11. Using R to Support Simulation Input and Output Analysis

A Case Study with System Dynamics

Using the tidyverse to support simulation

- Tidying input data
- Analysing simulation output
- Running sensitivity analysis

NOTES AND INSIGHTS

Input and output data analysis for system dynamics modelling using the tidyverse libraries of R

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(1) Tidying input data

Table 2. Time series influenza data from the 1957 pandemic (U.K. data)

Week	Young	Child	Adult	Elderly
1	0	0	1	1
2	0	2	6	1
3	0	2	4	2
4	23	73	63	11
5	63	208	173	41
6	73	207	171	27
7	66	150	143	7
8	26	40	87	29
9	17	18	33	12
10	3	4	13	6
11	2	6	16	5
12	1	6	11	3
13	0	1	6	5
14	0	2	2	2
15	0	1	3	0
16	0	1	4	6
17	0	1	3	0
18	2	1	7	1
19	1	1	6	2

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Using **readr** to access data

```
inc <- read_csv("../../11 simulation/code/sdr_paper1/data/I
```

```
## Parsed with column specification:
## cols(
##   Week = col_double(),
##   Young = col_double(),
##   Child = col_double(),
##   Adult = col_double(),
##   Elderly = col_double()
## )
```

```
slice(inc,1:2)
```

```
## # A tibble: 2 x 5
##    Week Young Child Adult Elderly
##   <dbl> <dbl> <dbl> <dbl>   <dbl>
## 1     1     0     0     1       1
## 2     2     0     2     6       1
```

Convert to Tidy Data

```
t_inc <- gather(inc,Cohort,Incidence,Young:Elderly)
slice(t_inc,1:8)
```

```
## # A tibble: 8 x 3
##    Week Cohort Incidence
##   <dbl> <chr>      <dbl>
## 1     1 Young          0
## 2     2 Young          0
## 3     3 Young          0
## 4     4 Young         23
## 5     5 Young         63
## 6     6 Young         73
## 7     7 Young         66
## 8     8 Young         26
```

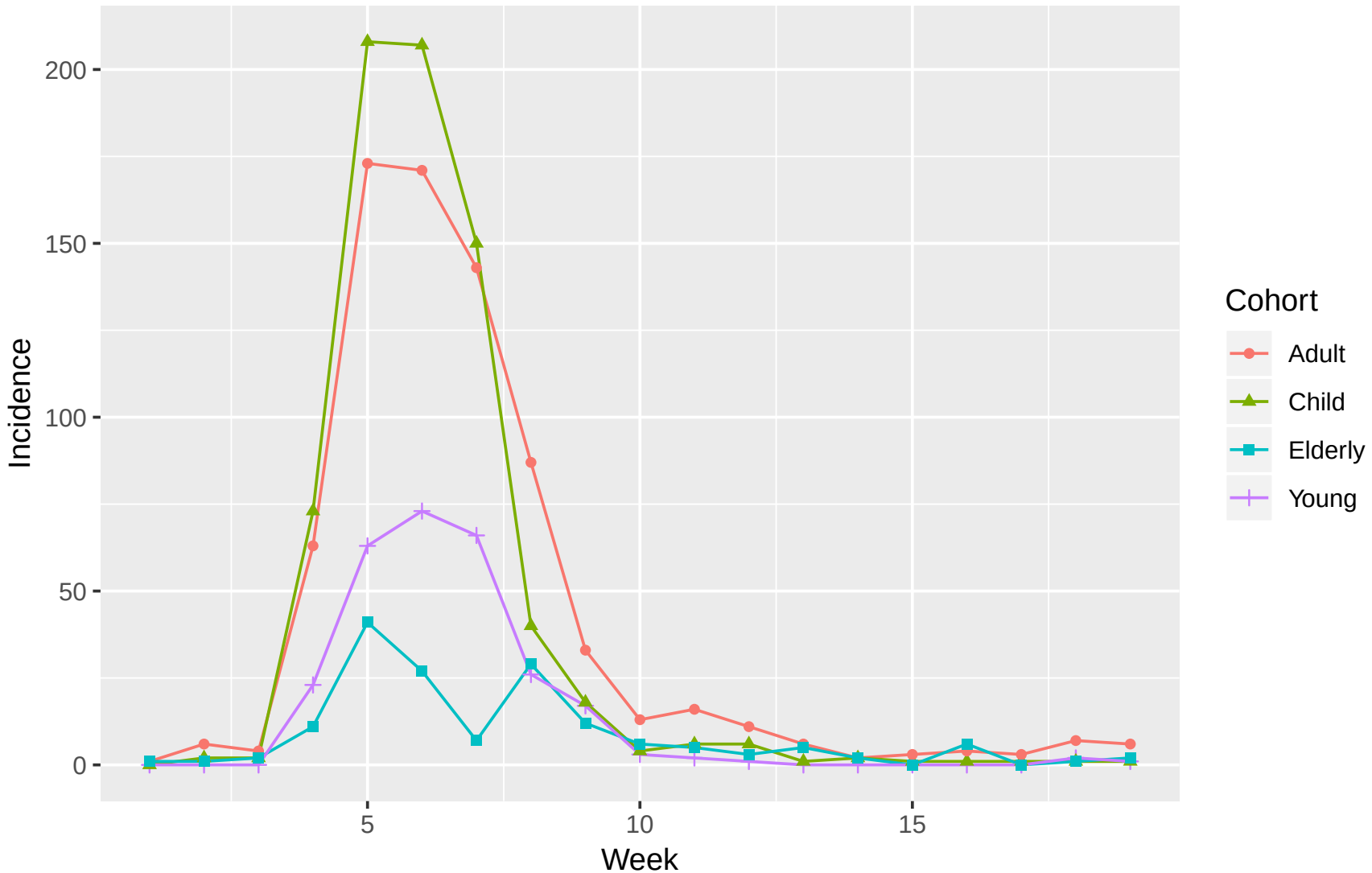
Summarise Data

```
wk_tot <- t_inc %>% group_by(Week) %>%
  summarise(Incidence=sum(Incidence)) %>%
  arrange(desc(Incidence))
slice(wk_tot,1:6)
```

```
## # A tibble: 6 x 2
##    Week Incidence
##   <dbl>     <dbl>
## 1     5       485
## 2     6       478
## 3     7       366
## 4     8       182
## 5     4       170
## 6     9        80
```

