Note added for publication

This paper contains estimates of the reproduction number (R) and growth rate for the UK, four nations and NHSE England regions.

R is an average value that can vary in different parts of the country, communities, and subsections of the population. It cannot be measured directly so there is always some uncertainty around its exact value.

Estimates of R and growth rates for Scotland, Wales, Northern Ireland and NHSE England regions are subject to greater uncertainty given the lower number of cases and increased variation.

Different modelling groups use different data sources to estimate these values using mathematical models that simulate the spread of infections. Some may even use all these sources of information to adjust their models to better reflect the real-world situation. There is uncertainty in all these data sources, which is why estimates can vary between different models, and why we do not rely on one model; evidence from several models is considered, discussed, combined, and the growth rate and R are then presented as ranges.

Given wide uncertainty ranges, it should not be concluded from estimates in this paper that R is higher or lower in different nations.

The latest R number and growth rates, and further background, is available on GOV.UK.

SPI-M-O: Consensus Statement on COVID-19

SIGNED OFF BY CHAIRS ON BEHALF OF SPI-M-O

Date: 17th June 2020

Summary

1. It is highly likely that the overall reproduction number, **R**, in all four nations of the UK is below 1. SPI-M-O's best estimate for **the UK is that R remains between 0.7 and 0.9**.

2. The **growth rate** records how quickly the number of infections is changing each day. If the growth rate is greater than zero (i.e. positive), then the number of infections will grow. If the growth rate is less than zero (i.e. negative) then the number of infections will shrink. SPI-M-O's consensus estimate is that **the growth rate in the UK is between -2% and -4% per day**.

3. Regional estimates of R and the growth rate are less reliable and less useful in determining the state of the epidemic at smaller spatial scales. R is an average measure and will smooth over outbreaks at very small spatial scales. There is no strong evidence of systematic regional variation in how the epidemic is growing or shrinking.

4. Any changes in transmission that may have occurred in the past two to three weeks will not yet be reflected in health system data, nor therefore in SPI-M-O's estimates of R or growth rates.

5. SPI-M-O is concerned about the discharge of infectious patients from hospital, both into the community and into high-risk environments such as care homes. The considerable numbers of likely nosocomial infections detected in hospital implies comparable numbers of patients are also being infected in hospital but then discharged before they become symptomatic. It is the collective view of SPI-M-O that the infection/infectious status of all individuals should be known at discharge, and consideration given to quarantine outside the home for potentially infectious persons.

6. Preliminary modelling suggests there is potential for serial testing strategies to enable early release of individuals from isolation, but that three tests might be required to achieve a low probability of a false negative result. Further evidence and analysis is required to inform the optimal strategy.

Reproduction number

7. The reproduction number is the average number of secondary infections produced by a single infected individual. R is an average over time, geographies and communities. Whilst it varies in different geographies and settings of the population, separating transmission within and between these sub-populations increases uncertainty.

8. Estimates of R are dependent on differences in modelling methodology (particularly around the assumed distribution of the generation interval, the data sources used, the time frame considered, and the estimation framework) and will always carry some level of uncertainty. SPI-M-O's approach is for different modelling groups to estimate R independently to reflect this inherent uncertainty, then combine them using a random / mixed effects model with equal proportion weights, and to agree a consensus. The methodology for this combination is continuously scrutinised and developed.

9. Uncertainty in R increases as the number of infections decrease, or when it is evaluated for a smaller population, such as for the devolved administrations and regions. SPI-M-O's agreed national estimates of R are summarised in **Table 1** and **Figures 1 and 2**.

10. **Any changes in transmission patterns that may have occurred in the last two to three weeks will not yet be reflected in the healthcare data, nor therefore in SPI-M-O's estimates of R**. Other data sources, however, may provide more timely indications of changes in transmission, such as the ONS swabbing survey and the CoMix behavioural survey that studies how contact patterns are changing over time.

11. The latest results from the CoMix behavioural survey suggest there has been a modest increase in the number of contacts. Furthermore, Google mobility data shows an increase

in visits to places outside the home, such as workplaces and shops, over the time since social distancing measures were relaxed. It is possible that the nature of contacts has changed compared to the start of the epidemic and so it is unclear how these increases in movement might impact transmission until reflected in the epidemiological data.

