

Trajectory Mapping Results

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25 March, 2021

```
## -- Attaching packages ----- tidyverse 1.3.0 --
```

```
## v ggplot2 3.3.0      v purrr  0.3.3
```

```
## v tibble  3.0.0      v dplyr  1.0.2
```

```
## v tidyr   1.0.2      v stringr 1.4.0
```

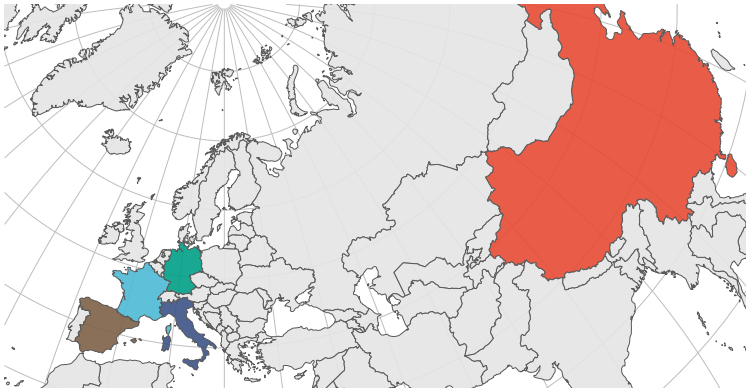
```
## v readr   1.3.1      v forcats 0.5.0
```

```
## -- Conflicts ----- tidyverse_conflicts() --
```

```
## x dplyr::filter() masks stats::filter()
```

```
## x dplyr::lag()     masks stats::lag()
```

Deme configuration



demeID	deme	division	country	region	exclude_country	min_date	max_date
2	China		China	Asia		2019-12-24	2020-01-23
0	France		France	Europe		2020-01-23	2020-03-08
1	Germany		Germany	Europe		2020-01-28	2020-03-08
3	Italy		Italy	Europe		2020-01-29	2020-03-08
4	OtherEuropean			Europe	France,Germany,Italy,Spain	2020-01-29	2020-03-08
5	Spain		Spain	Europe		2020-02-24	2020-03-08

Table 2: Total number of cases reported to ECDC on March 8, 2020

deme	c19od	ecdc	owid
China	80904	80768	80222
France	963	613	948
Germany	902	684	799
Italy	6007	4636	5883
OtherEuropean	2183	1561	1760
Spain	1136	764	500

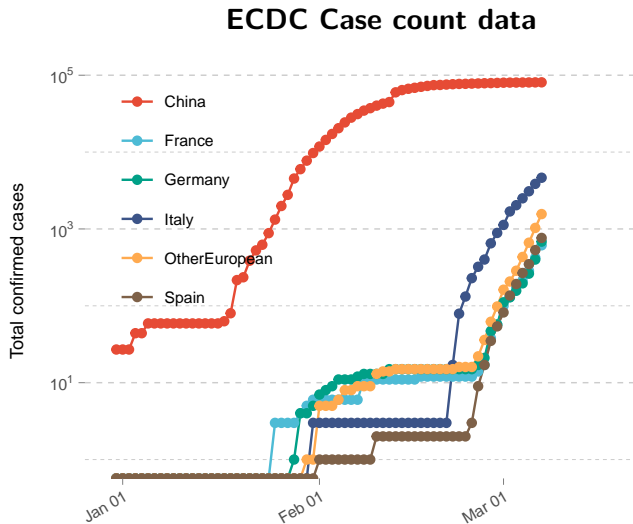


Figure 1: ECDC case counts for each deme from the beginning of the pandemic to March 8, 2020

Epidemic trajectory data

From the Stochastic Trajectory Mapping analysis, we sample with importance sampling one epidemic trajectory per set of parameters + typed node tree from the set of simulated trajectories.

The processing of the trajectory data includes the generation of two different datasets:

- **states:** We have the total number of inferred cases by trajectory, deme and time.
- **events:** We have each event that happened in a epidemic trajectory, with its type (origin, birth, death or migration), the source/destination deme and time.

Epidemic trajectory data

We use the events dataset to compute quantities of interest:

- B: transmissions (births) events
- D: becoming uninfected (deaths) events
- IM: migrations into the deme
- OM: migrations out of the deme
- S: sampling events
- O: origin
- in_pop : origin + transmissions + incoming migrations
- out_pop : deaths + outgoing migration + sampling events
- active_pop : origin + transmissions + incoming migrations - (deaths + outgoing migration + sampling events)