Plot tidy data

```
ggplot(t_inc,aes(x=Week,y=Incidence,color=Cohort,
                 shape=Cohort)) +
    geom_line() + geom_point()
```



Descriptive Statistics

```
t_coh <- t_inc %>%
           group_by(Cohort) %>%
           summarise(TotalInfected=sum(Incidence),
                     PeakValue=max(Incidence),
    PeakWeek=Week[which(Incidence==max(Incidence))],
                     AvrValue=mean(Incidence),
                     SD=sd(Incidence))
t_coh
```

```
## # A tibble: 4 x 6
##   Cohort  TotalInfected PeakValue PeakWeek AvrValue    S
##   <chr>           <dbl>     <dbl>    <dbl>    <dbl> <dbl
## 1 Adult             752       173        5     39.6   59.
## 2 Child             724       208        5     38.1   70.
## 3 Elderly           161        41        5      8.47  11.
## 4 Young             277        73        6     14.6   24.
```

(2) Analysing Simulation Output

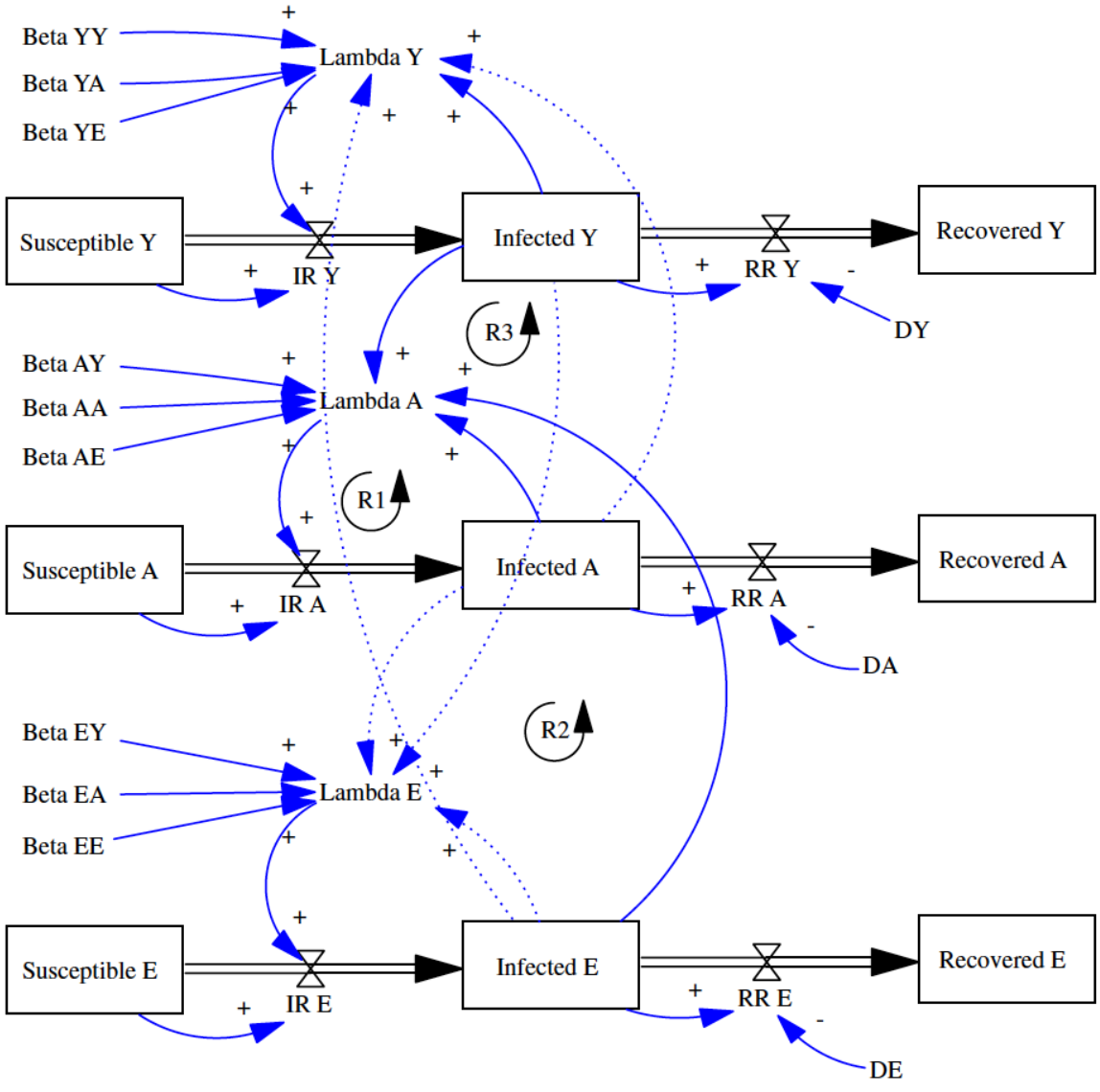


Fig. 3. The SIR Model for three cohorts [Color figure can be viewed at wileyonlinelibrary.com]

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Simulation results - many columns

```
##  [1] "Time"                "Beta AA"             "Beta AE"
##  [4] "Beta AY"             "Beta EA"             "Beta EE"
##  [7] "Beta EY"             "Beta YA"             "Beta YE"
## [10] "Beta YY"             "CE AA"               "CE AE"
## [13] "CE AY"               "CE EA"               "CE EE"
## [16] "CE EY"               "CE YA"               "CE YE"
## [19] "CE YY"               "DA"                  "DE"
## [22] "DY"                  "Infected A"          "Infected E"
## [25] "Infected Y"          "IR A"                "IR E"
## [28] "IR Y"                "Lambda A"            "Lambda E"
## [31] "Lambda Y"            "Pop A"               "Pop E"
## [34] "Pop Y"               "Prop A Infected"     "Prop E Infec
## [37] "Prop Y Infected"     "Recovered A"         "Recovered E"
## [40] "Recovered Y"         "RR A"                "RR E"
## [43] "RR Y"                "Susceptible A"       "Susceptible
## [46] "Susceptible Y"       "Total Population"
```

Selecting the stocks

```
out <- res %>%
         select(Time,starts_with("Susceptible"),
                     starts_with("Infected"),
                     starts_with("Recovered"))
glimpse(out)
```

```
## Observations: 161
## Variables: 10
## $ Time              <dbl> 0.000, 0.125, 0.250, 0.375, 0.50
## $ `Susceptible A`   <dbl> 50000, 50000, 50000, 50000, 500
## $ `Susceptible E`   <dbl> 25000, 25000, 25000, 25000, 250
## $ `Susceptible Y`   <dbl> 25000, 25000, 25000, 25000, 250
## $ `Infected A`      <dbl> 0.00000, 0.00000, 0.01562, 0.054
## $ `Infected E`      <dbl> 0.0000, 0.1250, 0.2891, 0.5083,
## $ `Infected Y`      <dbl> 1.000, 1.312, 1.738, 2.321, 3.12
## $ `Recovered A`     <dbl> 0.00000, 0.00000, 0.00000, 0.000
## $ `Recovered E`     <dbl> 0.00000, 0.00000, 0.00781, 0.025
## $ `Recovered Y`     <dbl> 0.0000, 0.0625, 0.1445, 0.2532,
```

Convert to tidy format

```
out_td <- out %>%
          gather(key=Variable,value = Amount,
                 `Susceptible A`:`Recovered Y`)
slice(out_td,1:5)
```

```
## # A tibble: 5 x 3
##    Time Variable       Amount
##   <dbl> <chr>           <dbl>
## 1 0     Susceptible A  50000
## 2 0.125 Susceptible A  50000
## 3 0.25  Susceptible A  50000
## 4 0.375 Susceptible A  50000
## 5 0.5   Susceptible A  50000
```

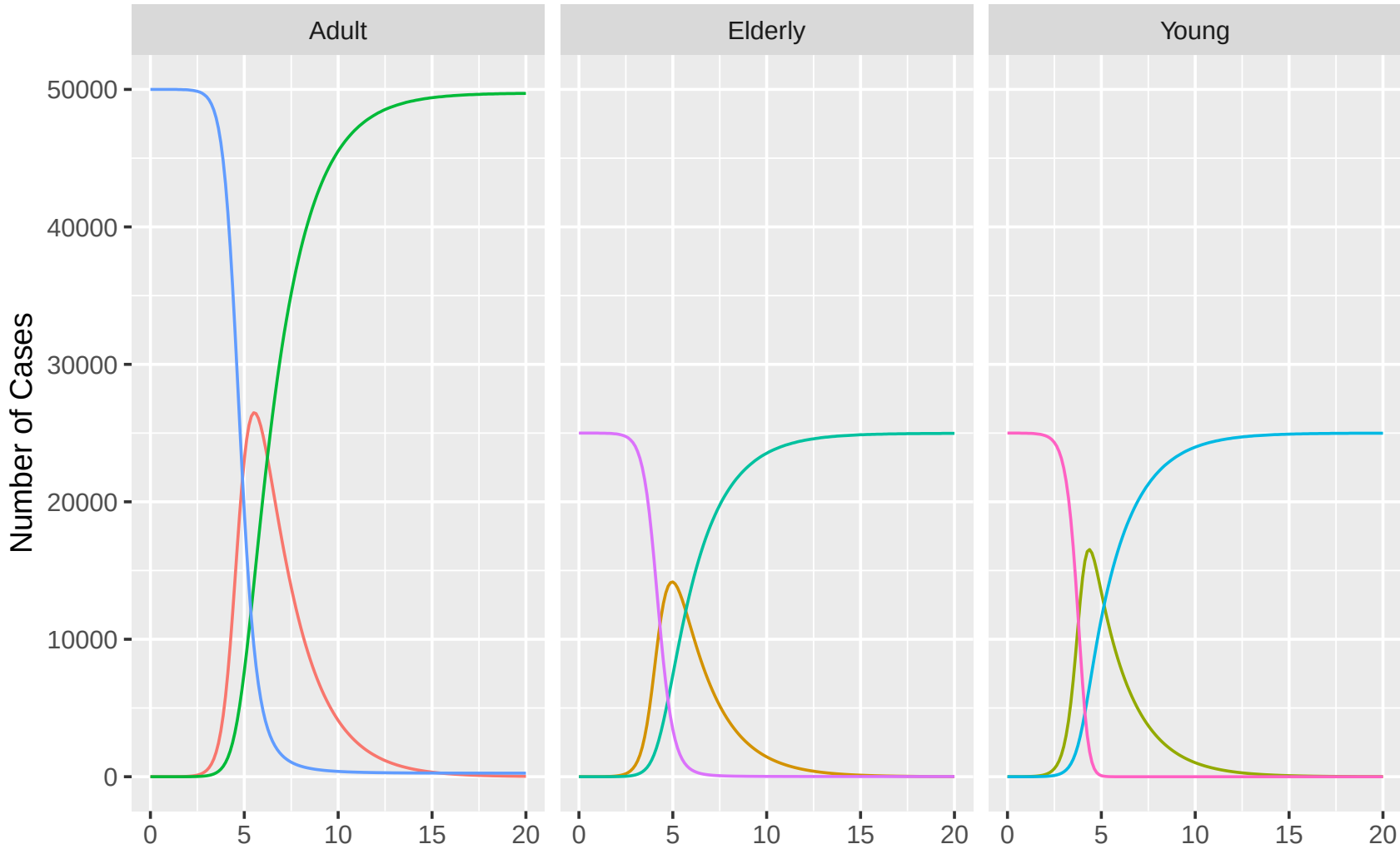
Add cohort and stock information

```
new_td <- out_td %>%
            mutate(Cohort=case_when(
                     grepl("A$",Variable) ~ "Adult",
                     grepl("E$",Variable) ~ "Elderly",
                     grepl("Y$",Variable) ~ "Young"),
                   Class=case_when(
                     grepl("^S",Variable) ~ "Susceptible",
                     grepl("^I",Variable) ~ "Infected",
                     grepl("^R",Variable) ~ "Recovered"))
slice(new_td,1:3)
```

```
## # A tibble: 3 x 5
##    Time Variable       Amount Cohort Class
##   <dbl> <chr>           <dbl> <chr>  <chr>
## 1 0     Susceptible A  50000 Adult  Susceptible
## 2 0.125 Susceptible A  50000 Adult  Susceptible
## 3 0.25  Susceptible A  50000 Adult  Susceptible
```