Growth rates

12. Estimates of the growth rate of the epidemic require fewer assumptions and are an inherently less volatile measure. SPI-M-O will produce consensus values of growth rates in order to provide an alternative measure of changes in transmission.

13. For small daily changes, the growth rate is approximately the proportion by which the number of infections increases or decreases each day, i.e. the rate at which an epidemic is growing or shrinking[1].

14. As with R, SPI-M-O's consensus estimates of the growth rate are based on a statistical combination of estimates from several modelling groups.

15. SPI-M-O's consensus estimate is that the epidemic is slowly shrinking in the UK, with a growth rate which can be interpreted as -2% to -4% per day. SPI-M-O's agreed national estimates of growth rate are summarised in **Table 1**.

16. Neither measure, growth rate or R, is inherently better. Growth rate relates to both data and projections more clearly whereas the reproduction rate relates more directly to strength of intervention required. As the epidemic progresses and numbers of cases decrease, both R will become a less useful indicator, and other measures such as incidence, prevalence or counts of clusters will become more useful summaries.

Regional variation

17. Estimates of R are less reliable and less useful in determining the state of the epidemic as cases decrease. There are three main reasons for this:

18. Firstly, when there are few cases, R is impossible to estimate with accuracy and will have wide confidence intervals that are likely to include 1. This does not necessarily mean that the epidemic is increasing but could be the result of greater uncertainty.

[1] The growth rate, λ, is the slope of the exponential curve $y = e^{\lambda t}$, where y is the number of new infections, and t is time, given in days

19. Secondly, as incidence decreases, R will tend towards 1, and has to be evaluated in conjunction with incidence. The policy implications of R = 1 when there are 1,000 new infections per day are very different to when there are 100,000 per day.

20. Finally, R is an average measure. When incidence is low, an outbreak in one place could result in estimates of R for the entire region to become higher than 1. Conversely, small, local outbreaks will not be detected. Estimates of R based on small numbers may also not capture change in the area fast enough to inform policy in a useful way.

21. Estimates of R at regional levels are subject to the same difficulties in interpretation of national estimates, but amplified because of the smaller numbers of cases. Publishing large numbers of estimates increases the statistical chance that one of them is artificially high. SPI-M-O does not have confidence that regional R estimates are sufficiently robust to inform regional policy decisions. This is true even after we have combined estimates from several groups to produce a consensus value.

22. Estimates of the growth rate of the epidemic require fewer assumptions and are inherently more statistically stable. For small daily changes, the growth rate is approximately the proportion by which the number of infections increases or decreases each day, i.e. the rate at which an epidemic is growing or shrinking.

23. Consensus estimates for the regional growth rates in England are also given in **Table 1** and **Figure 3**. They show that **there is little regional variation in growth rates**. It is highly likely that the epidemic is shrinking in all regions.

24. For completeness, consensus regional estimates of R for England are given in **Table 1** and **Figure 4.** Some of these ranges of R include 1. This does not necessarily mean the epidemic is increasing in that region, just that the uncertainty means that this cannot be ruled out. It is also possible that an outbreak in one specific place could result in an R above 1 for the whole region.

Incidence

25. The relationship between infection, symptoms, swab positivity, hospitalisation and death is becoming clearer, but uncertainties remain in estimating the number of new daily infections.

26. Modelled estimates of incidence are generally higher than those from the ONS swabbing surveys. The reason for this is not yet clear. It is likely to be partly explained by the fact that the ONS survey does not include care homes or hospitals, where infection rates are

higher than the general population. It is also possible that the data streams available to SPI-M-O are biased towards health and social care associated infections. Further data to disentangle the relationship between transmission in different settings is required. Further investigation of the within hospital data (including admissions is urgently required).

27. Data from the ONS swabbing survey between 31st May and 13th June estimate that an average of 33,000 people in the community in England (confidence interval 12,000 to 74,000) would have swabbed positive for SARS-CoV-2 during this time period. The study estimates that between 26th April and 13th June there were an average of 26,900 new infections per week in the community (including asymptomatic individuals), but with a wide confidence interval from 19,200 to 36,600.