Epidemic trajectory data

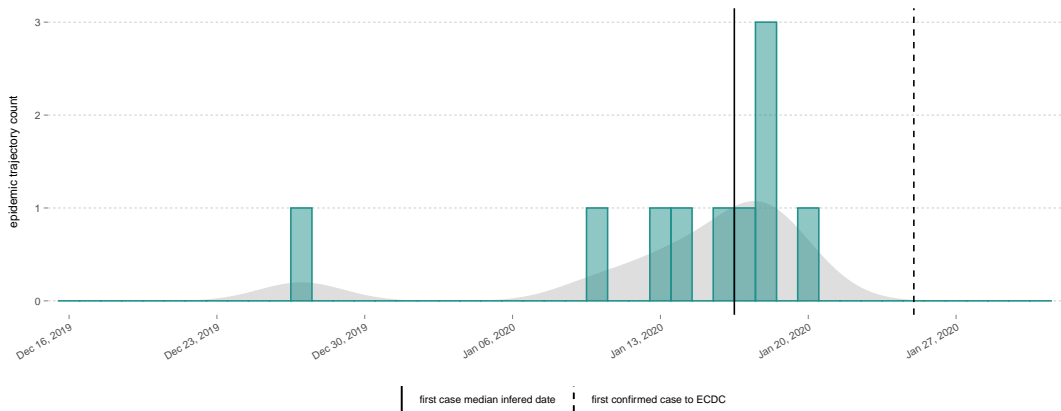
Table 3: Trajectories dataset

traj	var	deme	partner	date	value	cumvalue
1	active_pop	China		2019-12-08	1	1
1	in_pop	China		2019-12-08	1	1
1	O	China		2019-12-08	1	1
1	active_pop	China		2019-12-10	1	2
1	B	China		2019-12-10	1	1

To have a feasible time of analysis of the epidemic trajectories we take a random subsample of 500 trajectories.

To facilitate visualization and summarise the results, we take a grid time of 1 day and summarise the number of events that day as the sum of the events in the corresponding time interval; and the number of inferred cases as the maximum of the interval.

Origin of SARS-CoV-2 in Europe

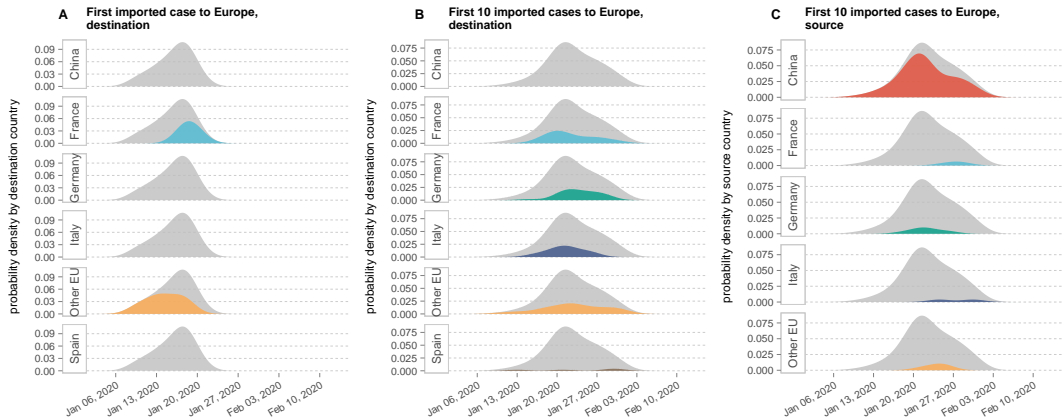


Median date: 2020-01-16

95% CCI: (2019-12-27, 2020-01-20)

ECDC first confirmed case: 2020-01-25

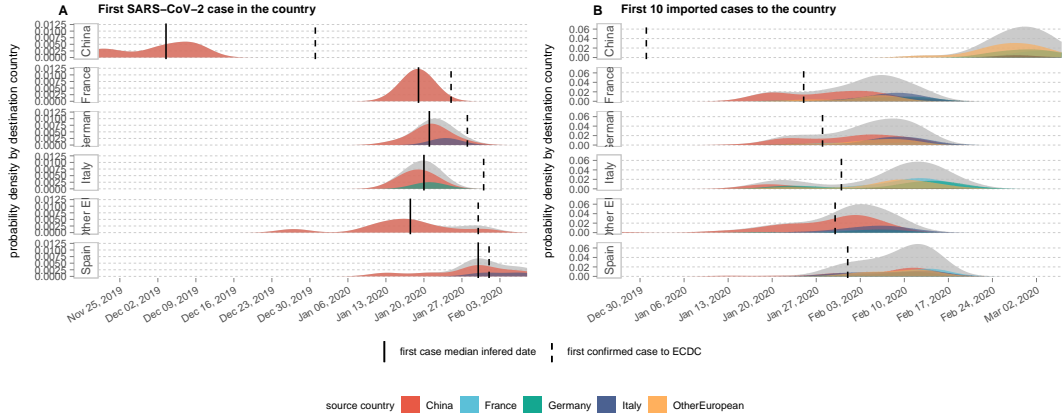
First imported cases to Europe, time and location



First imported cases to Europe, time and location

deme	n_1d	p_1d	n_10d	p_10d	n_10s	p_10s
France	3	0.3	25	0.25	4	0.04
Italy	1	0.1	20	0.20	4	0.04
OtherEuropean	6	0.6	30	0.30	7	0.07

