Istat | Istituto Nazionale di Statistica

Brussels, 12th March 2025

Conference on New Techniques and Technologies for official Statistics

Mobile Network Operator data for Tourism Statistics: facing the challenge of cross-roaming

Joint work with Egle RÜÜTLI, Margus TIRU, Kadri ARRAK (Positium);

Juan ARRANZ, Miguel PICORNELL, Ricardo HERRANZ (Nommon);

Florabela Carausu (GOPA Worldwide Consultants GmbH)

GOPA WORLDWIDE CONSULTANTS | positium | NOMMON

TIZIANA TUOTO

Istat | DIRECTORATE FOR METHODOLOGY AND STATISTICAL PROCESS DESIGN

Objective of this work

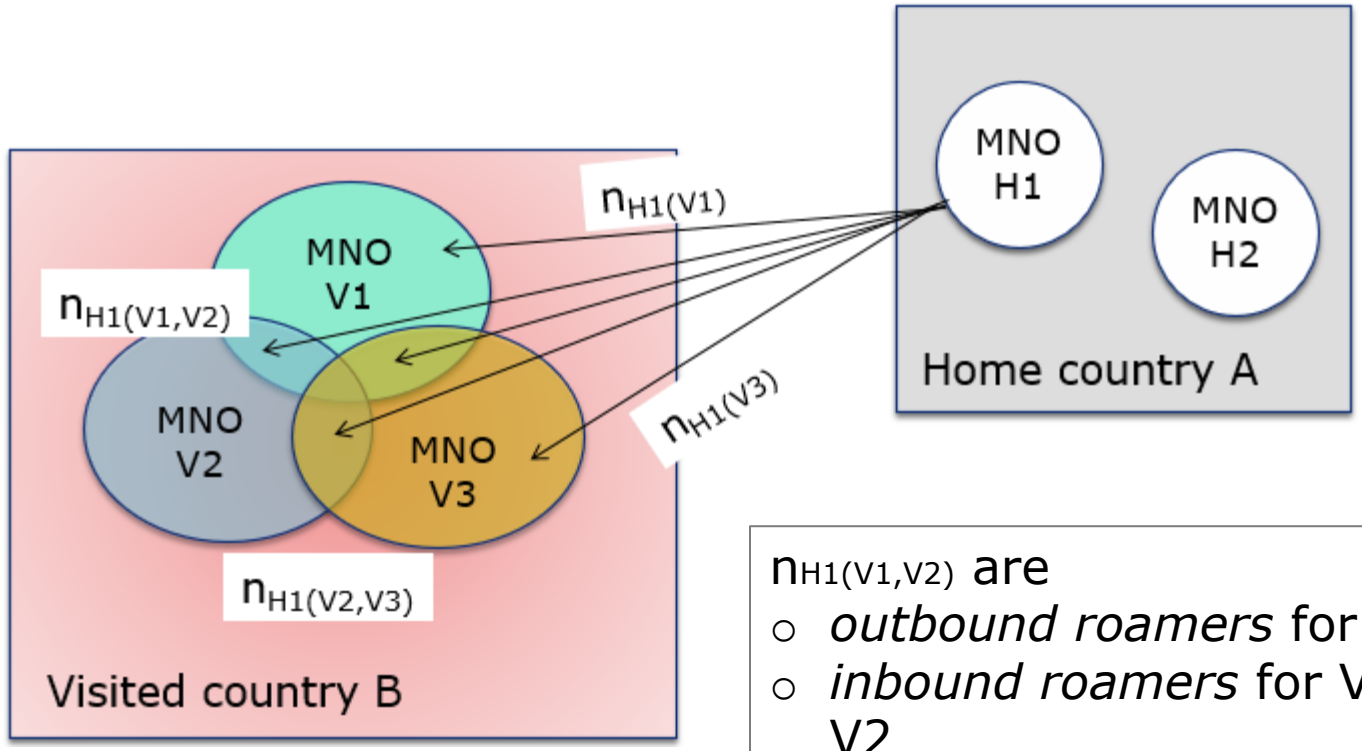
- Tourism and Mobile Network Operator data: investigate the effect of cross-roaming on Inbound tourism indicators
- **Inbound tourism**: visits to a country by visitors who are not residents of that country.
- Main Indicators:
  - ✓ **Arrivals**, the number of persons who arrive at a tourist accommodation and check in
  - ✓ **Overnight stays** aka Nights spent
  - ø NO same day visits in this experiments

Cross-roaming

- **Roaming** is the ability of a mobile device to make or receive voice calls, send or receive messages and data while outside the coverage of its mobile service provider.
- **International roaming**: the phone connects to a non-domestic (foreign) network when traveling abroad.
- **Cross roaming**: the phone connects to several non-domestic (foreign) networks in the same foreign country during the same visit.

$n_{H1} = sum(n_{H1(V1)}, n_{H1(V2)}, n_{H1(V3)}, n_{H1(V1,V2)}, n_{H1(V1,V3)}, n_{H1(V2,V3)}, n_{H1(V1,V2,V3)})$

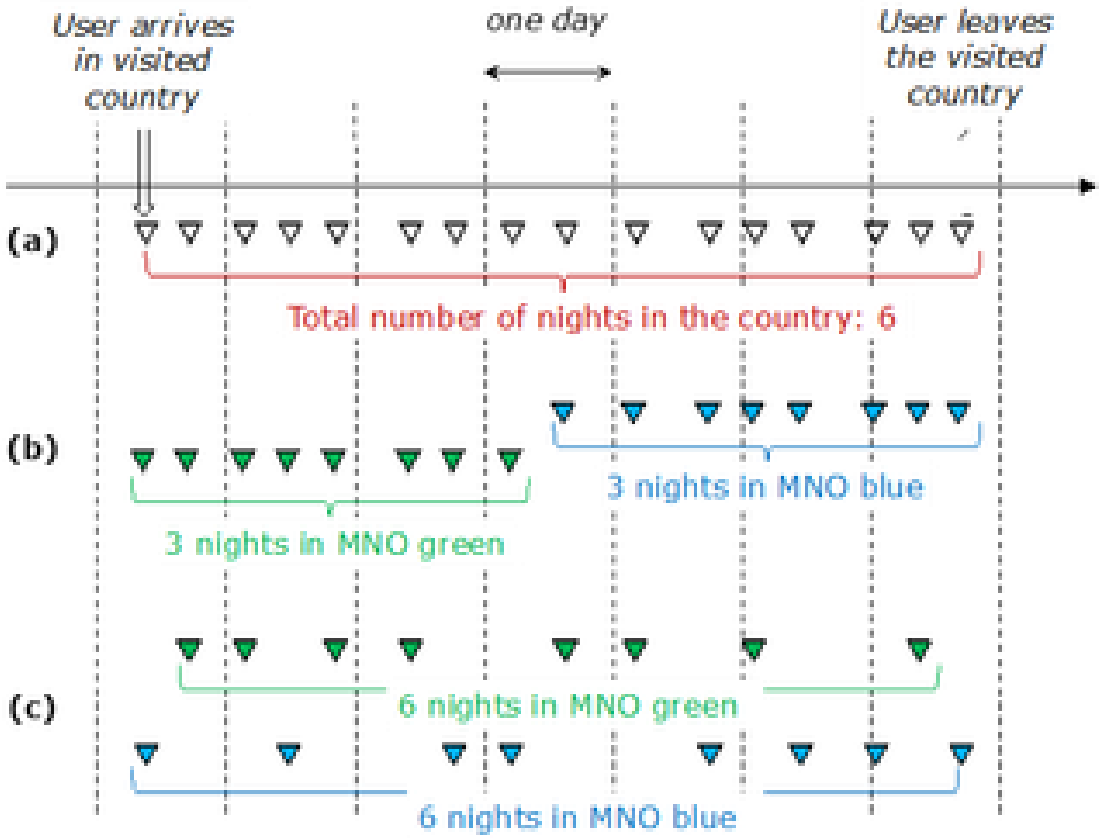
number of home subscribers from MNO H1 in home country A may roam across MNOs V1,V2… in visited country B



$n_{H1(V1,V2)}$ are
- *outbound roamers* for H1
- *inbound roamers* for V1 and V2

Potential effects of cross roaming on inbound tourism

- Complete view of a foreign SIM (inbound tourist) visiting a country for 6 days in red (a).
- Situations (b) and (c): two different cross-roaming behaviours of a single device across two visited MNOs, the blue and the green one



In (b) and (c), the single MNO analysis is partial and may produce biased results for the output indicators.

Similarly, multi-MNO aggregations of single-MNO observations coming from situations (b) and (c) may produce biased results.

Cross roaming on inbound tourism

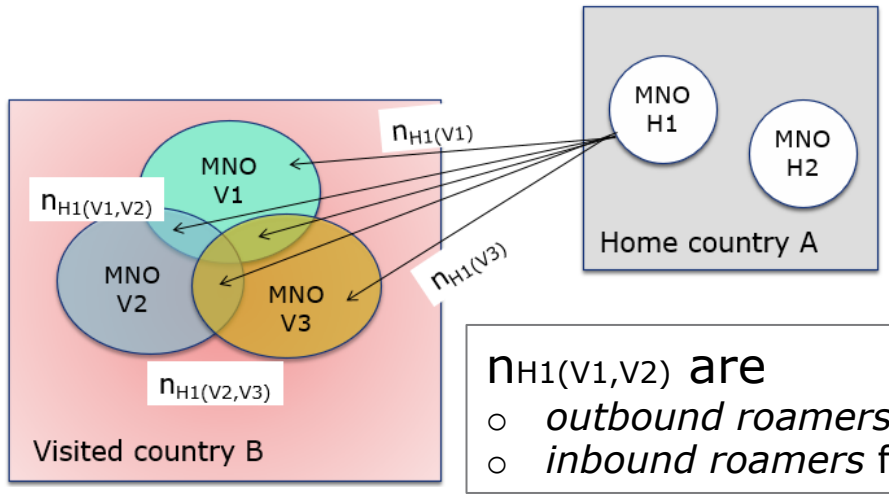
- One would reproduce and analyze the complete event generation if inter-MNO **linking at micro level** is allowed.
  - This requires the adoption of a secure computation environment based on advanced Privacy-Enhancing Technologies to comply with GDPR.
- Alternatively, **statistical methods** can be used to reduce/remove the bias in nights spent and arrivals based on multi-MNO aggregations of single-MNO counts.

In this work we investigate:

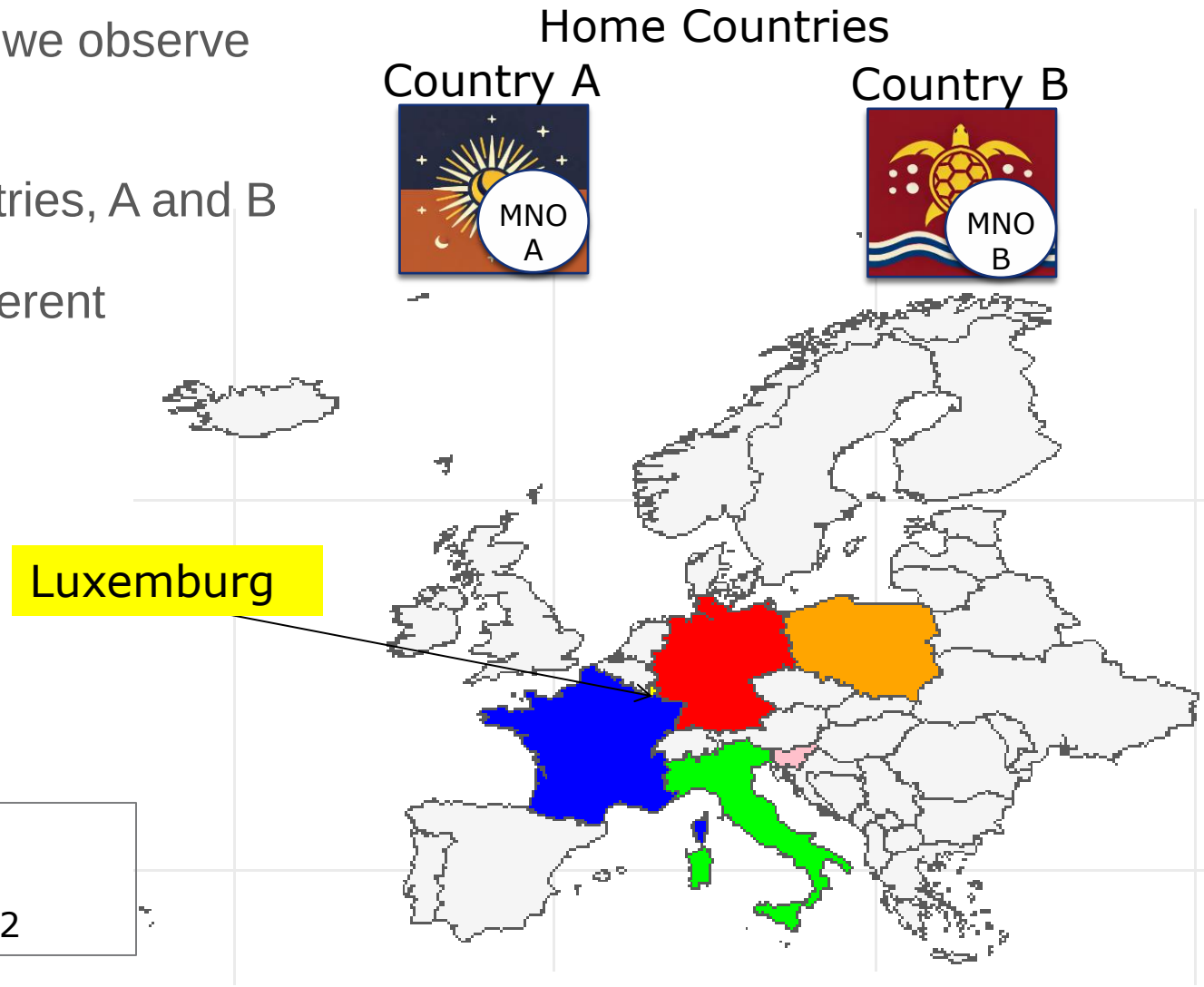
- 1. the **severity of** the phenomenon of **cross roaming** across multiple MNOs, and how such severity varies across the visited countries and home operators;
- 2. the **loss in accuracy** when deriving the indicators from aggregated data based on partial views from single MNO processing, compared to the fusion of individual data.

The outbound perspective on inbound tourism

- To collect complete data on inbound tourism, we observe them from their home operators
- **Two** home operators, from two different countries, A and B
- Data related to their subscribers visiting **6** different **countries**