Testing on discharge

28. SPI-M-O is concerned about the discharge of infected patients from hospital, both into the community and into high-risk environments such as care homes. The considerable numbers of likely nosocomial infections detected in hospital implies that comparable numbers of patients may also become infected in hospital but then be discharged before they become symptomatic. It is the collective view of SPI-M-O that the infection and infectious status of all individuals should be known at discharge, and consideration given to quarantine outside the home for potentially infectious persons. Ascertaining the infectious status of patients will likely require consideration of their swab status, Ct value if positive, and potential antibody status.

Serial testing and false negative rates

29. Individuals who are a contact of an index case under TTI or fall under the UK's travel quarantine currently need to self-isolate for 14 days. There are potential serial testing strategies that would enable early release of individuals that consistently test negative from isolation, but further evidence and analysis is required to inform the optimal strategy.

30. The swab test is not sensitive enough for a single test to be sufficient to release asymptomatic individuals from isolation. Infected individuals can receive a false negative result for SARS-CoV-2 with the associated risk of incorrectly releasing a person from isolation and enabling onward transmission. The probability of a false negative changes over the time since exposure (infection).

31. Preliminary modelling by one SPI-M-O academic group suggests that three sequential negative tests, five days or more after the initial exposure would reduce the risk of releasing an infected individual from isolation to below 5%. Starting testing before five days

post-exposure requires more tests to reach the same level of certainty, whereas starting testing more than five days after infection indicates no further reduction in the number of tests required. This could potentially reduce the period of isolation to 7 days for some individuals.

32. These results are broadly in agreement with the paper on double testing tabled by the SAGE secretariat with regard to the potential of repeated testing in reducing the rate of false negatives. The SAGE analysis estimates that double testing of international passengers on days 5 and 6 after arrival would reduce the risk of releasing infected individuals to approximately 4% to 5%.

33. SPI-M-O modelling indicates that *triple* optimises the minimisation of false positives without any constraint on test numbers, whereas the commission on double-testing only explores this within the constraint of two tests per person.

34. The SPI-M-O and SAGE results, however, depend on the test sensitivity profile during the incubation and infectious period, and more data are required to validate and refine these preliminary results.

35. The success of a serial testing strategy will also depend on the characteristics of the test, particularly how sensitivity varies over time, and how testing is applied. Further work is required to identify when best to commence a serial testing strategy following arrival of a passenger in the UK, or notification of a contact.

Annex: PHIA framework of language for discussing probabilities

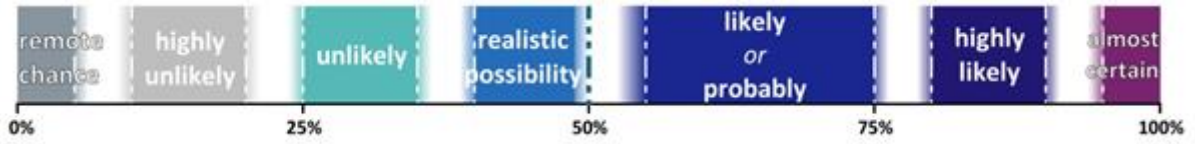

Table 1: Combined estimate of R and the growth rate in the UK, four nations and English NHS regions (90% confidence interval)

Nation	R	Growth rate per day
England	0.7 – 0.9	-4% to -1%
Scotland	0.6 – 0.8	-9% to -1%
Wales	0.7 – 1.0	-6% to +2%
Northern Ireland	0.6 – 0.9	-5% to -2%
UK	**0.7 - 0.9**	**-4% to -2%**

English NHS region	R	Growth rate per day
East of England	0.7 – 0.9	-6% to -1%
London	0.7 – 1.0	-5% to +1%
Midlands	0.8 – 1.0	-4% to 0%
North East and Yorkshire	0.7 – 0.9	-5% to -2%
North West	0.7 – 1.0	-4% to 0%
South East	0.7 – 0.9	-5% to -1%
South West	0.6 – 0.9	-6% to 0%

Figure 1: SPI-M groups' estimates of median R in the UK, including 90% confidence intervals. Bars represent different independent estimates. The grey shaded area represents the combined numerical range and the black bar is the combined range after rounding to 1 decimal place.

