

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 definiert 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(weightednbins, 1)  
+ I(log(density)*lag(inzidenz, 1))  
+ factor(week)  
, data =df4_pan, model = "within")  
  
re.step0 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)  
+ I(log(density)*lag(inzidenz, 1))  
+ factor(week)  
, data =df4_pan, model = "random")  
  
phptest(fe.step0, re.step0)  
  
##  
## Hausman Test  
##  
## data: inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 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(weightednbins, 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(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+ I(hotspotnb * lag(weightednbins, 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(weightednbins, 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(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+I(hotspotnb * lag(weightednbins, 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(weightednbins, 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(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+I(hotspotnb * lag(weightednbins, 1)) + I(rate_zweitimpf * hotspot)
+ A60.79.Anteil + A35.59.Anteil
+ factor(week)

```

```

        , data =df4_pan, model = "random")

pFtest(re.step4, re.step3)

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

re.step4.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 1.0067, df1 = 1, df2 = 13958, p-value = 0.3157
## alternative hypothesis: significant effects

## reject A35.59.Anteil

re.step5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 1.5696, df1 = 1, df2 = 13957, p-value = 0.2103
## alternative hypothesis: significant effects

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

```

```

        , 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

## 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

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

## 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))

```

```

+I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 0.10739, df1 = 1, df2 = 13957, p-value = 0.7431
## alternative hypothesis: significant effects

```

```

re.step7.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 0.1934, df1 = 1, df2 = 13958, p-value = 0.6601
## alternative hypothesis: significant effects

```

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

```

re.step8 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 0.95362, df1 = 1, df2 = 13957, p-value = 0.3288
## alternative hypothesis: significant effects

```

```

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

```

re.step10 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 0.23774, df1 = 1, df2 = 13957, p-value = 0.6259
## alternative hypothesis: significant effects

```

```

## reject rate_zweitimpf

re.step11 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  +I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 1.7357, df1 = 1, df2 = 13957, p-value = 0.1877
## alternative hypothesis: significant effects

```

```

re.step11.5 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 1)
                  + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
                  + I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 2.0971, df1 = 1, df2 = 13959, p-value = 0.1476
## alternative hypothesis: significant effects

```

```

## reject rate_drittimpf

re.step12 <- plm(inzidenz ~ lag(inzidenz, 1) + lag(weightednbins, 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_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

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

```

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

```

```

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(weightednbins, 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(weightednbins, 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(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+ I(hotspotnb * lag(weightednbins, 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(weightednbins, 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(weightednbins, 1)
+ I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
+ I(hotspotnb * lag(weightednbins, 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(weightednbins, 1) + I(log(density) * ...
## F = 1.1033, df1 = 1, df2 = 13957, p-value = 0.2936
## alternative hypothesis: significant effects

```

```

## 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

```

*## 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

```

factor(week) stays

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

```

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)
            + 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(weightednbinc, 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 Pesaran CD test:

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

```

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

```

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

```

## 
## Pesaran CD test for cross-sectional dependence in panels
## 
## data: inzidenz ~ lag(inzidenz, 1) + lag(weightednbinc, 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:

```
pbgtest(pool)
```

```

## 
## Breusch-Godfrey/Wooldridge test for serial correlation in panel models
## 
## data: inzidenz ~ lag(inzidenz, 1) + lag(weightednbinc, 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:

```
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, Stationarität wird angenommen.

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

```

bptest(inzidenz ~ lag(inzidenz, 1) + lag(weightednbinsz, 1)
       + I(log(density)*lag(inzidenz, 1)) + I(hotspot * lag(inzidenz, 1))
       + I(hotspotnb * lag(weightednbinsz, 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(weightednbinsz, 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:

```
coeftest(pool, vcovHC(pool, type="HCO"))
```

```

## 
## 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(weightednbinsz, 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(weightednbinsz, 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          ***
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## factor(week)51          **
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## factor(week)61          ***
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## factor(week)65          ***
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## 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 ***
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## 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[!(df4_pan$week==1),]

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

colnames(s)<-c("inzidenz1","weightednbins1","density_inzidenz1",
              "hotspot_inzidenz1", "hotspotnb_wnbinzidenz1",
              "zweitimpf_hotspot","A60.79.Anteil")

```

Residual-Plots for variables:













