.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                   + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                   + I(hotspotnb * lag(weightednbinz, 1)) + rate_drittimpf
                   + factor(week)
                   , data =df4_pan, model = "random")

pFtest(re.step11.5, re.step1.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 2.0971, df1 = 1, df2 = 13959, p-value = 0.1476
## alternative hypothesis: significant effects
```

```r
## reject rate_drittimpf

re.step12 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
```

```r
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil + rate_viertimpf
                 + factor(week)
                 , data =df4_pan, model = "random")
pFtest(re.step12, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.57954, df1 = 1, df2 = 13957, p-value = 0.4465
## alternative hypothesis: significant effects
```

```r
re.step12.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                   + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                   + I(hotspotnb * lag(weightednbinz, 1)) + rate_viertimpf
                   + factor(week)
                   , data =df4_pan, model = "random")

pFtest(re.step12.5, re.step1.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.84622, df1 = 1, df2 = 13959, p-value = 0.3576
## alternative hypothesis: significant effects
```

```r
## reject rate_viertimpf



re.step14 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 + I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil + I(rate_drittimpf * hotspot)
                 + factor(week)
                 , data =df4_pan, model = "random")

pFtest(re.step14, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.7056, df1 = 1, df2 = 13957, p-value = 0.1916
## alternative hypothesis: significant effects
```

```r
re.step14.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                   + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
```

```
                   + I(hotspotnb * lag(weightednbinz, 1)) + I(rate_drittimpf * hotspot)
                   + factor(week)
                   , data =df4_pan, model = "random")

pFtest(re.step14.5, re.step1.5)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 6.5117, df1 = 1, df2 = 13959, p-value = 0.01073
## alternative hypothesis: significant effects
```

```
## Entweder / oder zweitimpfung*hotspot oder drittimpfung*hotspot;
## beide ähnlich signifikant, drittimpf hatte einen kleineren p-value (0.01 zu 0.028)
## jedoch hat rate_drittimpf * hotspot extrem wenig Beobachtungen --> zweitimpfung*hotspot

re.step15 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 + I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil + I(A60.79.Anteil * rate_drittimpf)
                 + factor(week)
                 , data =df4_pan, model = "random")

pFtest(re.step15, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 3.0697, df1 = 1, df2 = 13957, p-value = 0.07978
## alternative hypothesis: significant effects
```

```
## soft reject A60.79.Anteil * rate_drittimpf; p value 0.08

re.step16 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 + I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil
                 + I(A15.34.Anteil * rate_drittimpf)
                 + factor(week)
                 , data =df4_pan, model = "random")

pFtest(re.step16, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 1.1033, df1 = 1, df2 = 13957, p-value = 0.2936
## alternative hypothesis: significant effects
```

```r
## reject A15.34.Anteil * rate_drittimpf

re.step17 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 + I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil
                 + I(A60.79.Anteil * hotspot)
                 + factor(week)
                 , data =df4_pan, model = "random")

pFtest(re.step17, re.step3)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 0.27796, df1 = 1, df2 = 13957, p-value = 0.5981
## alternative hypothesis: significant effects
```

```r
## reject of Age * hotspot (same conclusion for other age groups)

re.step18 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
                 + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                 +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
                 + A60.79.Anteil
                 , data =df4_pan, model = "random")

pFtest(re.step3, re.step18)
```

```
##
##  F test for individual effects
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## F = 130.4, df1 = 146, df2 = 13958, p-value < 2.2e-16
## alternative hypothesis: significant effects
```

```r
## factor(week) stays

#****
#*
#*
#*
#*
#*
#*
```

Testen ob Random Effects sinnvoll sind; ob Landkreise sich unterscheiden, mit Hilfe vom Breusch-Pagan Lagrange multiplier Test:

```r
pool <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
            + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
            +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
```

```r
            + A60.79.Anteil
            + factor(week)
            , data =df4_pan, model = "pooling")
plmtest(pool, type=c("bp"))
```

```
##
##  Lagrange Multiplier Test - (Breusch-Pagan)
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## chisq = 0.59669, df = 1, p-value = 0.4398
## alternative hypothesis: significant effects
```

Anhand des Tests ist pooling besser geeignet. Es konnte keinen signifikanten Unterschied zwischen den Landkreisen festgestellt werden.

Testen für cross-sectional dependence, mit Hilfe vom Breusch-Pagan LM test und Pasaran CD test:

```r
pcdtest(pool, test = c("lm"))
```

```
##
##  Breusch-Pagan LM test for cross-sectional dependence in panels
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *     lag(inzidenz, 1))
## chisq = 31433, df = 4560, p-value < 2.2e-16
## alternative hypothesis: cross-sectional dependence
```

```r
pcdtest(pool, test = c("cd"))
```

```
##
##  Pesaran CD test for cross-sectional dependence in panels
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *     lag(inzidenz, 1))
## z = -6.9756, p-value = 3.047e-12
## alternative hypothesis: cross-sectional dependence
```

Anhand der Test kann festgestellt werden, dass es cross-sectional independence gibt. Vermutlich, weil die Inzidenz der Nachbarorte im Modell enthalten ist.

Testen für serial correlation, mit Hilfe vom Breusch-Godfrey-Test:

```r
pbgtest(pool)
```

```
##
##  Breusch-Godfrey/Wooldridge test for serial correlation in panel models
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *  ...
## chisq = 440.72, df = 147, p-value < 2.2e-16
## alternative hypothesis: serial correlation in idiosyncratic errors
```

Anhand des Tests kann festgestellt werden, dass serial correlation vorhanden ist. Vermutlich, wegen der Inklusion vom Inzidenz der Vorwoche.

Testen für Stationärität, mit Hilfe vom Dickey-Fuller Test:

```r
adf.test(df4_pan$inzidenz, k=1)
```

```
## Warning in adf.test(df4_pan$inzidenz, k = 1): p-value smaller than printed
## p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  df4_pan$inzidenz
## Dickey-Fuller = -26.74, Lag order = 1, p-value = 0.01
## alternative hypothesis: stationary
```

Die Nullhypothese wird abgelehnt, Stationärität wird angenommen.

Testen für heteroskedasticity, mit Hilfe vom Breusch-Pagan Test:

```r
bptest(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1)
       + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
       +I(hotspotnb * lag(weightednbinz, 1)) + I(rate_zweitimpf * hotspot)
       + A60.79.Anteil
       + factor(week)
       + factor(district)
       , data =df4_pan, studentize = F)
```

```
##
##  Breusch-Pagan test
##
## data:  inzidenz ~ lag(inzidenz, 1) + lag(weightednbinz, 1) + I(log(density) *     lag(inzidenz, 1)) +
## BP = 1691614, df = 249, p-value < 2.2e-16
```

Nullhypothese wird abgelehnt, heteroskedasticity wird angenommen.

Die Parameter für Heteroskedastizität und serial-correlation korrigieren:

```r
coeftest(pool, vcovHC(pool, type="HC0"))
```

```
##
## t test of coefficients:
##
##                                         Estimate  Std. Error t value  Pr(>|t|)
## (Intercept)                          -9.0117e-04  1.1485e-02 -0.0785 0.9374589
## lag(inzidenz, 1)                      5.9661e-01  2.8962e-02 20.6001 < 2.2e-16
## lag(weightednbinz, 1)                 2.7351e-01  3.4736e-02  7.8738 3.692e-15
## I(log(density) * lag(inzidenz, 1))   -2.0009e-02  3.6553e-03 -5.4738 4.480e-08
## I(hotspot * lag(inzidenz, 1))         5.6233e-01  8.0820e-02  6.9578 3.611e-12
## I(hotspotnb * lag(weightednbinz, 1))  1.3104e-01  5.6719e-02  2.3103 0.0208862
## I(rate_zweitimpf * hotspot)          -1.6095e+02  4.6673e+01 -3.4483 0.0005657
## A60.79.Anteil                        -2.2597e+01  3.4750e+00 -6.5029 8.146e-11
## factor(week)3                        -1.1176e-02  2.3427e-02 -0.4770 0.6333351
## factor(week)4                        -5.0041e-03  1.3798e-02 -0.3627 0.7168653
## factor(week)5                         2.9737e-01  2.4748e-01  1.2016 0.2295407
## factor(week)6                         9.0973e-01  2.7422e-01  3.3175 0.0009105
```

```
## factor(week)7                          9.0010e+00  8.9248e-01 10.0854 < 2.2e-16
## factor(week)8                          2.7313e+01  2.3737e+00 11.5064 < 2.2e-16
## factor(week)9                          3.9066e+01  3.2123e+00 12.1615 < 2.2e-16
## factor(week)10                         3.8270e+01  4.4840e+00  8.5346 < 2.2e-16
## factor(week)11                         6.5753e-01  2.8758e+00  0.2286 0.8191537
## factor(week)12                        -3.4798e+00  2.3365e+00 -1.4893 0.1364233
## factor(week)13                         6.1419e-01  2.0995e+00  0.2925 0.7698809
## factor(week)14                        -1.5848e+00  1.0822e+00 -1.4644 0.1430952
## factor(week)15                         3.6572e+00  1.0182e+00  3.5917 0.0003296
## factor(week)16                         5.0275e+00  1.2679e+00  3.9652 7.370e-05
## factor(week)17                         3.0933e+00  1.0790e+00  2.8668 0.0041529
## factor(week)18                         3.3244e+00  8.3077e-01  4.0016 6.324e-05
## factor(week)19                         1.5893e+00  6.8484e-01  2.3207 0.0203161
## factor(week)20                         1.1775e+00  6.9641e-01  1.6908 0.0908952
## factor(week)21                         2.9574e+00  7.3346e-01  4.0322 5.556e-05
## factor(week)22                         3.4004e+00  7.1413e-01  4.7617 1.939e-06
## factor(week)23                         2.6698e+00  6.9662e-01  3.8325 0.0001274
## factor(week)24                         2.3733e+00  6.0173e-01  3.9441 8.048e-05
## factor(week)25                         2.3153e+00  5.4668e-01  4.2352 2.298e-05
## factor(week)26                         4.8562e+00  2.0667e+00  2.3498 0.0187987
## factor(week)27                         2.3300e+00  7.0601e-01  3.3002 0.0009687
## factor(week)28                         3.1253e+00  1.0587e+00  2.9521 0.0031611
## factor(week)29                         6.1303e+00  8.1393e-01  7.5317 5.315e-14
## factor(week)30                         7.2935e+00  9.3668e-01  7.7866 7.369e-15
## factor(week)31                         4.3369e+00  8.1046e-01  5.3511 8.881e-08
## factor(week)32                         6.2005e+00  1.0414e+00  5.9543 2.675e-09
## factor(week)33                         8.4535e+00  1.3754e+00  6.1463 8.146e-10
## factor(week)34                         7.5820e+00  1.0784e+00  7.0307 2.151e-12
## factor(week)35                         3.5048e+00  1.0884e+00  3.2200 0.0012847
## factor(week)36                         7.6030e+00  9.6693e-01  7.8630 4.023e-15
## factor(week)37                         1.5147e+01  1.4185e+00 10.6781 < 2.2e-16
## factor(week)38                         2.7147e+01  2.9592e+00  9.1737 < 2.2e-16
## factor(week)39                         4.8650e+01  3.6667e+00 13.2682 < 2.2e-16
## factor(week)40                         7.3034e+01  4.5917e+00 15.9055 < 2.2e-16
## factor(week)41                         6.7554e+01  5.5579e+00 12.1545 < 2.2e-16
## factor(week)42                         4.9316e+01  5.6592e+00  8.7143 < 2.2e-16
## factor(week)43                         4.7439e+01  5.6954e+00  8.3293 < 2.2e-16
## factor(week)44                         5.1096e+01  6.4872e+00  7.8763 3.619e-15
## factor(week)45                         4.4987e+01  5.8925e+00  7.6347 2.410e-14
## factor(week)46                         7.8654e+01  6.2124e+00 12.6608 < 2.2e-16
## factor(week)47                         5.8427e+01  6.2110e+00  9.4069 < 2.2e-16
## factor(week)48                         1.6695e+01  6.8016e+00  2.4546 0.0141153
## factor(week)49                         4.1716e+01  5.8130e+00  7.1763 7.521e-13
## factor(week)50                         5.0648e+01  6.0183e+00  8.4156 < 2.2e-16
## factor(week)51                         1.6262e+01  5.9346e+00  2.7401 0.0061490
## factor(week)52                         8.9251e+00  4.3740e+00  2.0405 0.0413205
## factor(week)53                         2.0753e+01  4.1154e+00  5.0427 4.647e-07
## factor(week)54                         1.3784e+01  4.0989e+00  3.3629 0.0007733
## factor(week)55                         3.2288e+00  2.6205e+00  1.2321 0.2179181
## factor(week)56                         2.1232e+01  3.5014e+00  6.0640 1.362e-09
## factor(week)57                         2.7468e+01  3.1429e+00  8.7396 < 2.2e-16
## factor(week)58                         3.0227e+01  3.5042e+00  8.6260 < 2.2e-16
## factor(week)59                         3.9338e+01  3.6332e+00 10.8274 < 2.2e-16
## factor(week)60                         5.0793e+01  4.4121e+00 11.5121 < 2.2e-16
```