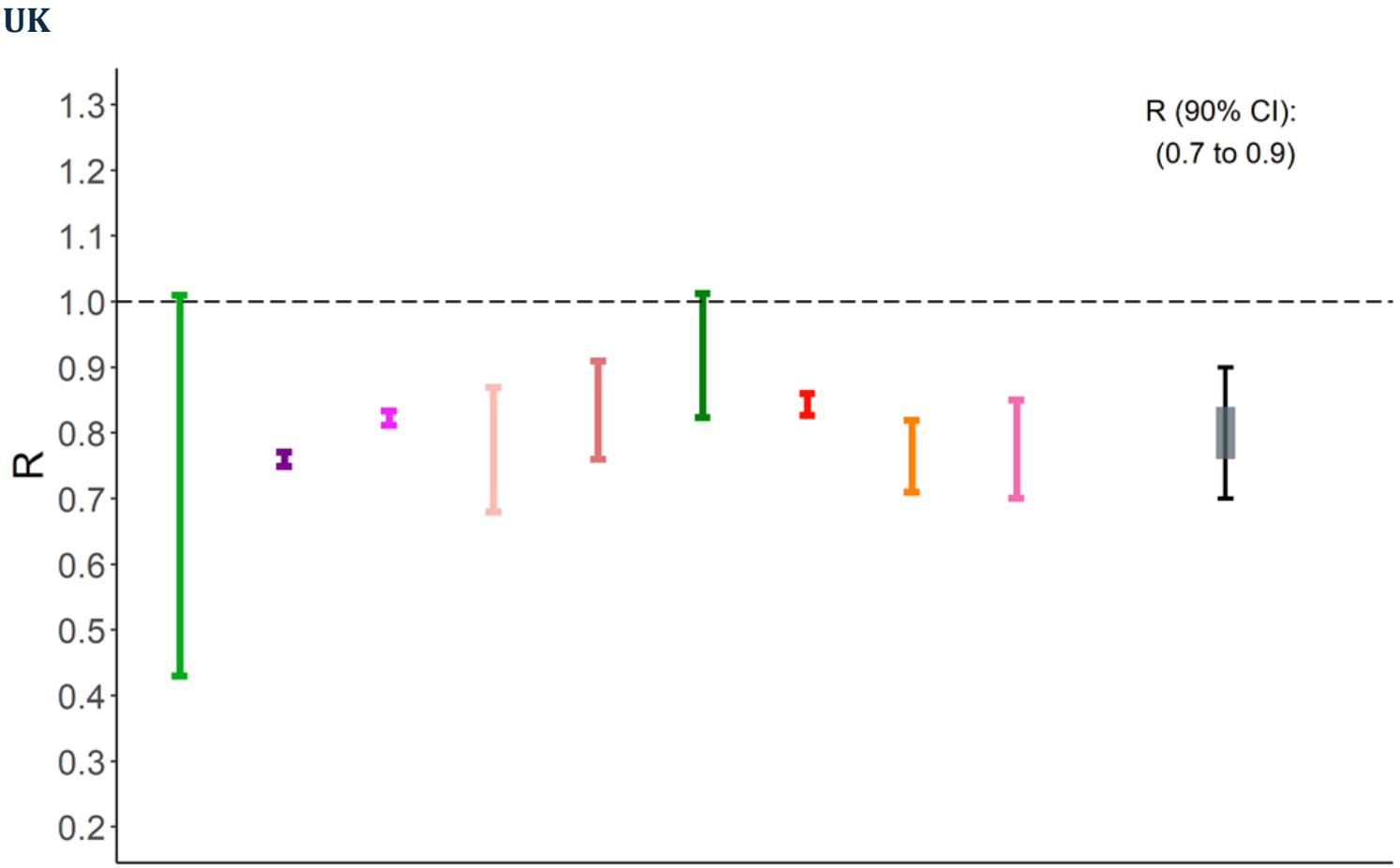

Figure 2: SPI-M groups estimates of median R in the four nations of the UK, including 90% confidence intervals. Bars represent different independent estimates. The grey shaded areas represent the combined numerical range and the black bars are the combined range after rounding to 1 decimal place.

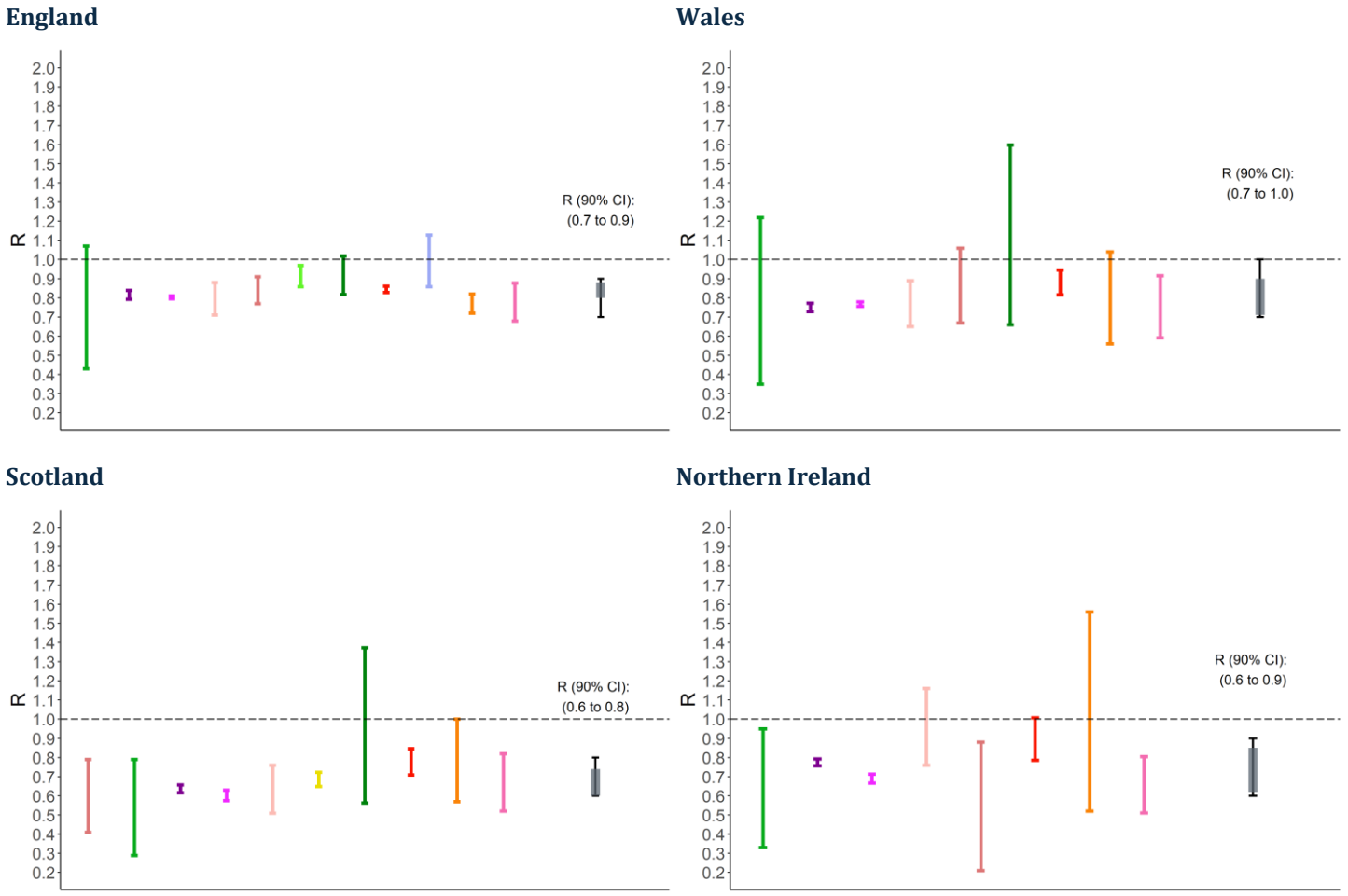

Figure 3: SPI-M groups estimates of the growth rate in English NHS regions, including 90% confidence intervals. Bars represent different modelling groups. The grey shaded areas represent the combined numerical range and the black bars are the combined range after rounding.

