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Comparison of COVID19 policies using a SIR-model

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Background

- COVID19 can be analyzed using a SIR-model
  - In the SIR-models the population is compartmentalized into susceptible-, infected- and recovered compartments
- Different strategies have been used to contain the spread of COVID19
  - Policy = Any non-pharmaceutical intervention(NPI) against COVID19
  - Example policies
    - Lockdowns
    - Distancing
    - Online teaching

Objective

- Use a SIR-model to compare COVID19 policies in countries
- Fit SIR-model to (weekly) data of Finland, France, Italy and Sweden (ECDC data)
- Government response data set
  - Contains a list of tracking policy changes in the countries
- Compare the COVID19 situation in the countries

Limitations

- Testing rates are not taken into account
- Government response data set is simple
  - Policies are also implemented at the same time
  - Only general insights of the policies are gained
- Economic outcomes excluded from the analysis
- Vaccination also excluded

SIR-model

$$\Delta s(t+1) = -\beta s(t)i(t), \tag{4}$$

$$\Delta i(t+1) = \beta s(t)i(t) - \gamma i(t), \tag{5}$$

$$\Delta r(t+1) = \gamma i(t), \tag{6}$$

where *s*, *i* and *r* are susceptible, infected and recovered proportions of the population, *β* is the rate of transmission and *γ* is the rate of recovery

- If D is the infectious period = time until recovery, then *γ*=1/D
- Expected new infections resulting from one infected := Basic reproduction number R.
- R= *β/γ*

Fitting the SIR-model

- The rate of transmission is estimated for consecutive time intervals
  - Time intervals chosen visually and based on policy changes (during the times)
- Rate of recovery constant (1/2 weeks, since D=2 weeks)
- Fit using sum of least squares estimation
- Time period: 52 weeks of 2020 (before vaccination)

Estimation

- Minimize the loss function $l(\hat{\beta}) = \sum_t (i(t) - \hat{i}(t))^2.$

  where *î* is the fitted infected proportion of the population
- Optimal solution obtained by the following procedure:

$$\hat{\beta}^+ = \hat{\beta}_n + d,$$
$$\hat{\beta}^- = \hat{\beta}_n - d,$$
$$\hat{\beta}_{n+1} = argmin_{\hat{\beta}}(\{l(\hat{\beta}^+), l(\hat{\beta}^-)\}),$$

  where *βn* is the *n*th estimate, *d* is the stepsize
- Iterate for a long time or until improvements are tiny