First introductions to each country, source



First introductions to each country, source

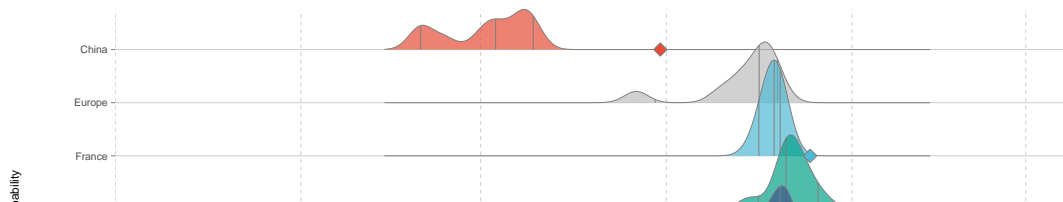
deme	m	l	h
China	2019-12-03	2019-11-21	2019-12-10
France	2020-01-19	2020-01-16	2020-01-20
Germany	2020-01-21	2020-01-15	2020-01-27
Italy	2020-01-20	2020-01-16	2020-01-22
OtherEuropean	2020-01-17	2019-12-27	2020-01-31
Spain	2020-01-30	2020-01-13	2020-02-08

deme	partner	n_1s	p_1s
China	China	10	1.0
France	China	10	1.0
Germany	China	8	0.8
Germany	Italy	2	0.2
Italy	China	7	0.7
Italy	Germany	2	0.2
Italy	OtherEuropean	1	0.1
OtherEuropean	China	9	0.9
OtherEuropean	France	1	0.1
Spain	China	7	0.7
Spain	Germany	1	0.1
Spain	Italy	2	0.2

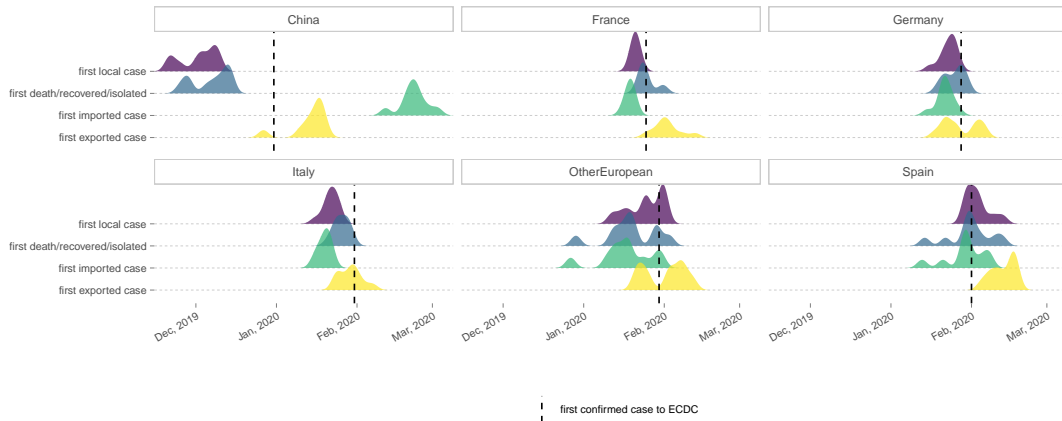
First introductions to each country, source

deme	partner	n_10s	p_10s
China	France	16	0.16
China	Germany	22	0.22
China	Italy	2	0.02
China	OtherEuropean	43	0.43
China	Spain	4	0.04
France	China	49	0.49
France	Germany	15	0.15
France	Italy	21	0.21
France	OtherEuropean	14	0.14
France	Spain	1	0.01
Germany	China	47	0.47
Germany	France	11	0.11
Germany	Italy	23	0.23
Germany	OtherEuropean	18	0.18
Germany	Spain	1	0.01

deme	partner	n_10s	p_10s
Italy	China	11	0.11
Italy	France	31	0.31
Italy	Germany	28	0.28
Italy	OtherEuropean	28	0.28
Italy	Spain	2	0.02
OtherEuropean	China	64	0.64
OtherEuropean	France	8	0.08
OtherEuropean	Germany	8	0.08
OtherEuropean	Italy	20	0.20
Spain	China	25	0.25
Spain	France	22	0.22
Spain	Germany	12	0.12
Spain	Italy	21	0.21
Spain	OtherEuropean	20	0.20