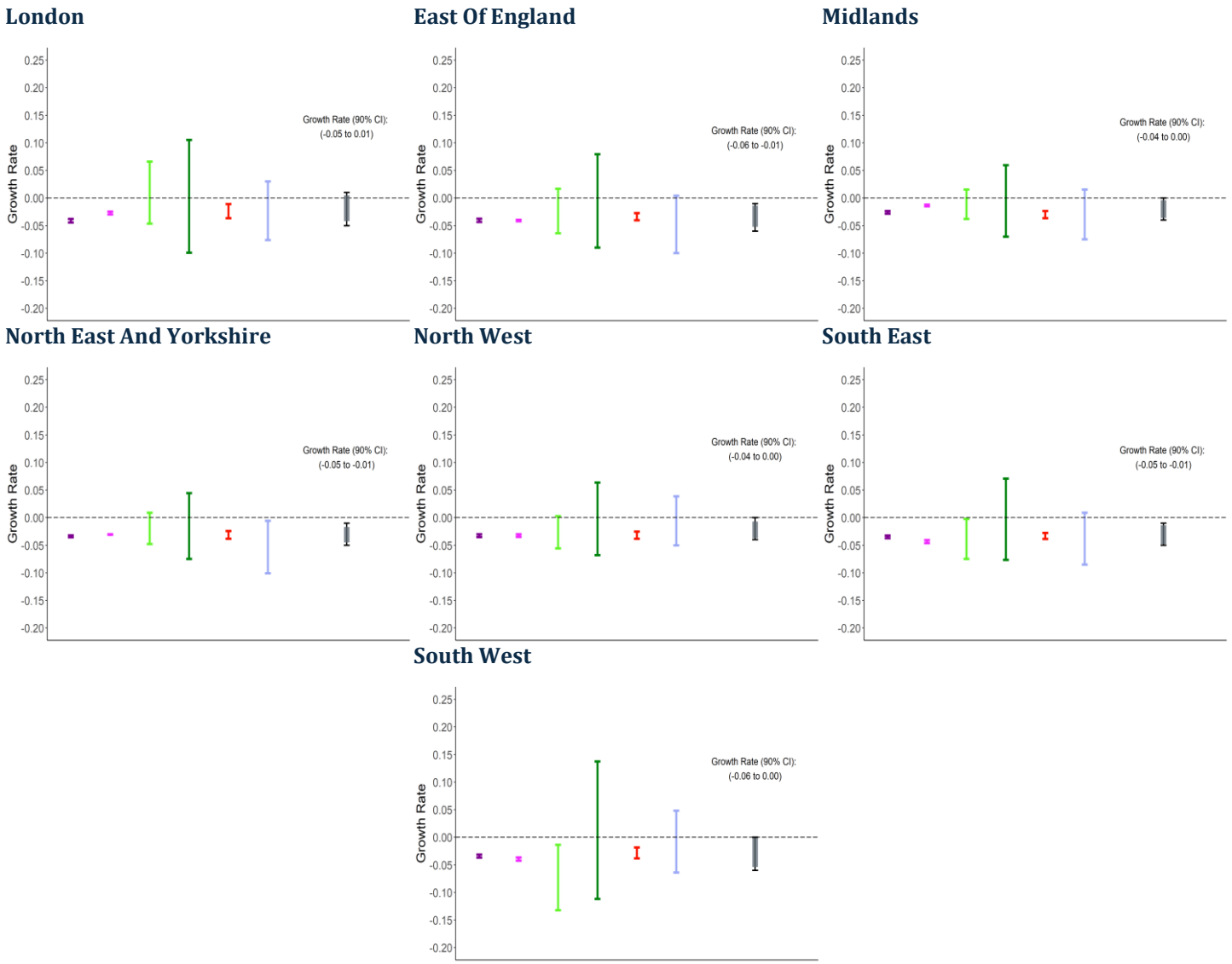

Figure 4: SPI-M groups estimates of median R in the English NHS regions, including 90% confidence intervals. Bars represent different independent estimates. The grey shaded areas represent the combined numerical range and the black bars are the combined range after rounding to 1 decimal place.