Results: Estimated coefficients

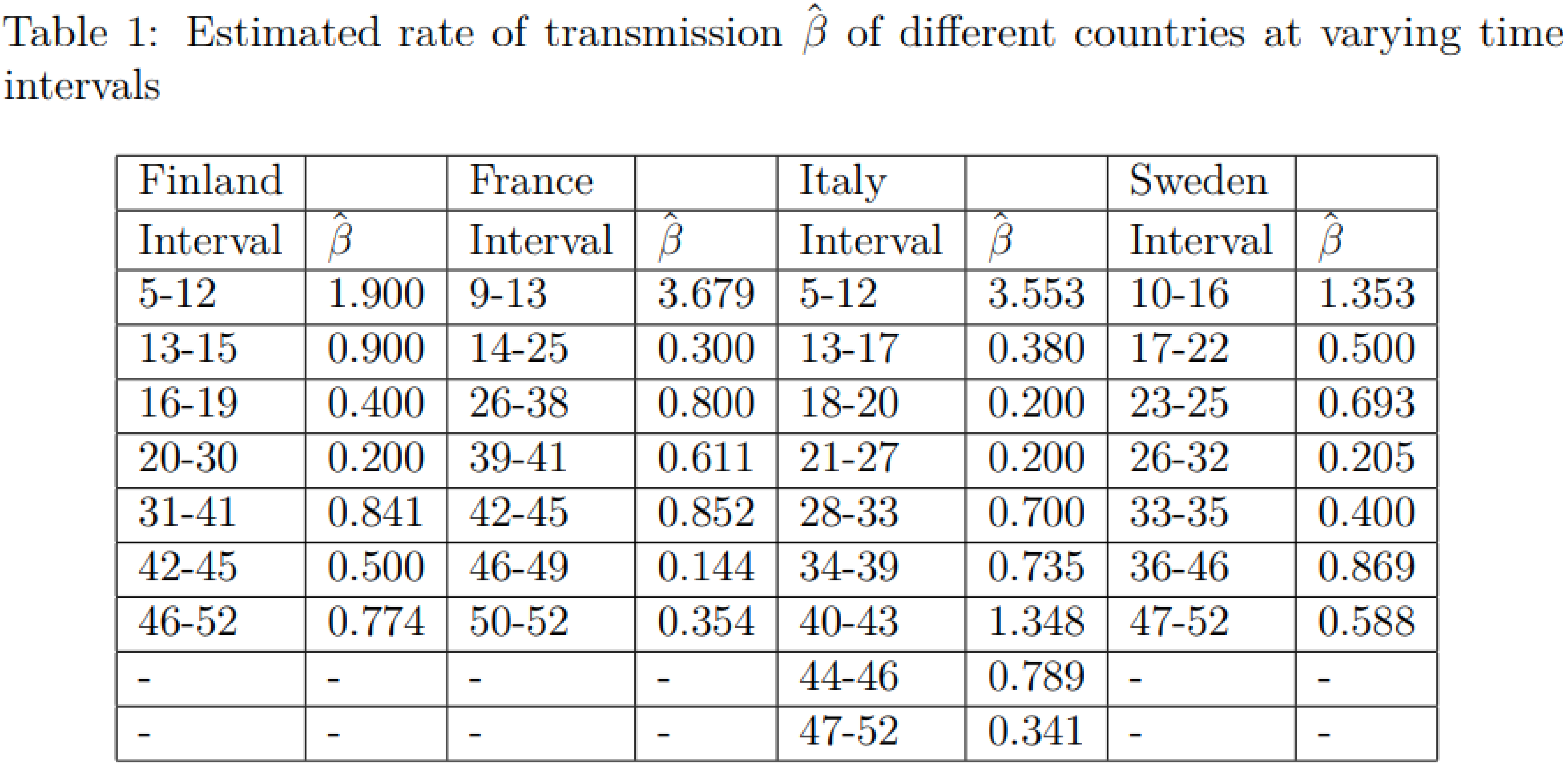