Events timing

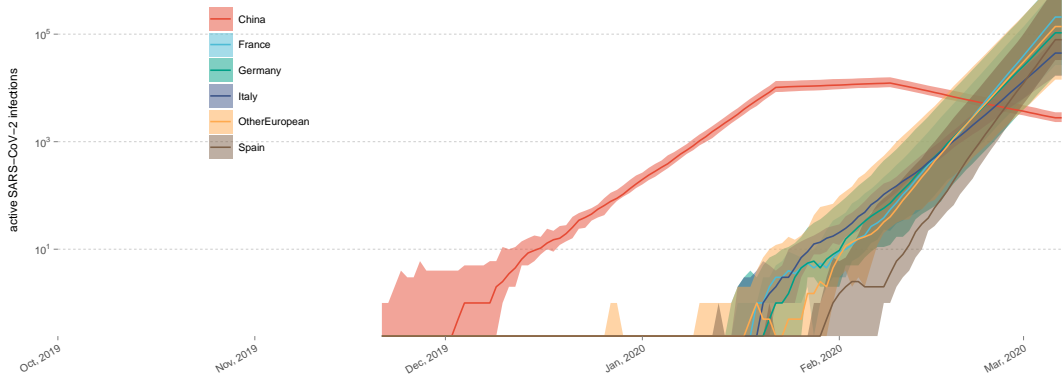


Events timing

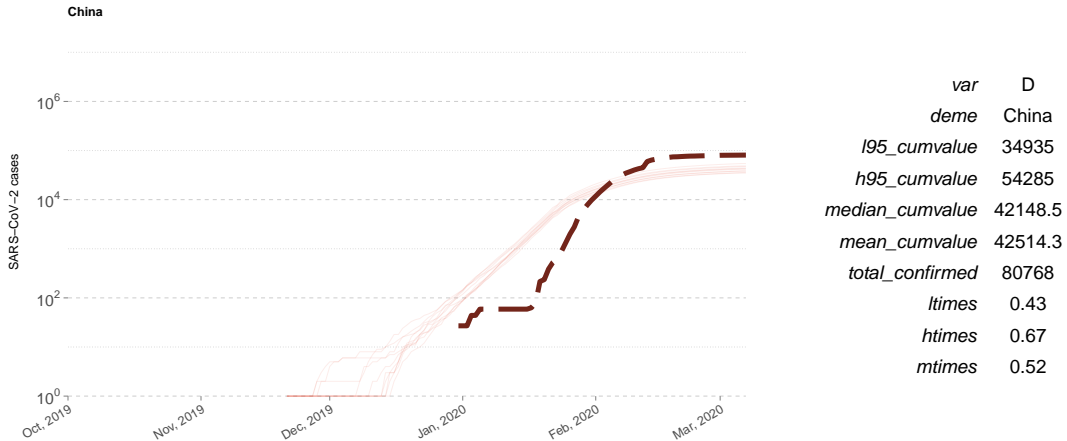
deme	var	m	l	h
China	B	2019-12-03	2019-11-21	2019-12-10
China	D	2019-12-09	2019-11-25	2019-12-14
China	IM	2020-02-23	2020-02-12	2020-03-03
China	OM	2020-01-16	2019-12-27	2020-01-20
France	B	2020-01-21	2020-01-20	2020-01-22
France	D	2020-01-24	2020-01-22	2020-02-01
France	IM	2020-01-19	2020-01-16	2020-01-20
France	OM	2020-02-01	2020-01-25	2020-02-13
Germany	B	2020-01-24	2020-01-16	2020-01-27
Germany	D	2020-01-26	2020-01-19	2020-01-30
Germany	IM	2020-01-21	2020-01-15	2020-01-27
Germany	OM	2020-01-26	2020-01-18	2020-02-06

deme	var	m	l	h
Germany	OM	2020-01-26	2020-01-18	2020-02-06
Italy	B	2020-01-22	2020-01-16	2020-01-25
Italy	D	2020-01-26	2020-01-21	2020-01-30
Italy	IM	2020-01-20	2020-01-16	2020-01-22
Italy	OM	2020-01-30	2020-01-24	2020-02-07
OtherEuropean	B	2020-01-25	2020-01-12	2020-02-01
OtherEuropean	D	2020-01-19	2019-12-29	2020-02-03
OtherEuropean	IM	2020-01-17	2019-12-27	2020-01-31
OtherEuropean	OM	2020-02-03	2020-01-21	2020-02-12
Spain	B	2020-02-02	2020-01-30	2020-02-13
Spain	D	2020-01-31	2020-01-14	2020-02-13
Spain	IM	2020-01-30	2020-01-13	2020-02-08
Spain	OM	2020-02-14	2020-02-05	2020-02-18

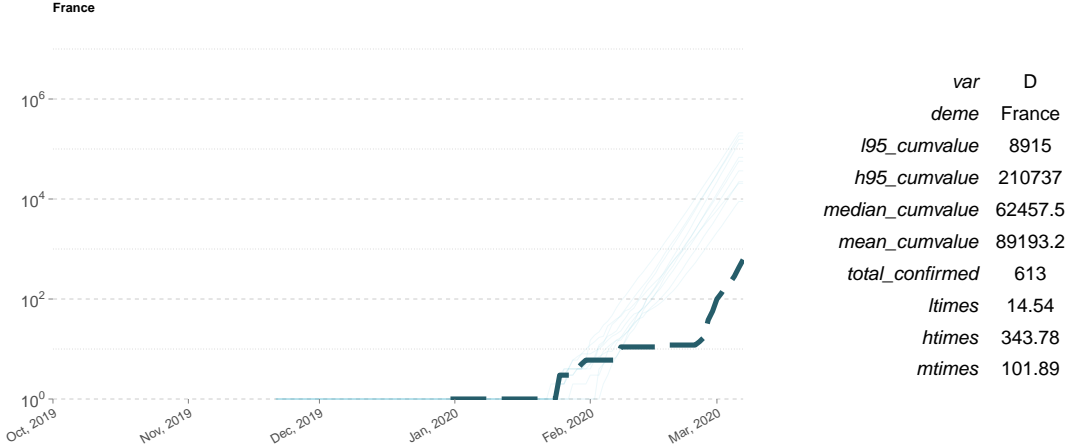
Summarised epidemic trajectories



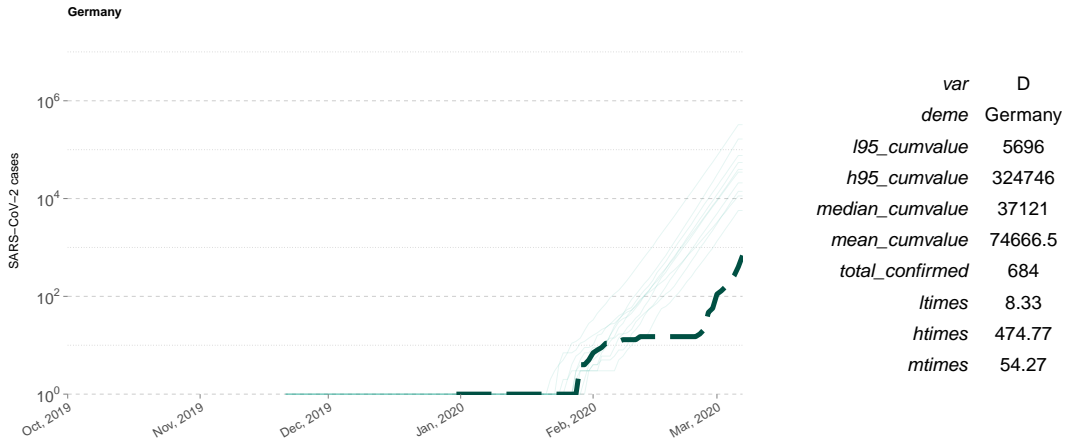
Inferred case counts - China



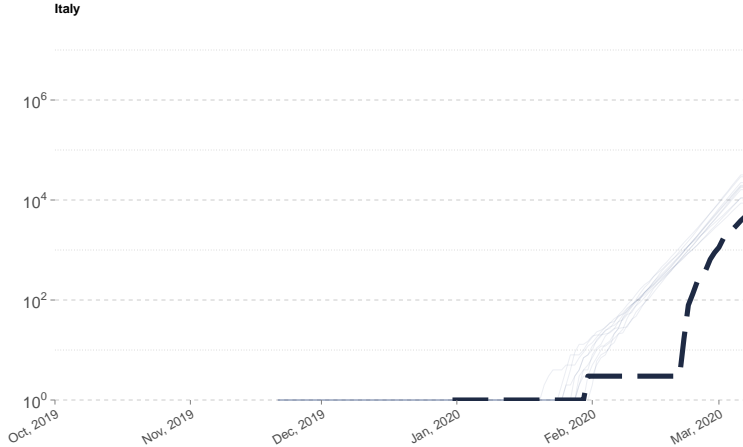
Inferred case counts - France



Inferred case counts - Germany

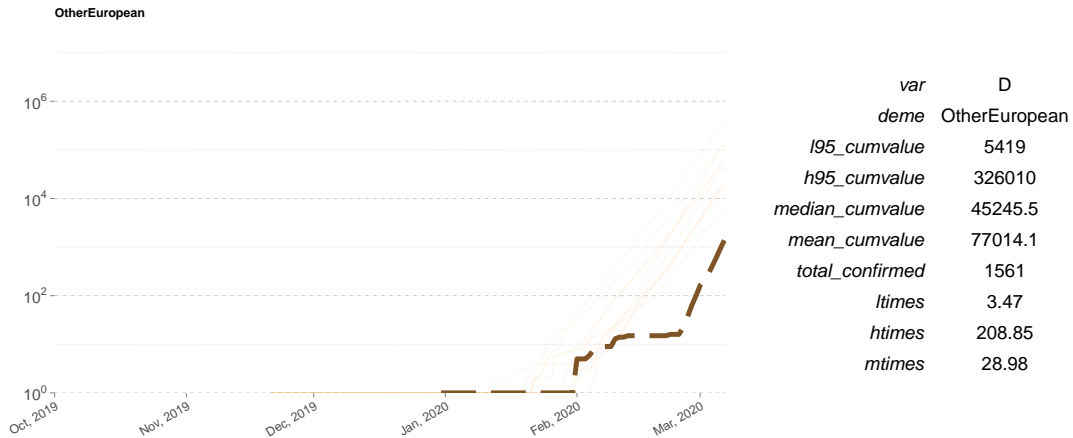


Inferred case counts - Italy

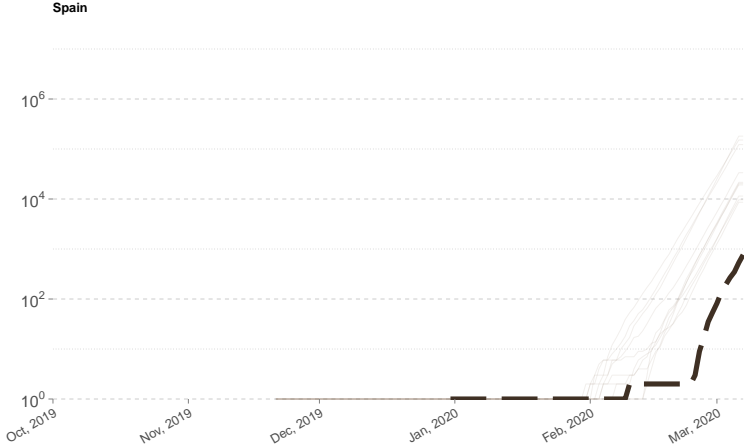


<i>var</i>	D
<i>deme</i>	Italy
<i>l95_cumvalue</i>	8637
<i>h95_cumvalue</i>	31756
<i>median_cumvalue</i>	18362
<i>mean_cumvalue</i>	18631.8
<i>total_confirmed</i>	4636
<i>ltimes</i>	1.86
<i>htimes</i>	6.85
<i>mtimes</i>	3.96

Inferred case counts - OtherEuropean

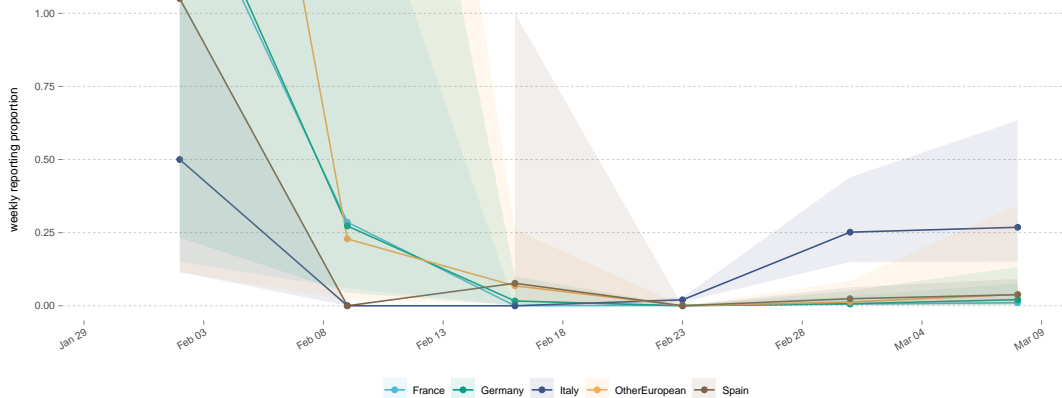


Inferred case counts - Spain



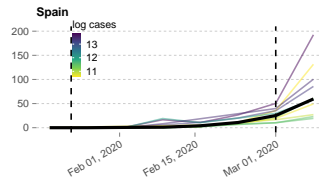
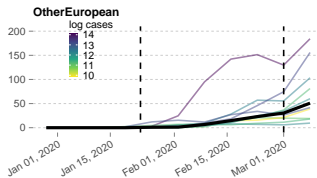
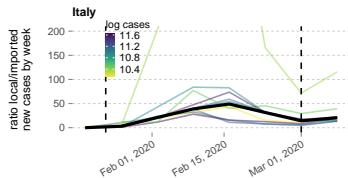
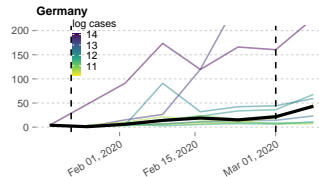
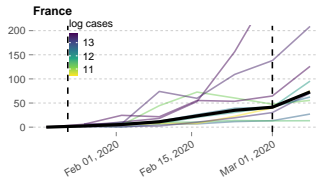
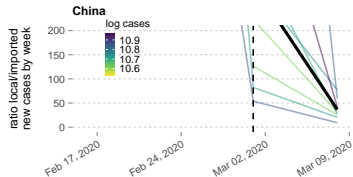
var	D
deme	Spain
l95_cumvalue	8610
h95_cumvalue	180798
median_cumvalue	20915
mean_cumvalue	57846.6
total_confirmed	764
ltimes	11.27
htimes	236.65
mtimes	27.38