```
## factor(week)61                       5.9795e+01  5.0422e+00 11.8589 < 2.2e-16
## factor(week)62                       3.5266e+01  5.0814e+00  6.9402 4.087e-12
## factor(week)63                       5.8222e+01  5.4241e+00 10.7340 < 2.2e-16
## factor(week)64                       7.0445e+01  6.5282e+00 10.7909 < 2.2e-16
## factor(week)65                       4.5052e+01  5.4120e+00  8.3246 < 2.2e-16
## factor(week)66                       6.2480e+00  5.8961e+00  1.0597 0.2893023
## factor(week)67                       1.3406e+01  4.5886e+00  2.9217 0.0034874
## factor(week)68                      -1.6316e+00  3.5306e+00 -0.4621 0.6439975
## factor(week)69                      -2.6179e+00  2.9064e+00 -0.9007 0.3677410
## factor(week)70                      -7.0906e+00  1.8409e+00 -3.8518 0.0001178
## factor(week)71                      -1.7739e+00  1.3865e+00 -1.2794 0.2007767
## factor(week)72                       3.9671e+00  1.3976e+00  2.8386 0.0045375
## factor(week)73                      -3.4783e+00  8.5053e-01 -4.0895 4.346e-05
## factor(week)74                       1.1533e+00  7.1372e-01  1.6159 0.1061445
## factor(week)75                       9.2127e-01  5.3935e-01  1.7081 0.0876380
## factor(week)76                       4.7664e+00  6.7199e-01  7.0930 1.375e-12
## factor(week)77                       7.1692e+00  1.1616e+00  6.1721 6.925e-10
## factor(week)78                       5.6607e+00  8.6608e-01  6.5360 6.539e-11
## factor(week)79                       5.3734e+00  8.1254e-01  6.6130 3.903e-11
## factor(week)80                       7.0720e+00  8.8855e-01  7.9590 1.867e-15
## factor(week)81                       1.6594e+01  1.4661e+00 11.3182 < 2.2e-16
## factor(week)82                       2.5144e+01  2.1397e+00 11.7508 < 2.2e-16
## factor(week)83                       4.0516e+01  2.9768e+00 13.6103 < 2.2e-16
## factor(week)84                       3.1421e+01  3.2534e+00  9.6579 < 2.2e-16
## factor(week)85                       2.9777e+01  3.4271e+00  8.6887 < 2.2e-16
## factor(week)86                       2.1588e+01  2.9760e+00  7.2542 4.253e-13
## factor(week)87                       1.7392e+01  3.2934e+00  5.2807 1.306e-07
## factor(week)88                       3.0541e+01  3.2500e+00  9.3971 < 2.2e-16
## factor(week)89                       2.8275e+01  3.6512e+00  7.7439 1.030e-14
## factor(week)90                       4.9107e+01  4.6963e+00 10.4564 < 2.2e-16
## factor(week)91                       1.0743e+02  7.4055e+00 14.5064 < 2.2e-16
## factor(week)92                       1.2962e+02  8.7415e+00 14.8275 < 2.2e-16
## factor(week)93                       1.5277e+02  1.0488e+01 14.5667 < 2.2e-16
## factor(week)94                       3.0370e+02  1.5475e+01 19.6256 < 2.2e-16
## factor(week)95                       2.2595e+02  1.8418e+01 12.2677 < 2.2e-16
## factor(week)96                       1.4685e+02  1.7916e+01  8.1966 2.687e-16
## factor(week)97                       5.1263e+01  1.9213e+01  2.6681 0.0076375
## factor(week)98                      -2.6543e-02  1.2914e+01 -0.0021 0.9983601
## factor(week)99                      -1.5683e+01  1.1541e+01 -1.3589 0.1742128
## factor(week)100                     -2.9233e+01  8.4989e+00 -3.4397 0.0005841
## factor(week)101                      4.4172e+01  6.2083e+00  7.1151 1.173e-12
## factor(week)102                      1.5443e+02  8.8428e+00 17.4642 < 2.2e-16
## factor(week)103                      2.9543e+02  1.4594e+01 20.2433 < 2.2e-16
## factor(week)104                      5.0643e+02  2.5789e+01 19.6375 < 2.2e-16
## factor(week)105                      7.2493e+02  4.1584e+01 17.4327 < 2.2e-16
## factor(week)106                      7.0498e+02  5.2167e+01 13.5139 < 2.2e-16
## factor(week)107                      6.0112e+02  5.5095e+01 10.9105 < 2.2e-16
## factor(week)108                      4.9856e+02  5.8412e+01  8.5353 < 2.2e-16
## factor(week)109                      3.6152e+02  4.8313e+01  7.4829 7.705e-14
## factor(week)110                      3.2144e+02  4.4359e+01  7.2464 4.505e-13
## factor(week)111                      9.4110e+02  4.4599e+01 21.1014 < 2.2e-16
## factor(week)112                      6.7835e+02  5.9251e+01 11.4488 < 2.2e-16
## factor(week)113                      6.2789e+02  6.2483e+01 10.0489 < 2.2e-16
## factor(week)114                      1.1962e+00  6.8490e+01  0.0175 0.9860657
```

```
## factor(week)115                     -8.3208e+01  4.8604e+01 -1.7120 0.0869278
## factor(week)116                     -4.8488e+01  3.7690e+01 -1.2865 0.1982905
## factor(week)117                      1.0194e+02  2.7122e+01  3.7584 0.0001717
## factor(week)118                      1.0023e+02  2.5380e+01  3.9490 7.885e-05
## factor(week)119                      6.3666e+01  2.0850e+01  3.0536 0.0022656
## factor(week)120                      6.3141e+01  1.8438e+01  3.4245 0.0006178
## factor(week)121                     -5.4861e+01  1.5336e+01 -3.5772 0.0003484
## factor(week)122                     -6.7049e+01  9.8043e+00 -6.8388 8.318e-12
## factor(week)123                      1.1874e+02  1.0697e+01 11.1005 < 2.2e-16
## factor(week)124                      1.3418e+02  1.3104e+01 10.2398 < 2.2e-16
## factor(week)125                      1.5591e+02  1.3723e+01 11.3606 < 2.2e-16
## factor(week)126                      2.7795e+02  1.6019e+01 17.3520 < 2.2e-16
## factor(week)127                      2.3161e+02  1.7832e+01 12.9885 < 2.2e-16
## factor(week)128                      2.7745e+02  1.8579e+01 14.9337 < 2.2e-16
## factor(week)129                      3.7623e+02  2.8287e+01 13.3005 < 2.2e-16
## factor(week)130                      2.7126e+02  2.5399e+01 10.6798 < 2.2e-16
## factor(week)131                      4.0279e+00  2.8667e+01  0.1405 0.8882603
## factor(week)132                     -9.7153e+01  2.0535e+01 -4.7311 2.254e-06
## factor(week)133                     -2.6391e+01  1.4210e+01 -1.8572 0.0633039
## factor(week)134                      2.5370e+00  9.6859e+00  0.2619 0.7933847
## factor(week)135                      5.7395e+01  1.3387e+01  4.2875 1.819e-05
## factor(week)136                      5.0661e+01  9.4771e+00  5.3456 9.153e-08
## factor(week)137                      7.0853e+01  9.5667e+00  7.4063 1.374e-13
## factor(week)138                      1.1804e+02  1.3021e+01  9.0659 < 2.2e-16
## factor(week)139                      1.7722e+02  9.5436e+00 18.5698 < 2.2e-16
## factor(week)140                      3.7928e+02  1.3729e+01 27.6264 < 2.2e-16
## factor(week)141                      3.3327e+02  2.2876e+01 14.5685 < 2.2e-16
## factor(week)142                      2.3245e+02  2.7750e+01  8.3764 < 2.2e-16
## factor(week)143                     -5.3067e+01  2.4848e+01 -2.1357 0.0327230
## factor(week)144                     -8.9528e+01  1.5235e+01 -5.8766 4.283e-09
## factor(week)145                     -7.2257e+01  1.0515e+01 -6.8716 6.617e-12
## factor(week)146                      2.3057e+01  6.1498e+00  3.7492 0.0001781
## factor(week)147                     -7.0018e+00  4.8321e+00 -1.4490 0.1473507
## factor(week)148                      1.3100e+01  4.1929e+00  3.1244 0.0017854
##
## (Intercept)
## lag(inzidenz, 1)                    ***
## lag(weightednbinz, 1)               ***
## I(log(density) * lag(inzidenz, 1))  ***
## I(hotspot * lag(inzidenz, 1))       ***
## I(hotspotnb * lag(weightednbinz, 1)) *
## I(rate_zweitimpf * hotspot)         ***
## A60.79.Anteil                       ***
## factor(week)3
## factor(week)4
## factor(week)5
## factor(week)6                       ***
## factor(week)7                       ***
## factor(week)8                       ***
## factor(week)9                       ***
## factor(week)10                      ***
## factor(week)11
## factor(week)12
## factor(week)13
```

```
## factor(week)14
## factor(week)15                       ***
## factor(week)16                       ***
## factor(week)17                       **
## factor(week)18                       ***
## factor(week)19                       *
## factor(week)20                       .
## factor(week)21                       ***
## factor(week)22                       ***
## factor(week)23                       ***
## factor(week)24                       ***
## factor(week)25                       ***
## factor(week)26                       *
## factor(week)27                       ***
## factor(week)28                       **
## factor(week)29                       ***
## factor(week)30                       ***
## factor(week)31                       ***
## factor(week)32                       ***
## factor(week)33                       ***
## factor(week)34                       ***
## factor(week)35                       **
## factor(week)36                       ***
## factor(week)37                       ***
## factor(week)38                       ***
## factor(week)39                       ***
## factor(week)40                       ***
## factor(week)41                       ***
## factor(week)42                       ***
## factor(week)43                       ***
## factor(week)44                       ***
## factor(week)45                       ***
## factor(week)46                       ***
## factor(week)47                       ***
## factor(week)48                       *
## factor(week)49                       ***
## factor(week)50                       ***
## factor(week)51                       **
## factor(week)52                       *
## factor(week)53                       ***
## factor(week)54                       ***
## factor(week)55
## factor(week)56                       ***
## factor(week)57                       ***
## factor(week)58                       ***
## factor(week)59                       ***
## factor(week)60                       ***
## factor(week)61                       ***
## factor(week)62                       ***
## factor(week)63                       ***
## factor(week)64                       ***
## factor(week)65                       ***
## factor(week)66
## factor(week)67                       **
```

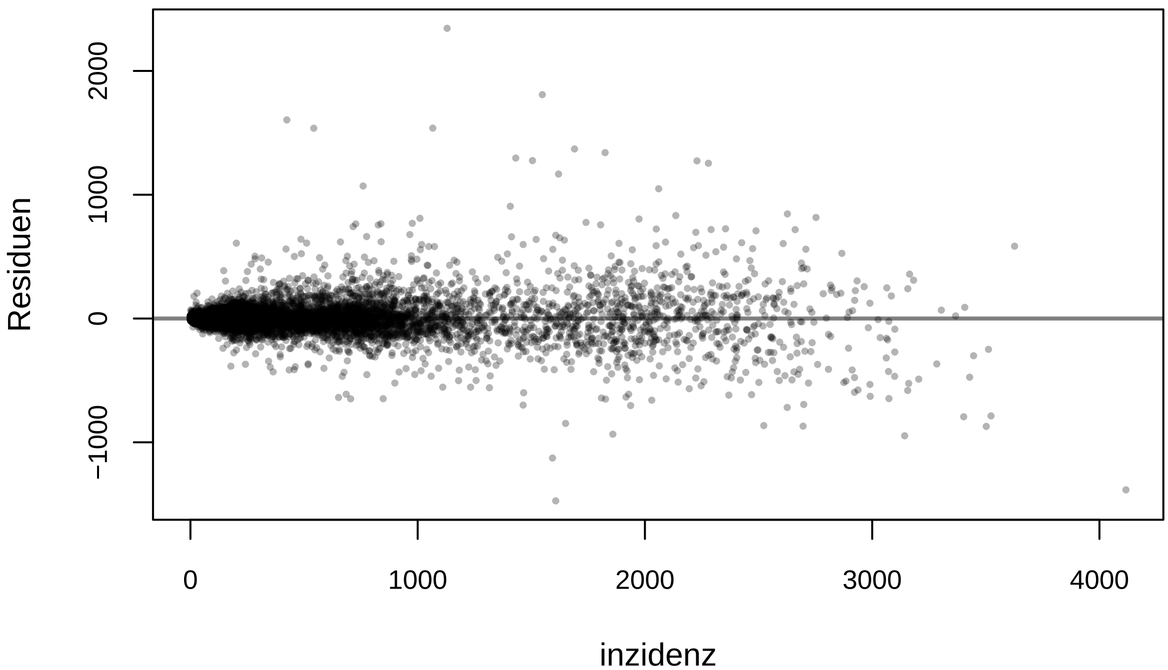
```
## factor(week)68
## factor(week)69
## factor(week)70                      ***
## factor(week)71
## factor(week)72                      **
## factor(week)73                      ***
## factor(week)74
## factor(week)75                      .
## factor(week)76                      ***
## factor(week)77                      ***
## factor(week)78                      ***
## factor(week)79                      ***
## factor(week)80                      ***
## factor(week)81                      ***
## factor(week)82                      ***
## factor(week)83                      ***
## factor(week)84                      ***
## factor(week)85                      ***
## factor(week)86                      ***
## factor(week)87                      ***
## factor(week)88                      ***
## factor(week)89                      ***
## factor(week)90                      ***
## factor(week)91                      ***
## factor(week)92                      ***
## factor(week)93                      ***
## factor(week)94                      ***
## factor(week)95                      ***
## factor(week)96                      ***
## factor(week)97                      **
## factor(week)98
## factor(week)99
## factor(week)100                     ***
## factor(week)101                     ***
## factor(week)102                     ***
## factor(week)103                     ***
## factor(week)104                     ***
## factor(week)105                     ***
## factor(week)106                     ***
## factor(week)107                     ***
## factor(week)108                     ***
## factor(week)109                     ***
## factor(week)110                     ***
## factor(week)111                     ***
## factor(week)112                     ***
## factor(week)113                     ***
## factor(week)114
## factor(week)115                     .
## factor(week)116
## factor(week)117                     ***
## factor(week)118                     ***
## factor(week)119                     **
## factor(week)120                     ***
## factor(week)121                     ***
```

```
## factor(week)122                      ***
## factor(week)123                      ***
## factor(week)124                      ***
## factor(week)125                      ***
## factor(week)126                      ***
## factor(week)127                      ***
## factor(week)128                      ***
## factor(week)129                      ***
## factor(week)130                      ***
## factor(week)131
## factor(week)132                      ***
## factor(week)133                      .
## factor(week)134
## factor(week)135                      ***
## factor(week)136                      ***
## factor(week)137                      ***
## factor(week)138                      ***
## factor(week)139                      ***
## factor(week)140                      ***
## factor(week)141                      ***
## factor(week)142                      ***
## factor(week)143                      *
## factor(week)144                      ***
## factor(week)145                      ***
## factor(week)146                      ***
## factor(week)147
## factor(week)148                      **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

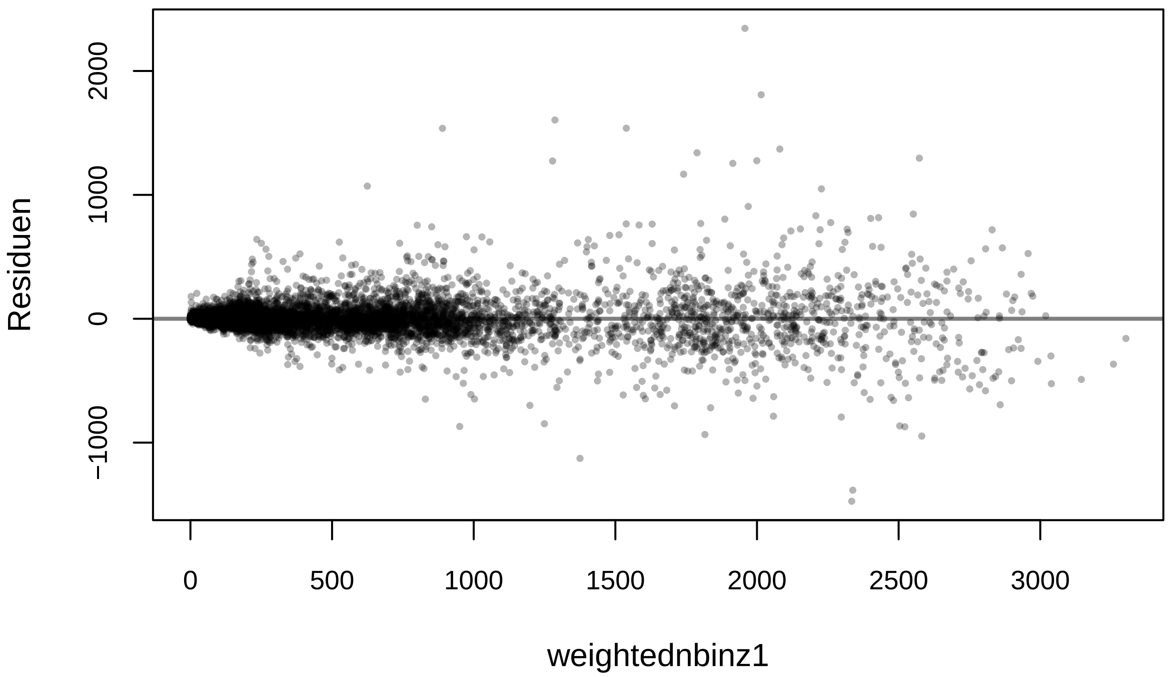
Data used for the plots:

```
df_pan2<-df4_pan[-(which(df4_pan$week==1)),]

s<-data.frame(c(lag(df_pan2$inzidenz, 1)),c(lag(df_pan2$weightednbinz, 1)),
              c(I(log(df_pan2$density)*lag(df_pan2$inzidenz, 1))),
              c(I(df_pan2$hotspot*lag(df_pan2$inzidenz,1))),
              c(I(df_pan2$hotspotnb*lag(df_pan2$weightednbinz,1))),
              c(I(df_pan2$rate_zweitimpf * df_pan2$hotspot)),
              c(df_pan2$A60.79.Anteil))

colnames(s)<-c("inzidenz1","weightednbinz1","density_inzidenz1",
               "hotspot_inzidenz1", "hotspotnb_wnbinzidenz1",
               "zweitimpf_hotspot","A60.79.Anteil")
```

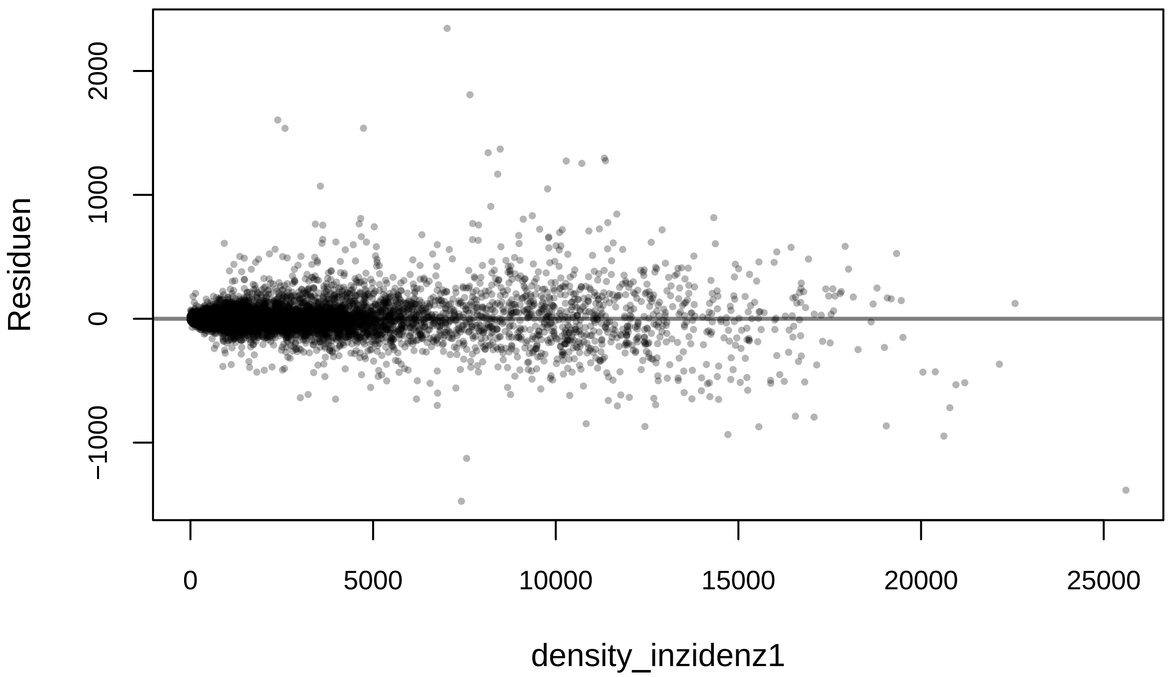
Residual-Plots for variables:



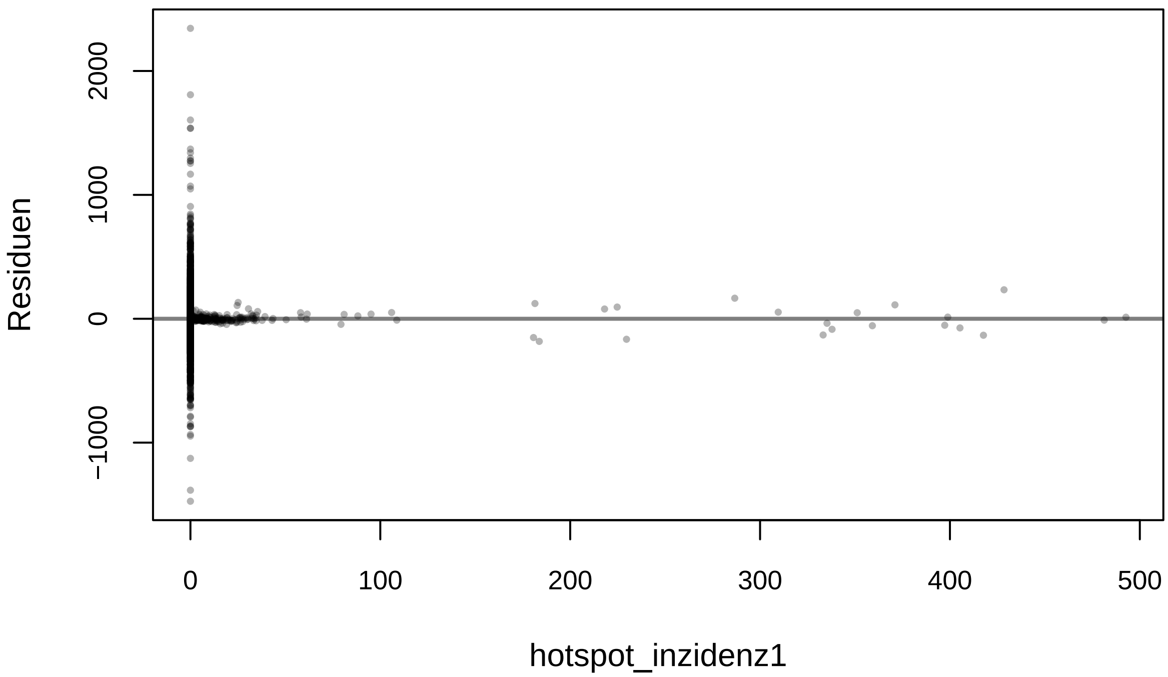

```
## integer(0)
```


Residuen
2000
1000
0
−1000
0
500
1000
1500
2000
2500
3000
weightednbinz1

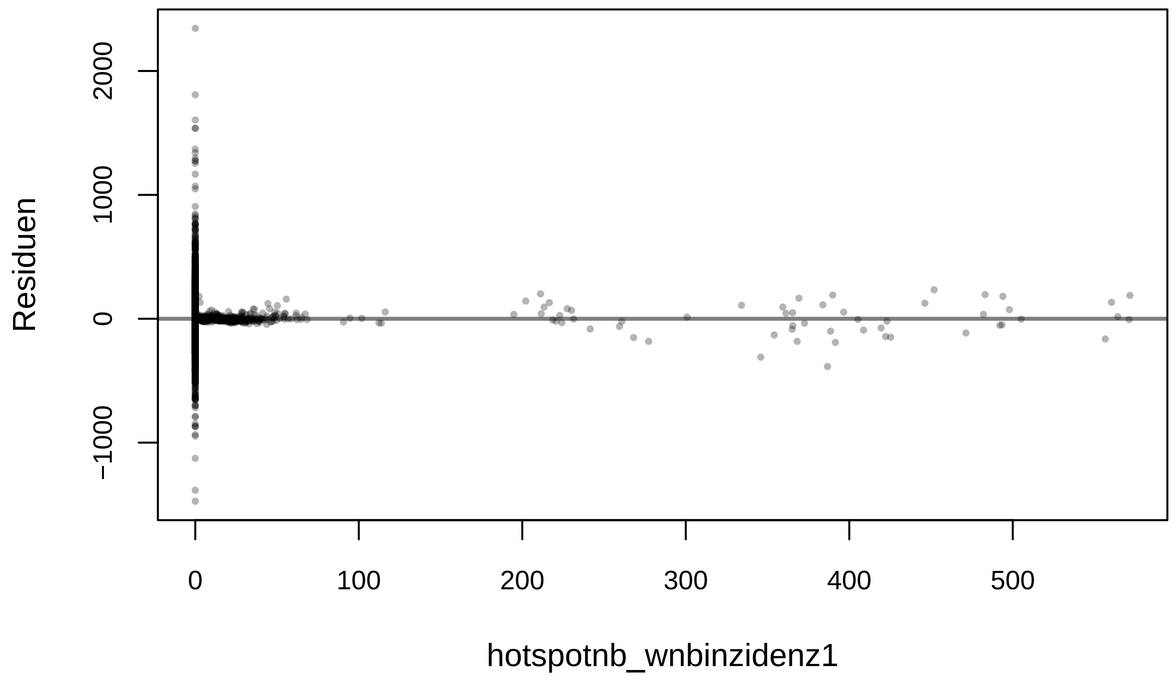
```
## integer(0)
```


Residuen
2000
1000
0
−1000
0
5000
10000
15000
20000
25000
density_inzidenz1

```
## integer(0)
```

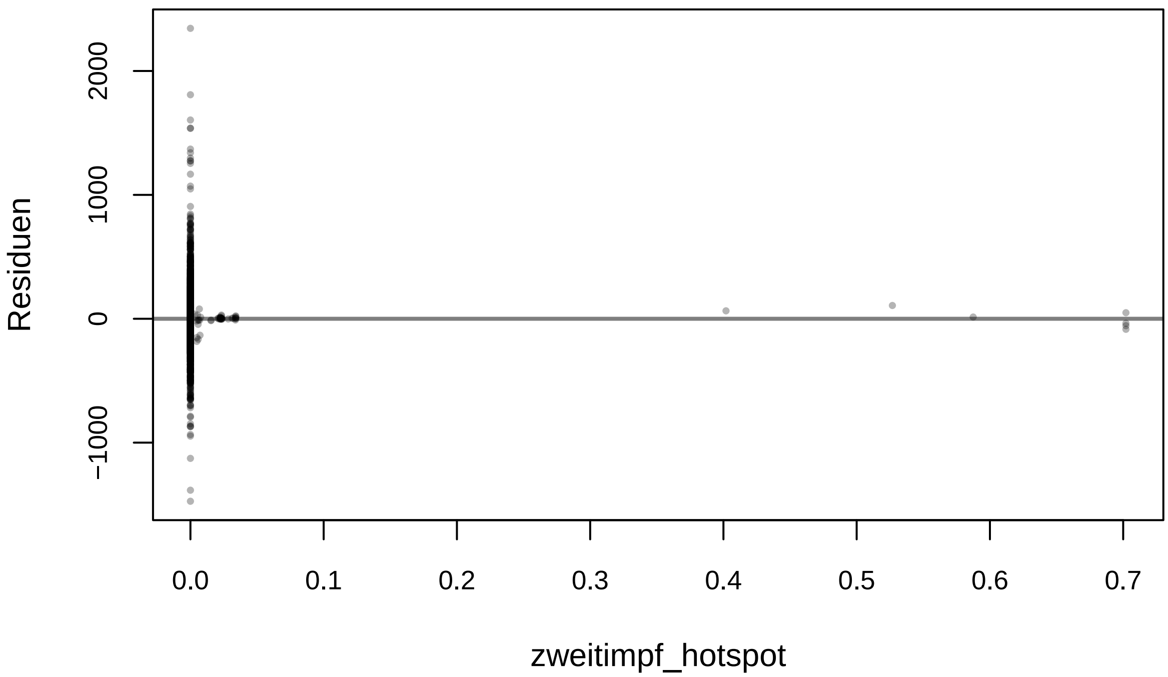

Residuen
2000
1000
0
−1000
0
100
200
300
400
500
hotspot_inzidenz1

```
## integer(0)
```

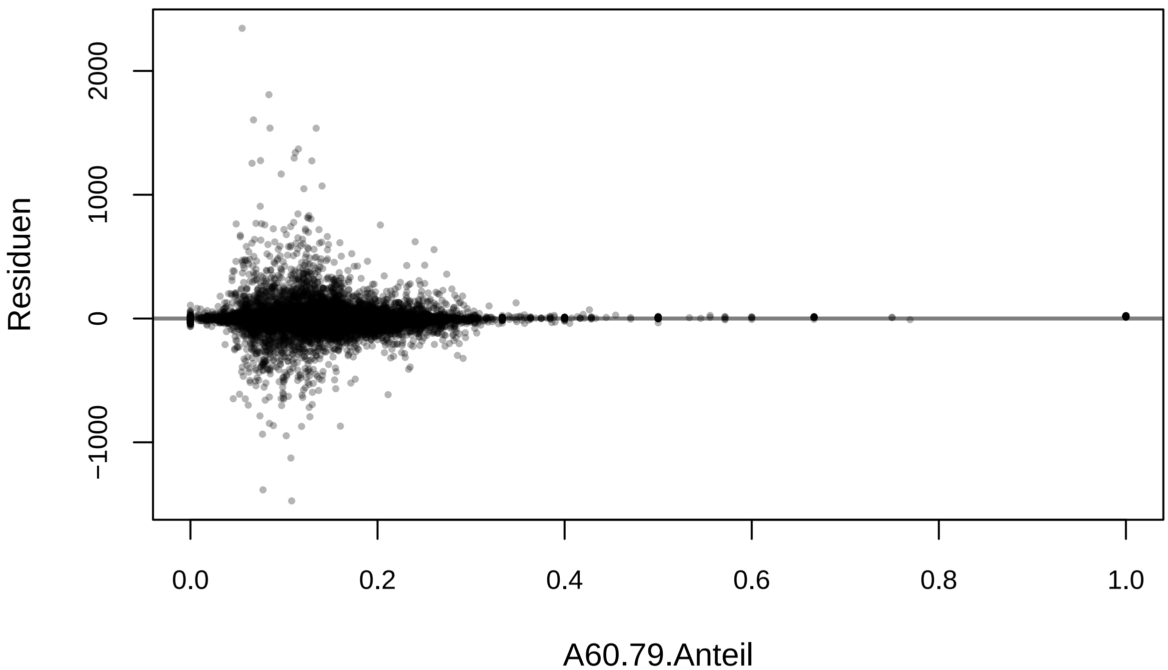


Residuen
2000
1000
0
−1000
0
100
200
300
400
500
hotspotnb_wnbinzidenz1


```
## integer(0)
```


Residuen
2000
1000
0
−1000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
zweitimpf_hotspot

```
## integer(0)
```




```
## integer(0)
```