Display chart

```
ggplot(new_td) +
  geom_path(aes(x=Time,y=Amount,colour=Variable))+
  ylab("Number of Cases")+
  facet_wrap(~Cohort)+guides(colour=F)
```



(3) Exploring Sensitivity Data

```
d <- read_tsv("../../11 simulation/code/sdr_paper1/data/Ser
dim(d)
```

```
## [1] 200 244
```

```
d[1:3,1:5]
```

```
## # A tibble: 3 x 5
##   Simulation    R0      VF `T1 Infected` `T2 Infected`
##        <dbl> <dbl>   <dbl>         <dbl>          <dbl>
## 1          1  2.76 0.0263              1           1.11
## 2          2  2.66 0.0739              1           1.10
## 3          3  4.06 0.159               1           1.19
```

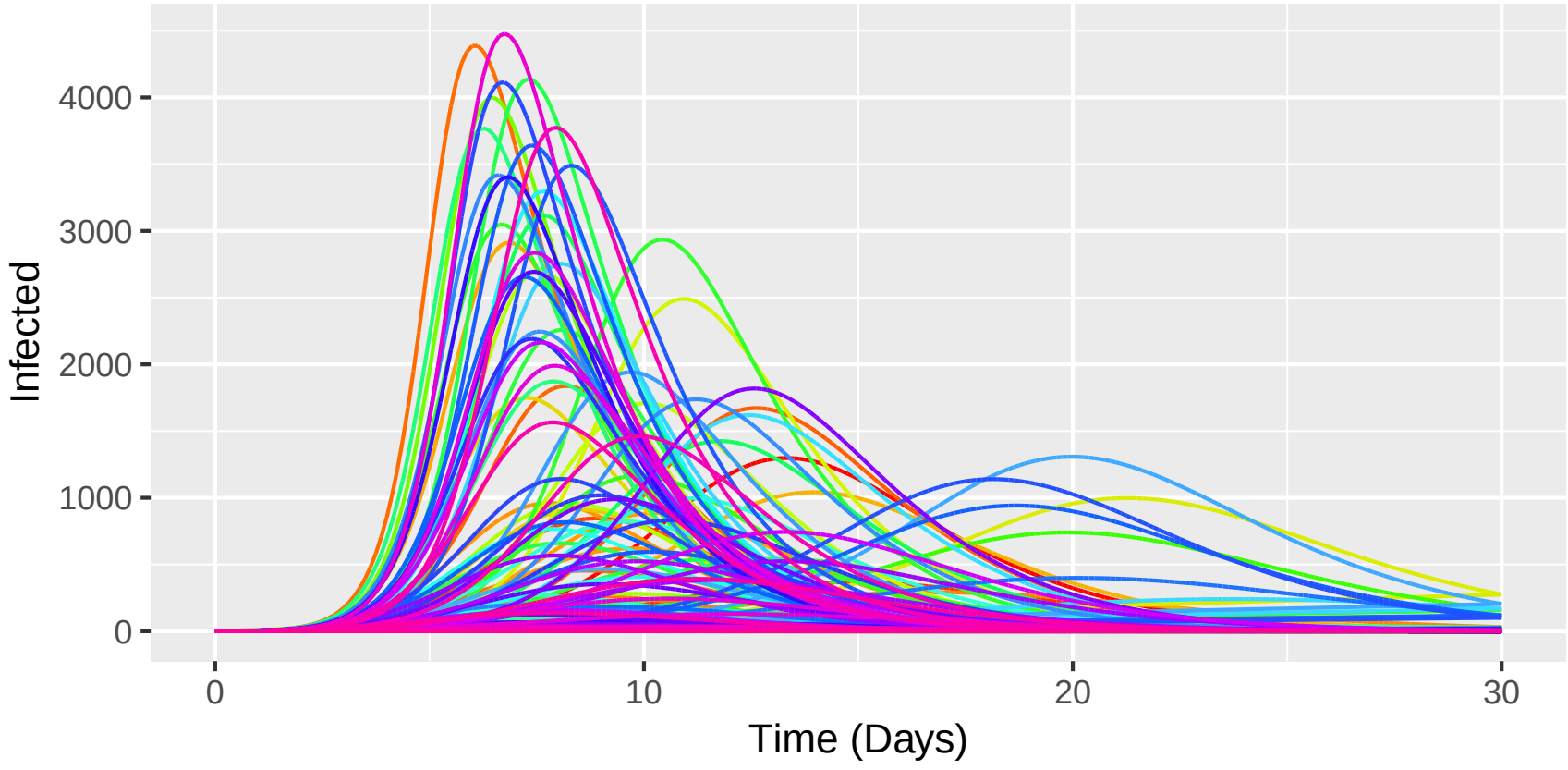
Convert to Tidy Data

```
START_TIME <- 0
DT <- 0.125

td <- gather(d,TimeVariable,Value,-(Simulation:VF)) %>%
  mutate(TSeq=parse_integer(
    str_extract(TimeVariable,"\\d+"))) %>%
  mutate(SimTime=START_TIME+(TSeq-1)*DT) %>%
  separate(TimeVariable,into = c("T","Variable")) %>%
  select(Simulation,SimTime,R0,VF,Variable,Value) %>%
  arrange(Simulation,SimTime)

slice(td,1:2)
```

```
## # A tibble: 2 x 6
##   Simulation SimTime    R0      VF Variable Value
##        <dbl>   <dbl> <dbl>   <dbl> <chr>    <dbl>
## 1          1   0      2.76 0.0263 Infected  1
## 2          1   0.125  2.76 0.0263 Infected  1.11
```

Display simulation traces

```
ggplot(td,aes(x=SimTime,y=Value,color=Simulation)) +
  geom_path() +
  scale_colour_gradientn(colours=rainbow(10))+
  ylab("Infected") + xlab("Time (Days)")  +
  guides(color=FALSE)
```