Weekly confirmed cases proportion



deme	date	l95_cumvalue	h95_cumvalue	median_cumvalue	total_confirmed	median_report	h95_re
China	2020-03-07	34935	54285	42148.5	80768	1.9162722	2.311
France	2020-03-07	8915	210737	62457.5	613	0.0098147	0.068
Germany	2020-03-07	5696	324746	37121.0	684	0.0184262	0.120
Italy	2020-03-07	8637	31756	18362.0	4636	0.2524779	0.536
OtherEuropean	2020-03-07	5419	326010	45245.5	1561	0.0345007	0.288
Spain	2020-03-07	8610	180798	20915.0	764	0.0365288	0.088

Local transmission vs imported cases



Local transmission vs imported cases - China

Local transmission vs imported cases - France

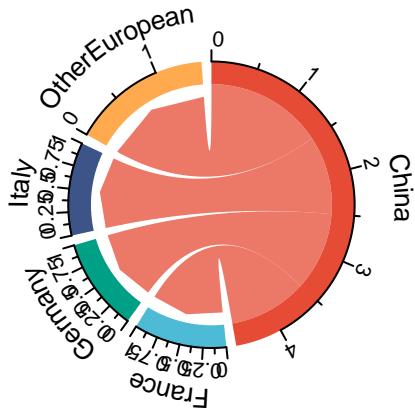
Local transmission vs imported cases - Germany

Local transmission vs imported cases - Italy

Local transmission vs imported cases - OtherEuropean

Local transmission vs imported cases - Spain

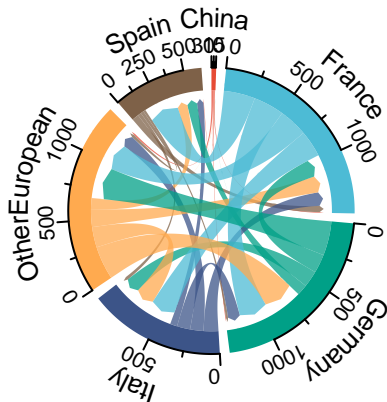
Migrations - Period 1



partner	deme	Nm
China	France	1.0
China	Germany	1.0
China	Italy	1.0
China	OtherEuropean	1.5

```
## $df
## # A tibble: 30 x 3
##   partner deme      Nm
##   <chr>   <fct>    <dbl>
## 1 China   France     1
## 2 China   Germany    1
```

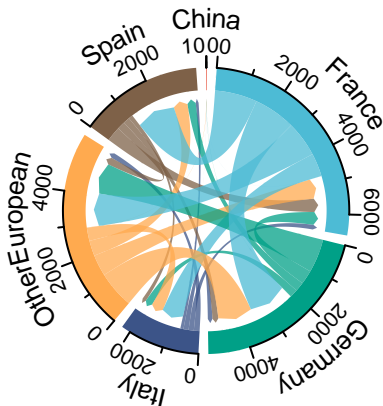
Migrations - Period 2



```
## $df
## # A tibble: 30 x 3
##   partner deme      Nm
##   <chr>   <fct>   <dbl>
## 1 China   France     6
## 2 China   Germany    6
```

partner	deme	Nm
China	France	6.0
China	Germany	6.0
China	OtherEuropean	13.5
China	Spain	4.0
France	Germany	252.0
France	Italy	217.0
France	OtherEuropean	234.5
France	Spain	257.5
Germany	China	1.0
Germany	France	153.0
Germany	Italy	134.5
Germany	OtherEuropean	280.0
Germany	Spain	88.5
Italy	France	122.0
Italy	Germany	108.0
Italy	OtherEuropean	108.5
Italy	Spain	58.0
OtherEuropean	China	2.0
OtherEuropean	France	146.0
OtherEuropean	Germany	273.0
OtherEuropean	Italy	167.0
OtherEuropean	Spain	88.5
Spain	France	56.0
Spain	Germany	19.5
Spain	Italy	28.0
Spain	OtherEuropean	25.0

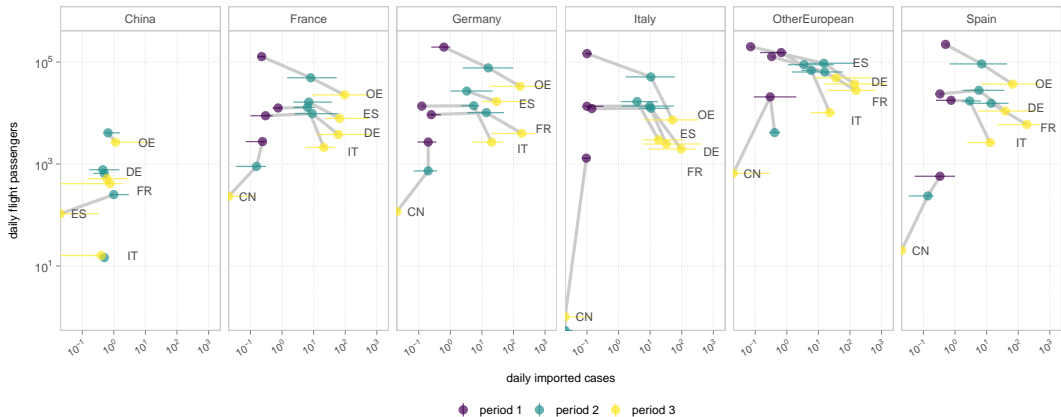
Migrations - Period 3



```
## $df
## # A tibble: 30 x 3
##   partner deme      Nm
##   <chr>   <fct>    <dbl>
## 1 China   France      0
## 2 China   Germany      0
```