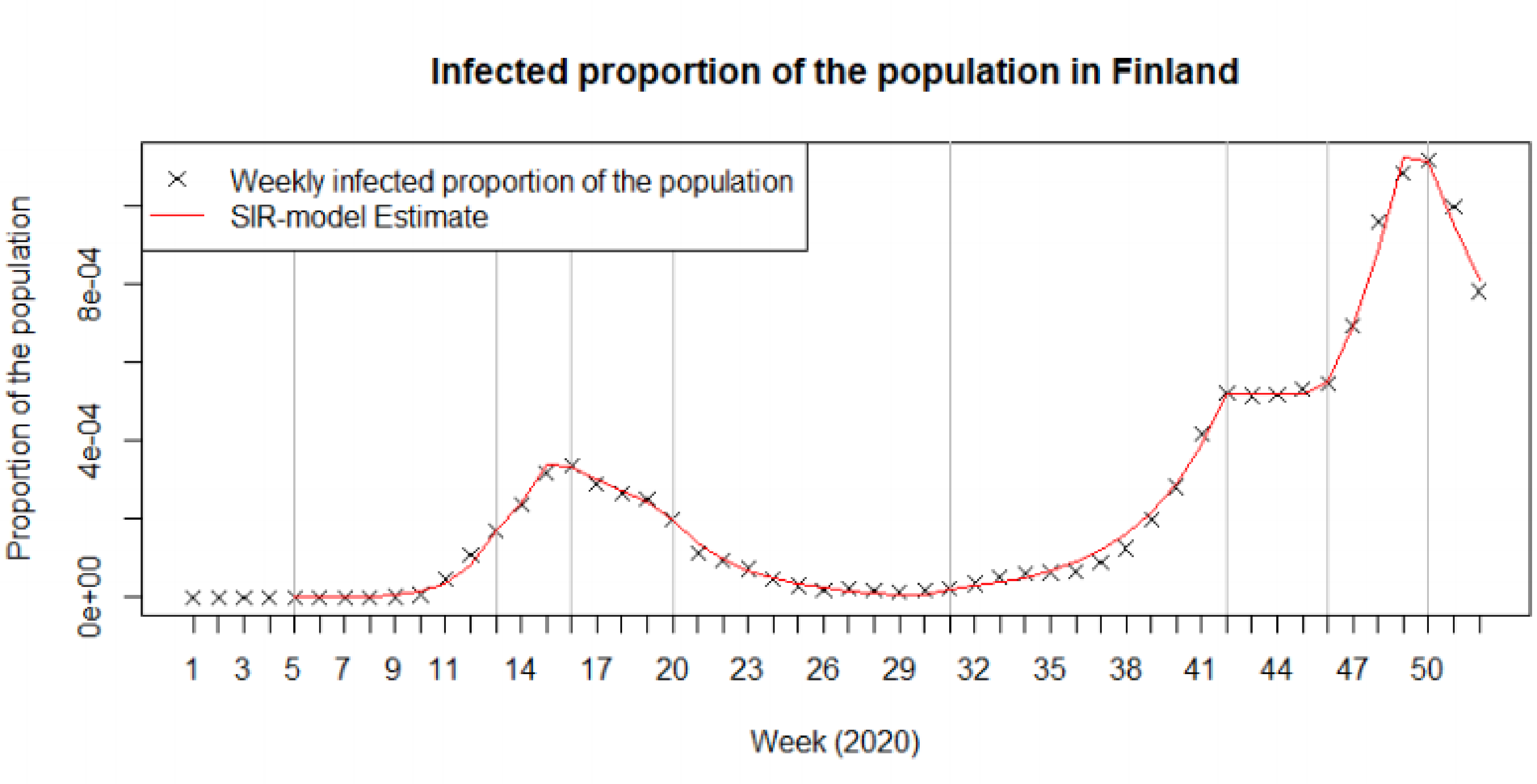


Table 1: Estimated rate of transmission $\hat{\beta}$ of different countries at varying time intervals

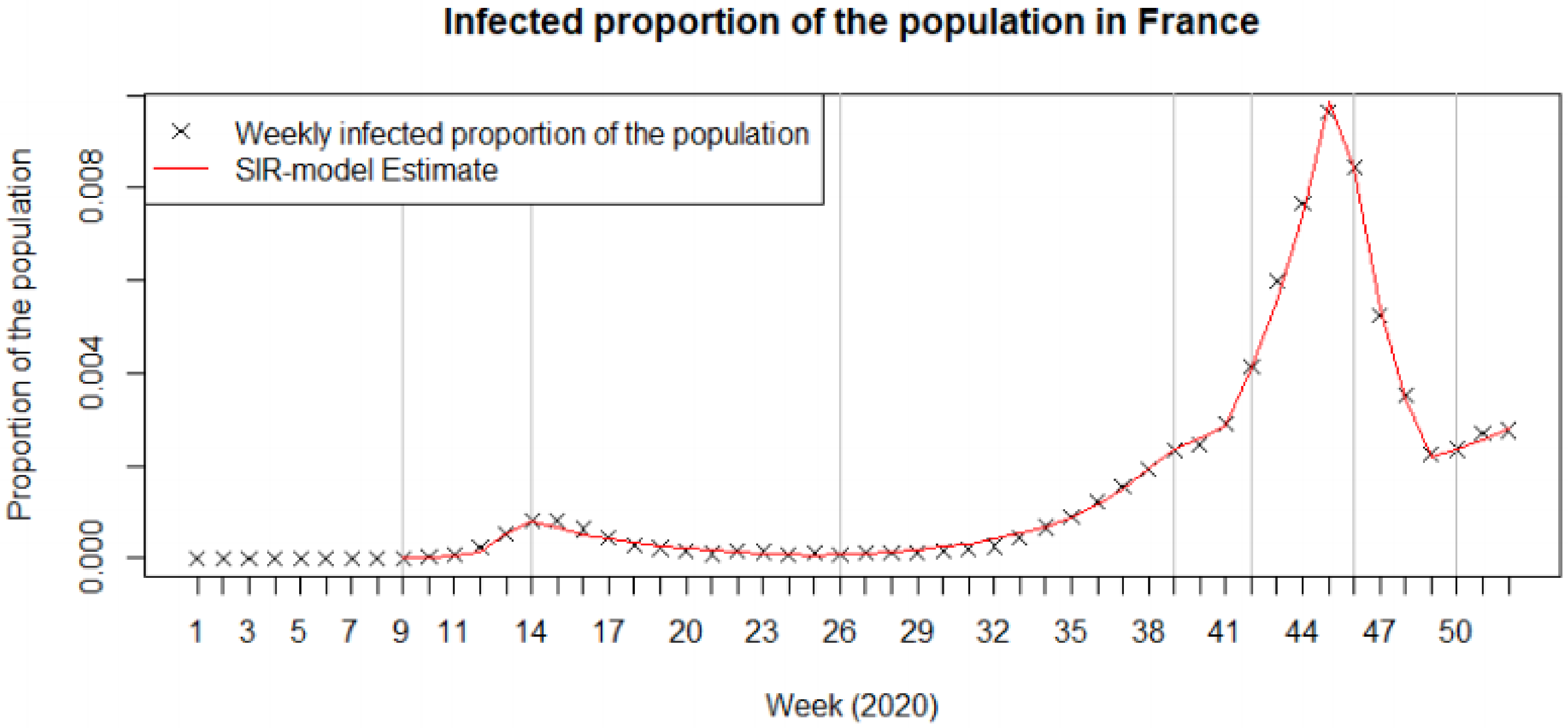
Finland		France		Italy		Sweden	
Interval	$\hat{\beta}$	Interval	$\hat{\beta}$	Interval	$\hat{\beta}$	Interval	$\hat{\beta}$
5-12	1.900	9-13	3.679	5-12	3.553	10-16	1.353
13-15	0.900	14-25	0.300	13-17	0.380	17-22	0.500
16-19	0.400	26-38	0.800	18-20	0.200	23-25	0.693
20-30	0.200	39-41	0.611	21-27	0.200	26-32	0.205
31-41	0.841	42-45	0.852	28-33	0.700	33-35	0.400
42-45	0.500	46-49	0.144	34-39	0.735	36-46	0.869
46-52	0.774	50-52	0.354	40-43	1.348	47-52	0.588
-	-	-	-	44-46	0.789	-	-
-	-	-	-	47-52	0.341	-	-