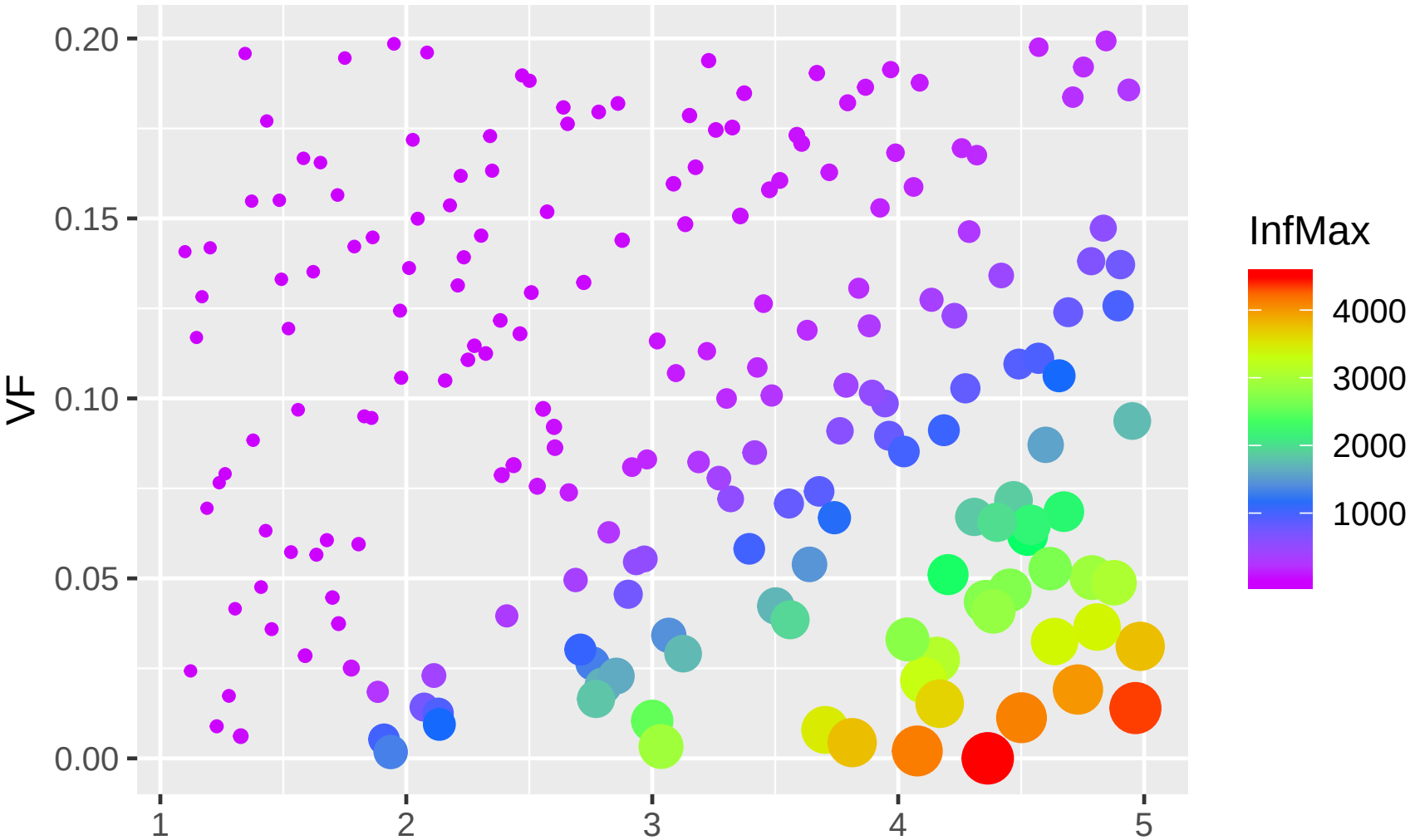
Calculate Summary Data

```
i_td <- td %>% group_by(Simulation) %>%
                  summarise(InfMax=max(Value),
                            R0=R0[1],
                            VF=VF[1])
slice(i_td,1:5)
```

```
## # A tibble: 5 x 4
##   Simulation InfMax    R0      VF
##        <dbl>  <dbl> <dbl>  <dbl>
## 1          1 1298.    2.76 0.0263
## 2          2   78.9   2.66 0.0739
## 3          3  127.    4.06 0.159
## 4          4  367.    2.69 0.0496
## 5          5   14.0   3.23 0.194
```

Explore Parameter Space

```
ggplot(data=i_td,aes(x=R0,y=VF,size=InfMax,colour=InfMax))
  geom_point() +
  scale_colour_gradientn(colours=rev(rainbow(5)))+
  guides(size=F)
```



Conclusion

Conclusion

While R is primarily viewed as a toolset to support data scientists, innovative new libraries such as the `tidyverse` can be leveraged to support the system dynamics model-building process. This paper has shown how time series data can be accessed and manipulated, and how the entire model output from a simulation run can be processed for informative summaries and for data visualisation. A further application of the `tidyverse` is to support the process of analysing large datasets produced through sensitivity analysis of system dynamics models.

Test Slide with Plot