partner	deme	Nm
France	China	3.0
France	Germany	1388.0
France	Italy	770.5
France	OtherEuropean	1178.0
France	Spain	1405.0
Germany	China	5.0
Germany	France	465.5
Germany	Italy	267.0
Germany	OtherEuropean	1115.0
Germany	Spain	306.0
Italy	China	1.0
Italy	France	172.5
Italy	Germany	169.0
Italy	OtherEuropean	192.5
Italy	Spain	104.0
OtherEuropean	China	9.0
OtherEuropean	France	707.0
OtherEuropean	Germany	1235.5
OtherEuropean	Italy	436.0
OtherEuropean	Spain	508.0
Spain	China	1.0
Spain	France	490.5
Spain	Germany	215.5
Spain	Italy	143.0
Spain	OtherEuropean	265.5

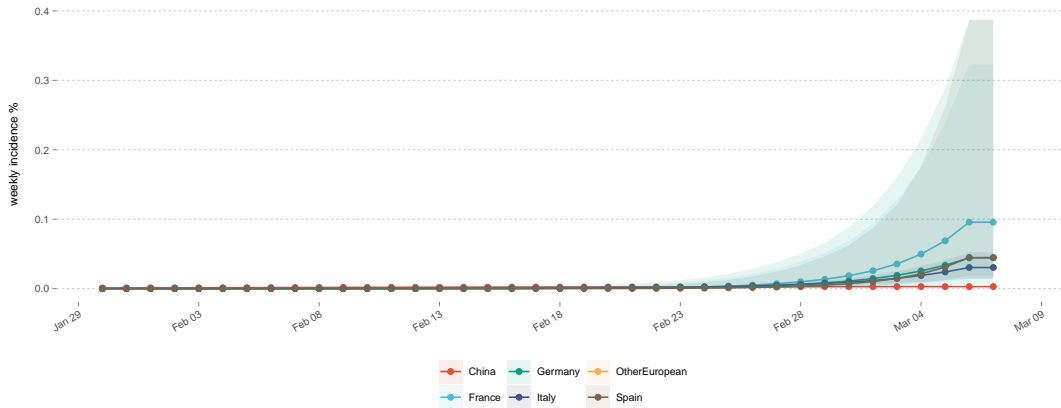
Daily flight passengers vs daily imported cases



Daily flight passengers vs daily imported cases

dest	epoch	v	ev	lev	hev
China	2	5784.536	3.1071429	2.1388889	7.0555556
China	3	3723.258	2.9000000	0.9428571	19.1190476
France	1	152696.194	1.5165751	0.8380952	2.0934066
France	2	89259.321	30.6307016	8.5603448	162.7192994
France	3	36716.903	241.8571429	50.7142857	1911.5714286
Germany	1	222692.435	1.2000000	0.6659091	1.9886364
Germany	2	128893.536	38.7729827	9.2187192	177.7541911
Germany	3	57032.226	394.4285714	54.2857143	1893.0000000
Italy	1	173978.887	0.4383117	0.3885281	0.7440476
Italy	2	94175.714	34.6357036	8.5106975	176.0873858
Italy	3	14780.839	197.9285714	27.0000000	1127.1428571
OtherEuropean	1	503681.419	1.3696742	0.6385281	3.4047619
OtherEuropean	2	320581.036	40.6364639	9.6874713	242.0000000
OtherEuropean	3	125030.742	355.8571429	46.4285714	2576.4285714
Spain	1	264647.581	1.9166667	1.1359649	2.8333333
Spain	2	153106.214	29.6131164	6.7811584	136.9679803
Spain	3	56485.710	305.1428571	35.8571429	1326.8571429

Weekly incidence population



Weekly incidence population percentage

deme	population	date	l95_cumvalue	h95_cumvalue	median_cumvalue	median_inc	h95_inc
China	1439323774	2020-03-07	34935	54285	42148.5	0.0029284	0.0024272
France	65273512	2020-03-07	8915	210737	62457.5	0.0956858	0.0136579
Germany	83783945	2020-03-07	5696	324746	37121.0	0.0443056	0.0067984
Italy	60461828	2020-03-07	8637	31756	18362.0	0.0303696	0.0142850
OtherEuropean		2020-03-07	5419	326010	45245.5		
Spain	46754783	2020-03-07	8610	180798	20915.0	0.0447334	0.0184152