- Note that time intervals differ between countries

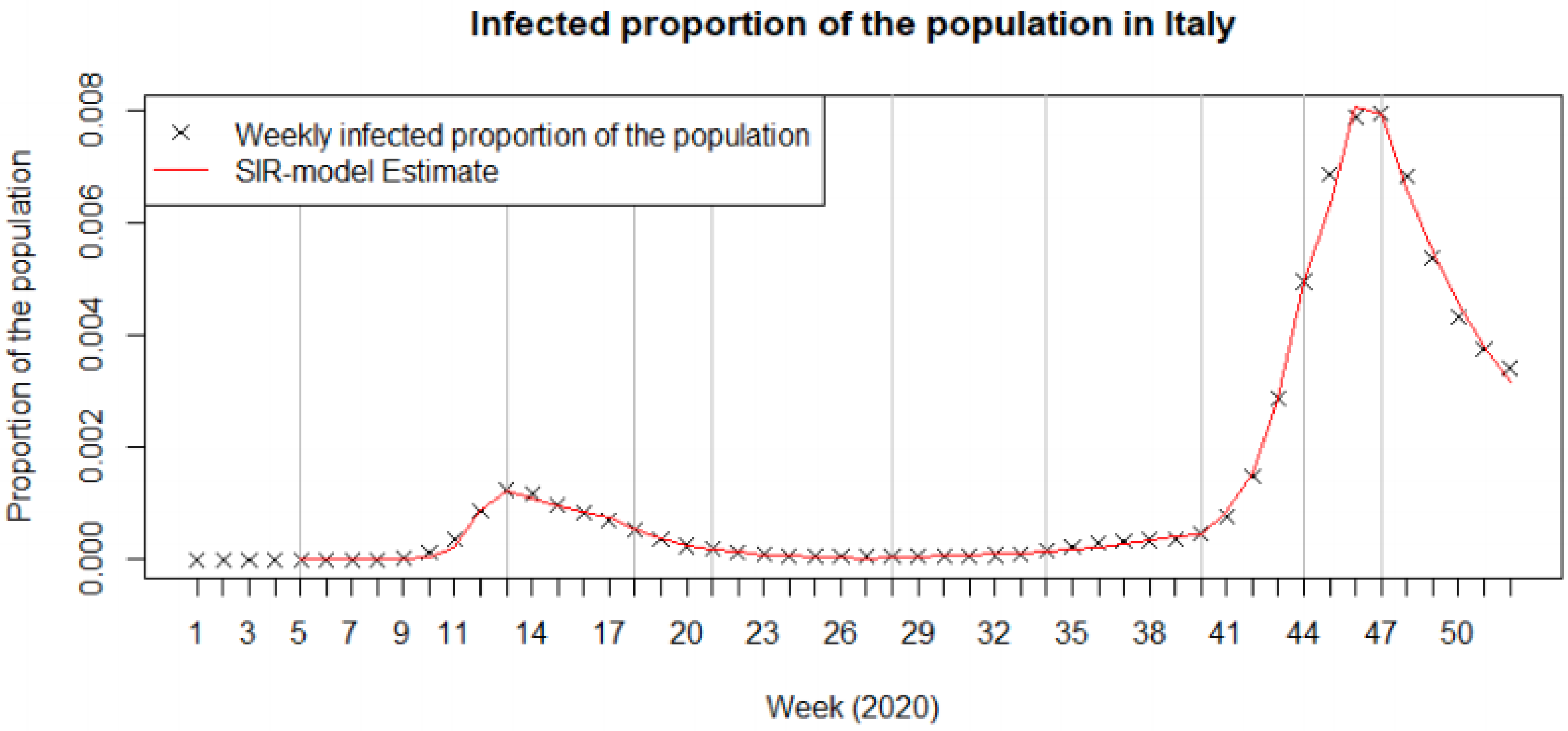
Estimated SIR-model (Finland)