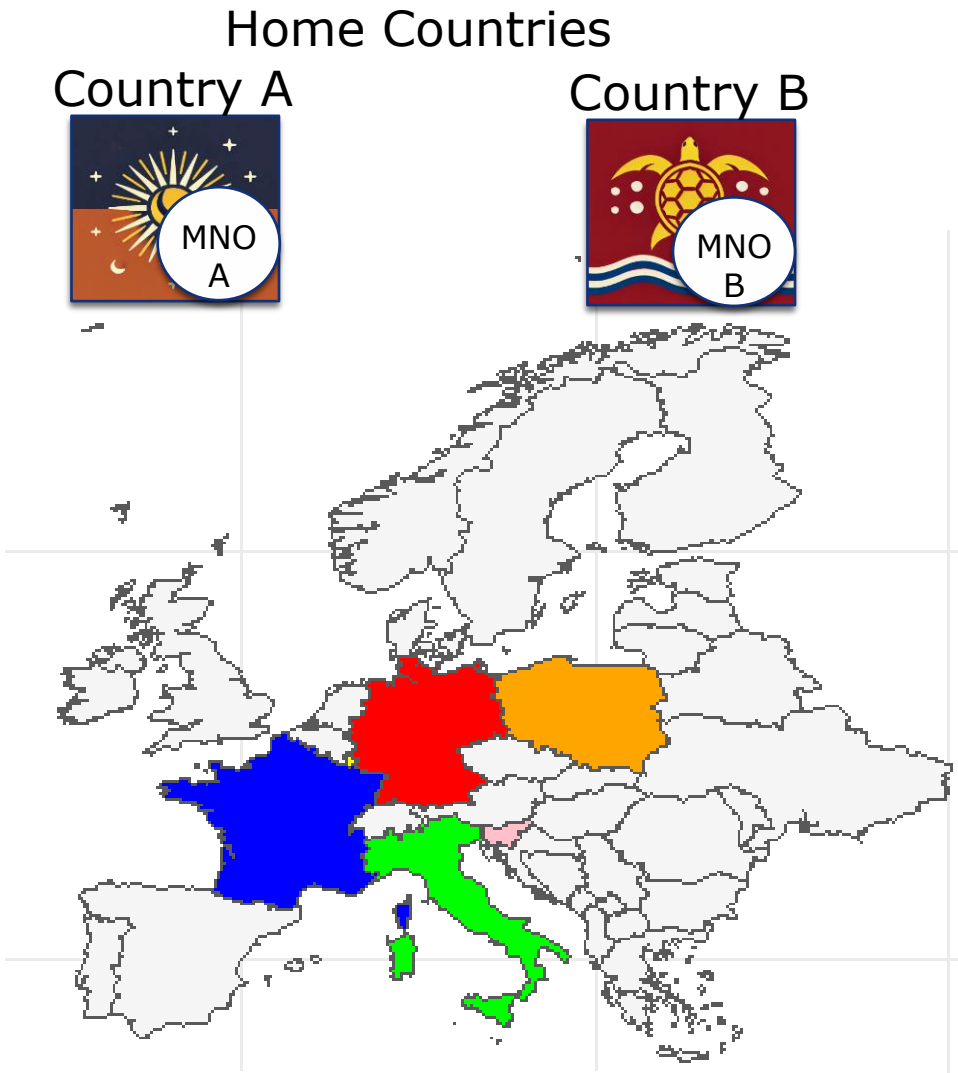


$n_{H1(V1,V2)}$ are
- *outbound roamers* for H1
- *inbound roamers* for V1 and V2



The origin countries A and B

- Country A is more than 30 times greater than country B in terms of **citizens**
- Country A is more than 30 times greater than country B in terms of **arrivals** in the 5 selected countries of destination
- Country A is more than 70 times greater than country B in terms of **nights spent** abroad in the 5 selected countries of destination



A simple algorithm to compute tourism statistics

For each `SIM`: Arrivals and Overnight Stays are calculated on the basis of the `timestamp` of the `events`:

1. Identify new presence
2. Presence continues if the next event is on the same day or next day
3. Presence is new if there is a gap of more than 1 day
4. Calculate the number of nights spent for each presence
5. Label and filter out same-day-visit, e.g presences with nights spent = 0

Group by visited country and by MNO within the country

Some Results: the magnitude of the cross-roaming

Devices by country

	Percentage of devices	
Destination	**from A**	**from B**
DE	13	**32**
FR	**48**	10
IT	**34**	13
LU	1	1
PL	2	**30**
SI	1	2

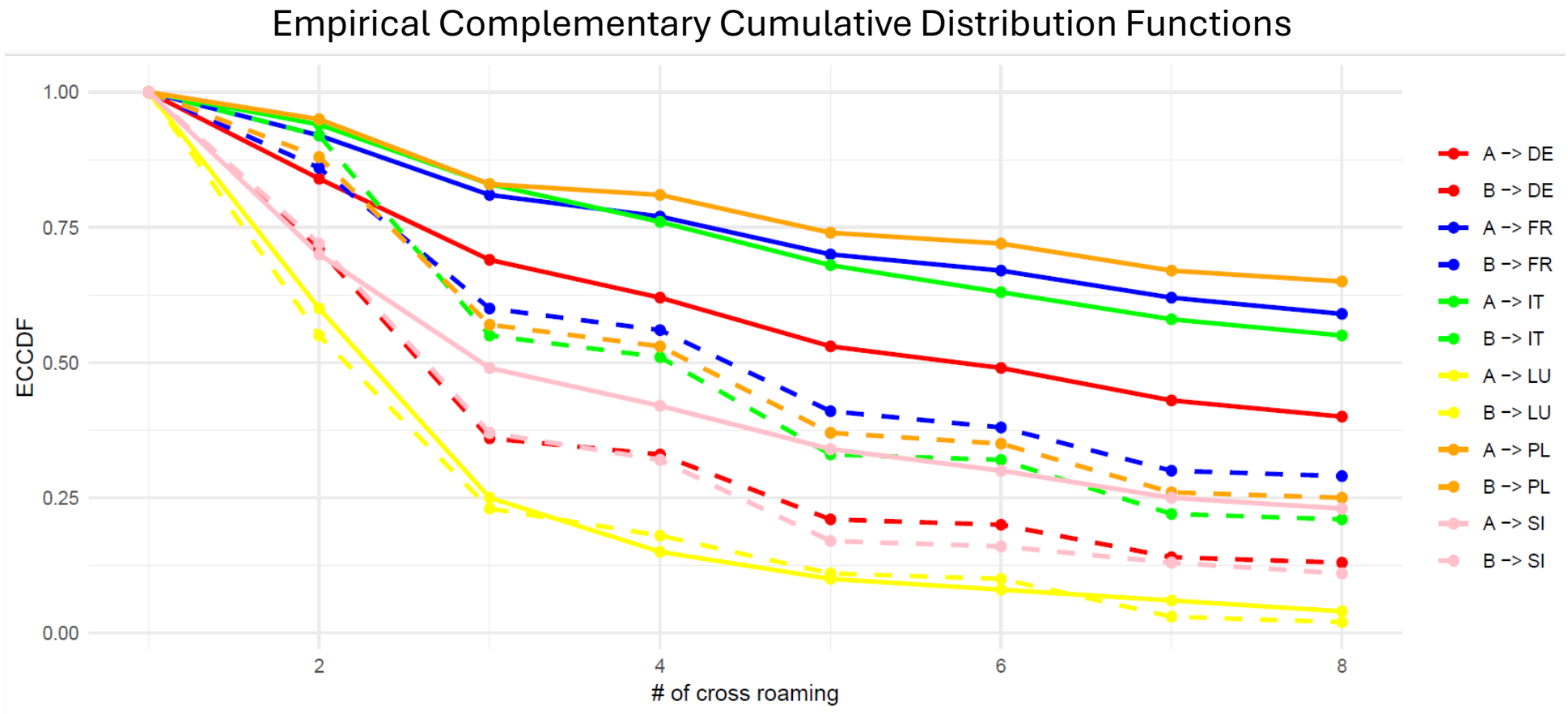
How many devices experience cross-roaming?

	# of visited MNOs (%)									
	1		2		3		4		(2+3+4)	
	NO (%)								YES (%)	
Destination	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	A	B
DE	39	69	30	30	31	1			61	31
FR	36	42	22	47	23	11	19		64	**58**
IT	31	60	27	40	40	*	2		69	40
LU	**94**	**74**	5	23	1	3			6	26
PL	29	51	35	37	36	12	*	*	**71**	49
SI	58	67	40	28	2	4			42	32

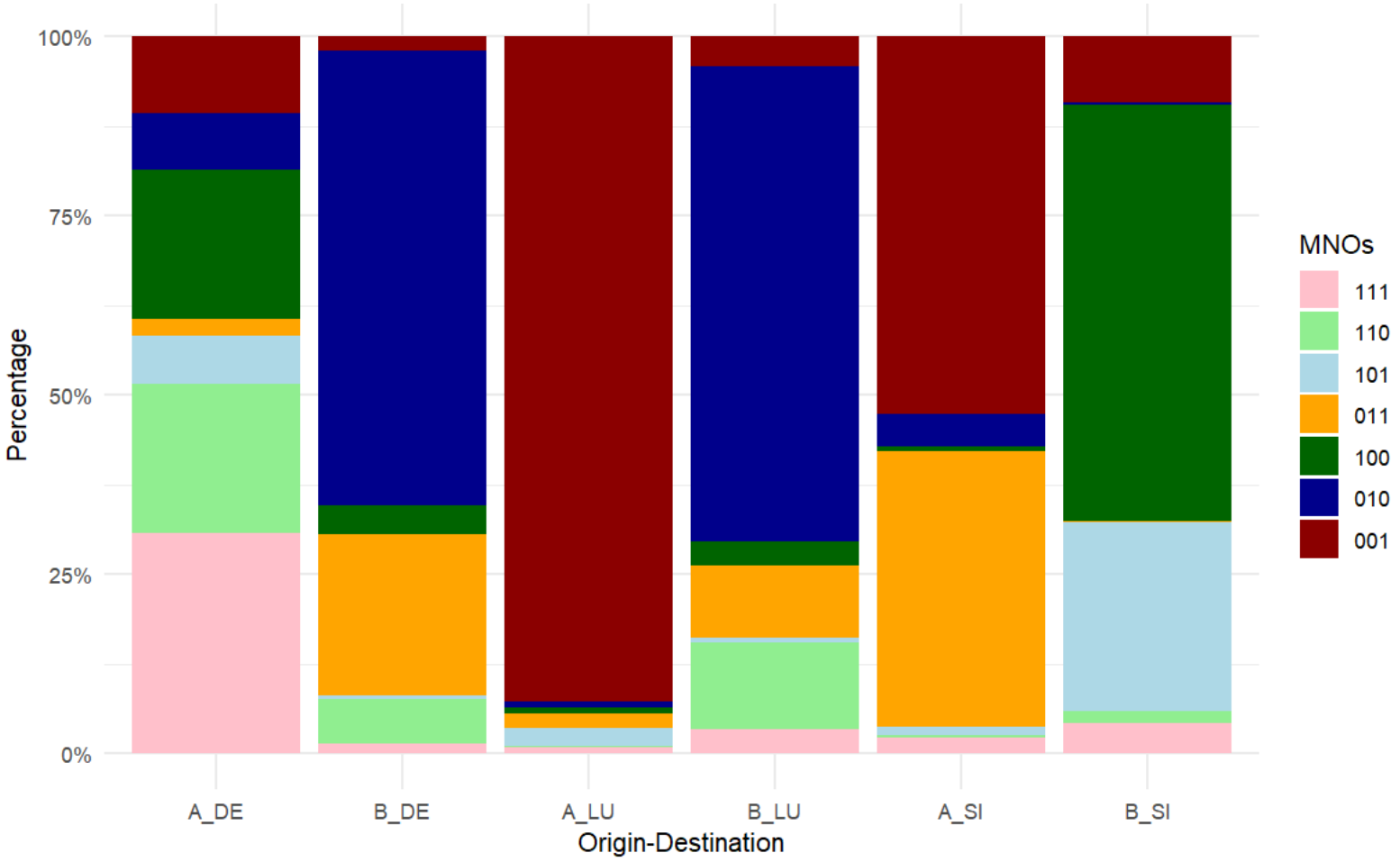
Some Results: the magnitude of the cross-roaming

How many times devices experience cross-roaming? How many cross-roaming experience?

- 95% of the devices from A cross roam up to 100 times when visiting FR, IT, PL
- From A to DE, FR, IT, PL there are extreme values of even more than 1000 cross roaming



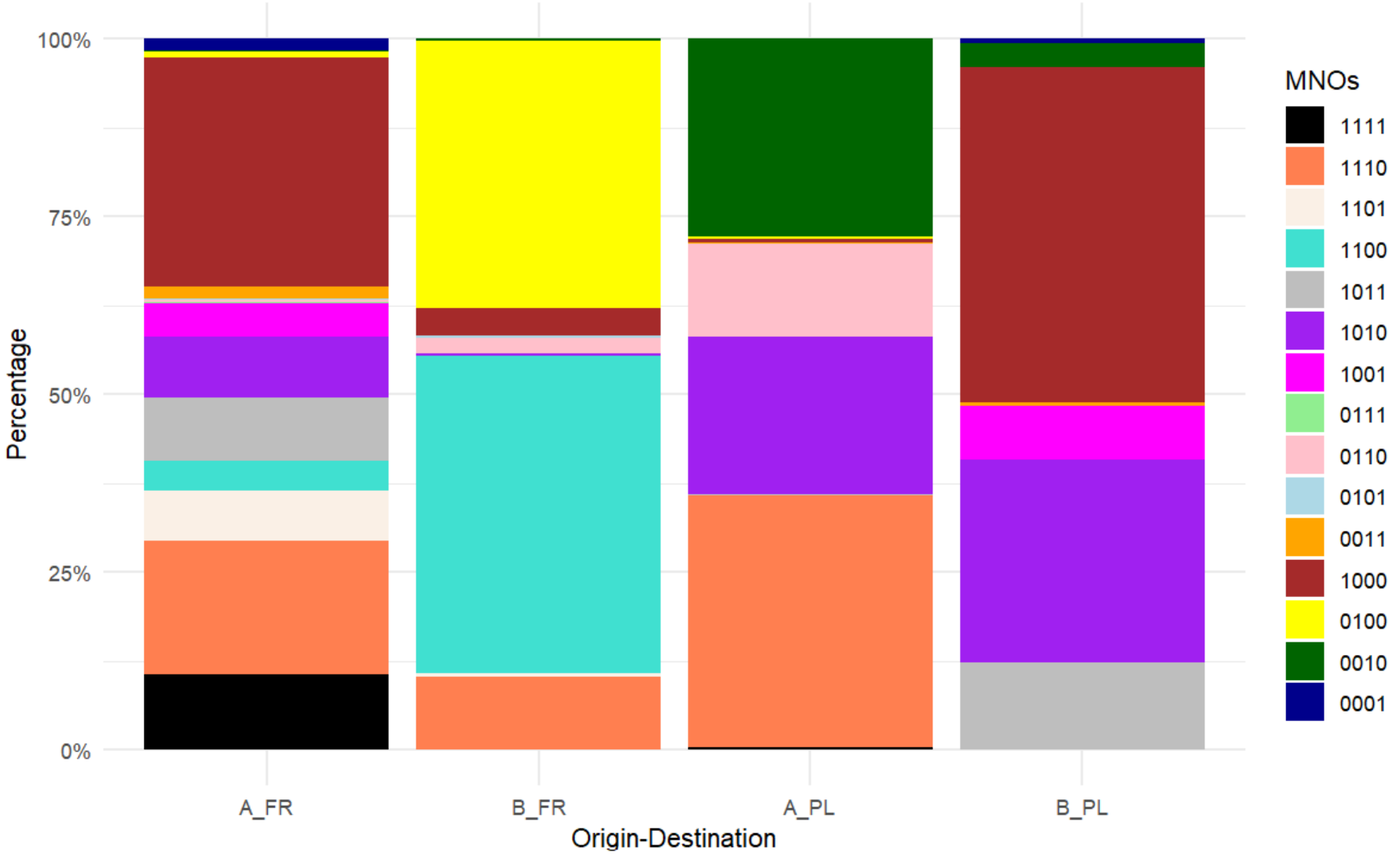
Operators and cross-roaming



Countries with 3 operators

- For B as origin, there is often a **«prevaling» operator** in the visited countries
- When SI is destination, A and B seem to behave similarly, even if the «prevaling» operator is different
- Not easy to find other regulaties, for A, and between A and B, considering also that the origin countries and the destination countries are quite different in size

Operators and cross-roaming



Countries with 4 operators

Probabilities of visiting operators

Using DE as example

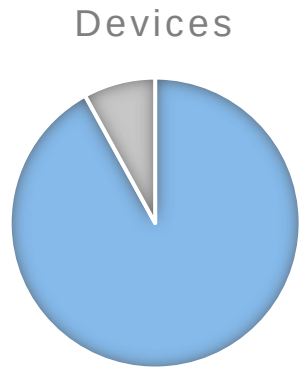
Visited operators	Devices %	
Destination	DE	
Origin	A	B
001	10,72	2,05
010	7,78	63,37
100	20,84	3,91
011	2,44	22,50
101	6,63	0,53
110	20,84	6,31
111	30,75	1,33

Probabilities of being caught by operators

	DE			
	A		B	
MNO	Capture Prob	1st Capture Prob	Capture Prob	1st Capture Prob
001	0.51	0.21	0,26	0,05
010	0.62	0.23	0,93	0,90
100	0.79	0.56	0,12	0,05

Market share in DE (asking Google for 2023)

MNO	Market share %
Deutsche Telekom	32-33
Vodafone	38-42
Telefonica 02	28-24



	From 100 To 010	From 100 To 001	From 010 To 100	From 010 To 001	From 001 To 100	From 001 To 010
A	**32**	12	**33**	6	12	6
B	6	1	8	**42**	2	**41**

Nights spent indicator

Percentage of nights spent - ground truth from the home MNO

	Average nights		Tot nights %		Tot devices %	
Destination country	B	A	B	A	B	A
DE	8.89	6.87	48.97	8.72	31.6	12.99
FR	4.05	9.22	6.96	42.63	9.87	47.35
IT	5.66	13.19	12.67	46.60	12.84	36.18
LU	4.05	4.14	0.34	0.21	0.48	0.52
PL	2.16	7.74	11.68	1.46	31.02	1.93
SI	2.54	3.7	0.48	0.25	1.09	0.69

Mean of nights spent per device from B: 5.7

Mean of nights spent per device from A: 11.0

Effect of cross-roaming on nights spent indicator

Relative Difference (RD) on the total of nights spent compared to the outbound counts

Destination country		DE		FR		IT		LU		PL		SI	
Origin Country		A	B	A	B	A	B	A	B	A	B	A	B
RD (%) Number of Nights Spent	***Sum(MNOs)***	***+13***	***+0.9***	***+13***	***+11***	***+10***	***+4***	***+0.5***	***+3***	***+30***	***+10***	***+12***	***+6***
	1000	-39	-83	**-9**	-80	-70		-97	-94	-86	**-9**	-98	-13
	0100	-75	-24	-93	-11	-86	**-1**	-98	-6	-78	-99	-81	-99
	0010	-73	-91	-92	-98	-54	-95	-5	-97	**-6**	-83	**-9**	-82
	0001			-94	-99	-80				-99	-98		
Average of nights spent	***Mean(MNOs)***	***4.87***	***7.68***	***6.18***	***3.48***	***5.76***	***5.05***	***4.11***	***3.60***	***5.47***	***2.03***	***3.08***	***2.37***
	1000	*5.87*	11.06	**8.73**	2.51	5.75		5.69	1.83	2.91	***2.13***	1.86	***2.56***
	0100	3.58	***7.49***	2.79	***3.86***	9.02	***5.62***	4.01	***4.06***	3.92	5.33	1.87	1.12
	0010	4.65	5.61	2.7	2.01	*6.21*	1.77	***4.07***	1.29	***7.07***	1.63	***3.62***	1.8
	0001			2.72	3.31	4.1				1.73	1.48		
	GT - From home	**6.87**	**8.89**	**9.22**	**4.05**	**13.19**	**5.66**	**4.14**	**4.05**	**7.74**	**2.16**	**3.7**	**2.45**

Insights on nights spent in DE

Back= the true distribution given by the outbound analysis

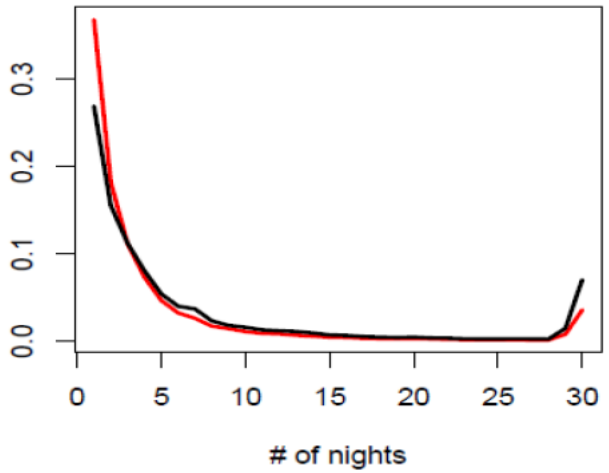
Red= the distribution obtained by summing up the operators

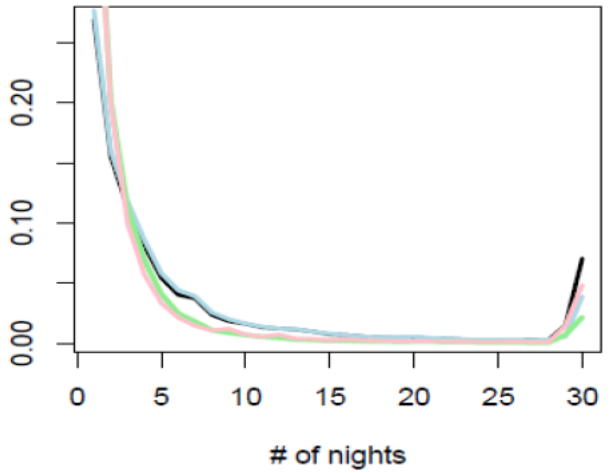
Light blue= MNO 100

Light green= MNO 010

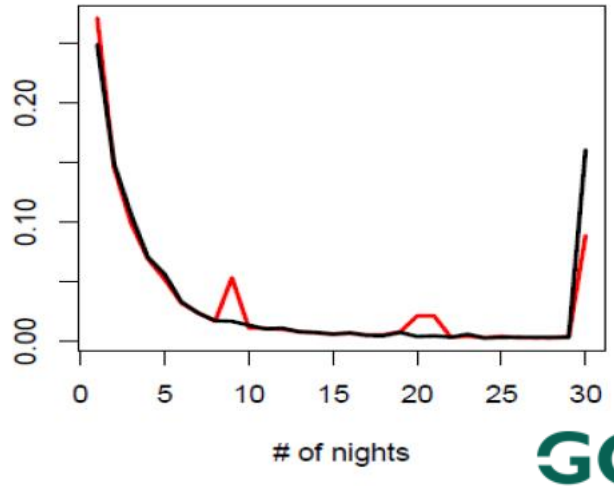
Pink= MNO 001

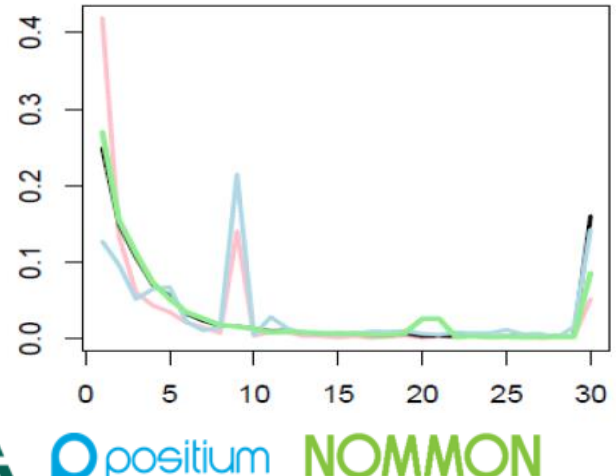
From A to DE





From B to DE





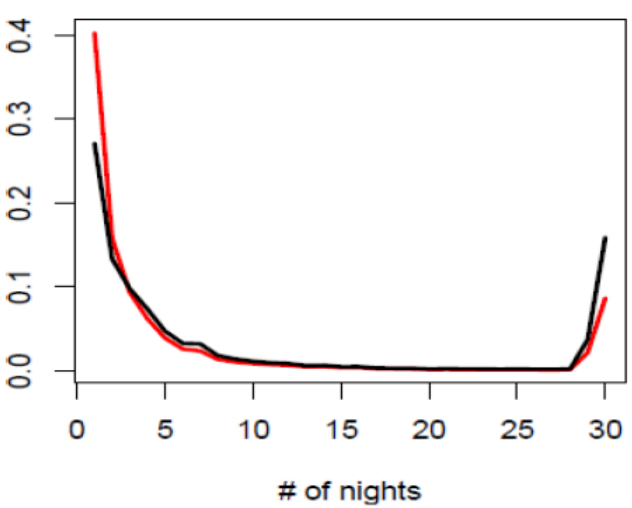
Insights on nights spent in FR

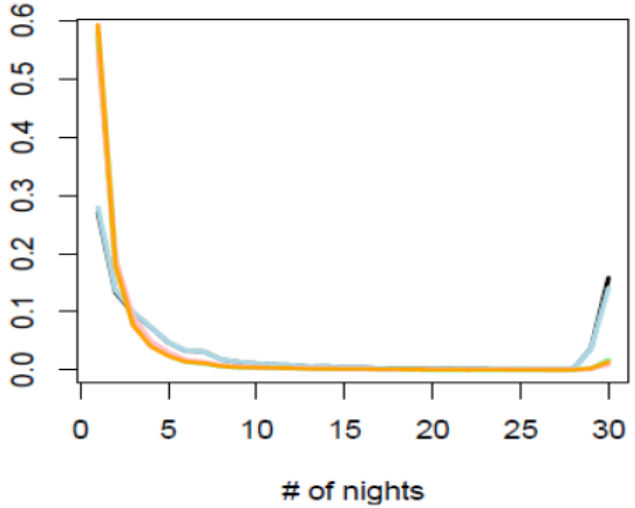
Back= the true distribution given by the outbound analysis

Red= the distribution obtained by summing up the operators

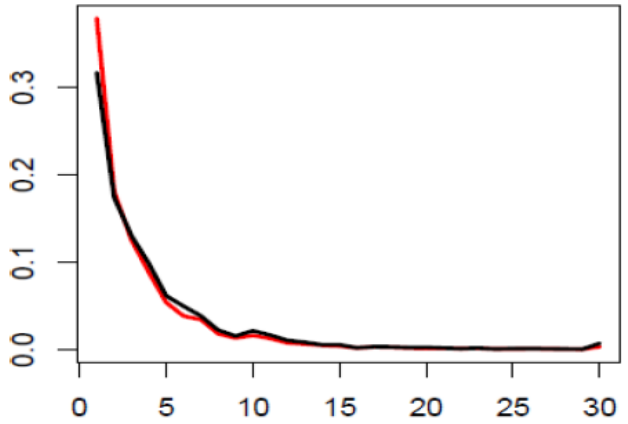
Light blue= MNO 1000
Light green= MNO 0100
Pink= MNO 0010
Orange= MNO 0001

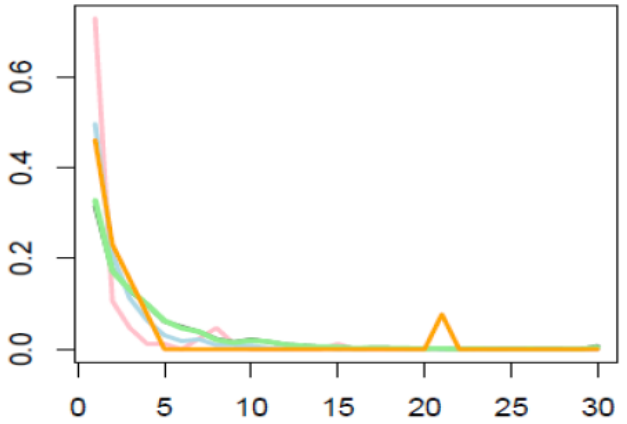
From A to FR





From B to FR





Arrivals indicator

Relative Difference (RD) on the total of arrivals compared to the ground truth form the home operator outbound

Destination country		DE		FR		IT		LU		PL		SI	
Origin Country		A	B	A	B	A	B	A	B	A	B	A	B
RD(%) Number of Arrivals	*Sum(MNOs)*	***+59***	***+17***	***+68***	***+29***	***+151***	***+17***	***+1***	***+16***	***+84***	***+16***	***+35***	***+13***
	1000	-29	-87	-4	-67	-32		-98	-88	-61	-8	-96	-13
	0100	-51	-10	-77	-7	-80	-0	-98	-6	-58	-100	-62	-98
	0010	-61	-86	-70	-98	-3	-83	-3	-91	**+3**	-78	-6	-75
	0001			-81	-100	-34				-100	-97		

Destination country		DE		FR		IT		LU		PL		SI	
Origin Country		A	B	A	B	A	B	A	B	A	B	A	B
RD(%) Number of Nights Spent	*Sum(MNOs)*	***+13***	***+0.9***	***+13***	***+11***	***+10***	***+4***	***+0.5***	***+3***	***+30***	***+10***	***+12***	***+6***
	1000	-39	-83	-9	-80	-70		-97	-94	-86	-9	-98	-13
	0100	-75	-24	-93	-11	-86	-1	-98	-6	-79	-100	-81	-99
	0010	-73	-91	-91	-99	-54	-95	-5	-97	-6	-83	-9	-82
	0001			-94	-100	-80				-100	-98		

Concluding remarks

- Cross roaming seems to have an impact on inbound tourism indicators
- MNO Market share does not seem useful for adjustment
- Potential effective statistical adjustments seem to require some specific knowledge about countries, MNOs, inter-MNO agreements
- Micro-linkage in a privacy preserved environment seems worth to be explored

Thank you for the attention
Grazie

TIZIANA TUOTO | tuoto@istat.it

When and where:

23-25 September 2025

OECD Conference Centre,
Paris, France

cros.ec.europa.eu/mno-minds

tss-meth-too@istat.it

Istat