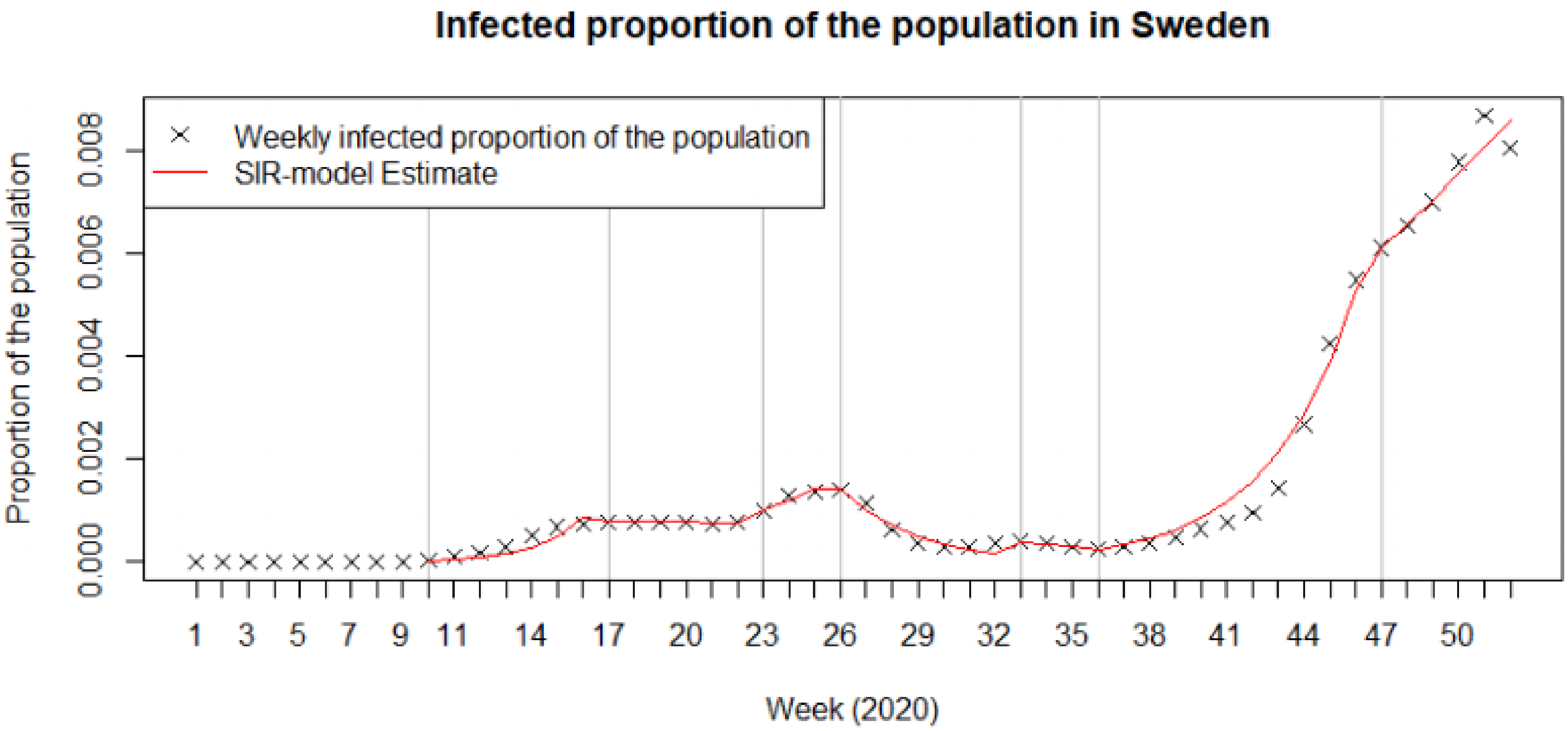
Estimated SIR-model (France)



Estimated SIR-model (Italy)



Estimated SIR-model (Sweden)



Summary

- The SIR-model can be fit to COVID19 data
  - Using methods such as sum of least squares estimation
- NPI policy reduces the rate of transmission
  - The rate of transmission increases when the policies are removed or replaced with more mild policies

Improvement suggestions

- Include vaccination
  - For example, a certain proportion of susceptible individuals become recovered
- COVID19 forecasting using the model
- Hybrid models
  - SEIRD-ARIMA [4]
  - Branching process+SIR [2]
- Economic reactions to policies such as in [5]

References

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- [2] Bertozzi, A. et al. (2020), ‘The challenges of modeling and forecasting the spread of covid-19’, Proceedings of the National Academy of Sciences, 117 (29) 16732-16738 . DOI: 10.1073/pnas.2006520117. 3. MRSIR
- [4] Ala’raj M. et al. (2020), ’ Modeling and forecasting of COVID-19 using a hybrid dynamic model based on SEIRD with ARIMA corrections’, Infectious Disease Modelling, 6 98-111 . DOI: 10.1016/j.idm.2020.11.007
- [5] Toda, A. (2020), ‘Susceptible-infected-recovered (sir) dynamics of covid-19 and economic impact’. URL: https://arxiv.org/abs/2003.11221