

Impact of Free Route Airspace Implementation on Safety Performance - Ex-post Analysis of Northern Europe Free Route Airspace (NEFRA)



9th SESAR Innovation Days

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Background

- SESAR solutions
 - Free Route Airspace (FRA)
- Growing need to assess the post-implementation impact of SESAR solutions on ATM performance
- One of the key recommendations in the Special report of European Court of Auditors: *“appropriate monitoring of performance benefits delivered by ATM modernization”*

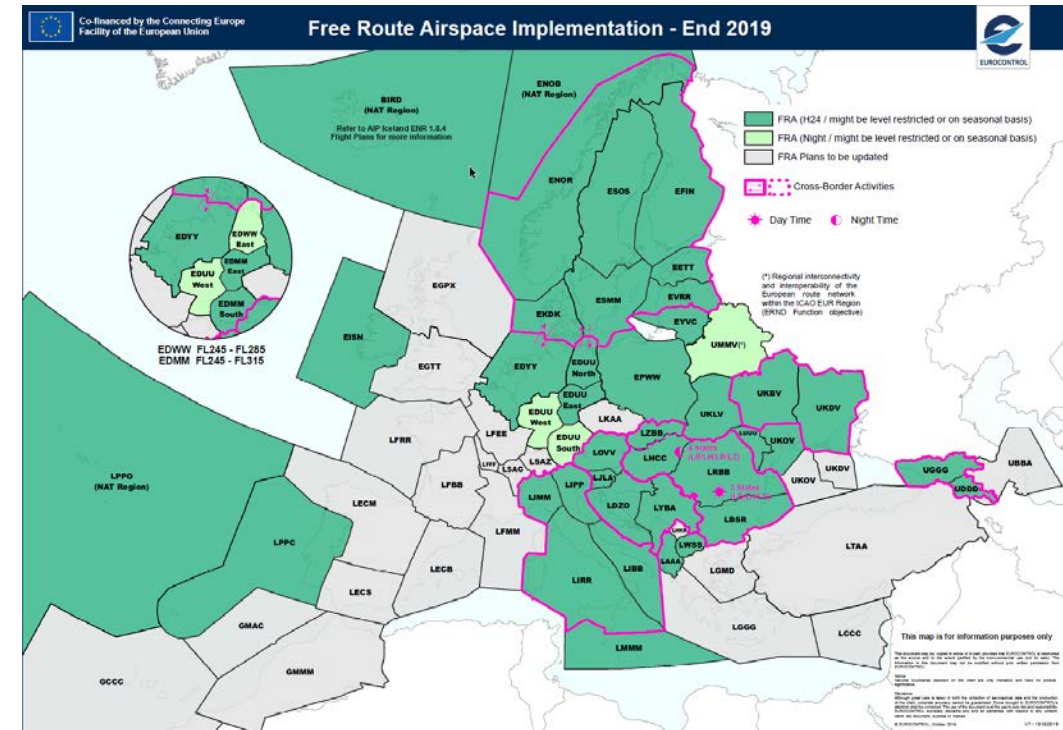


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Free Route Airspace (FRA)

- *airspace within which users can freely plan a route between a defined entry point and a defined exit point...*
- Situation end 2019 :
 - Full 24h FRA > 20 States
 - Partial FRA > 40 ACCs



Source: EUROCONTROL



Performance (benefit) assessment

Pre-ops	Post-ops
Simulation and optimisation tools	Operational performance data
Controlled environment	Many (concealed) extraneous variables
(simplistic) assumptions	Airline business models, uncertainty, etc.
Cause and effect relationship relatively easy to establish	Difficult to isolate the impact of one factor on a dependent variable
↓	↓
significant work so far	scarcity of (research) publications



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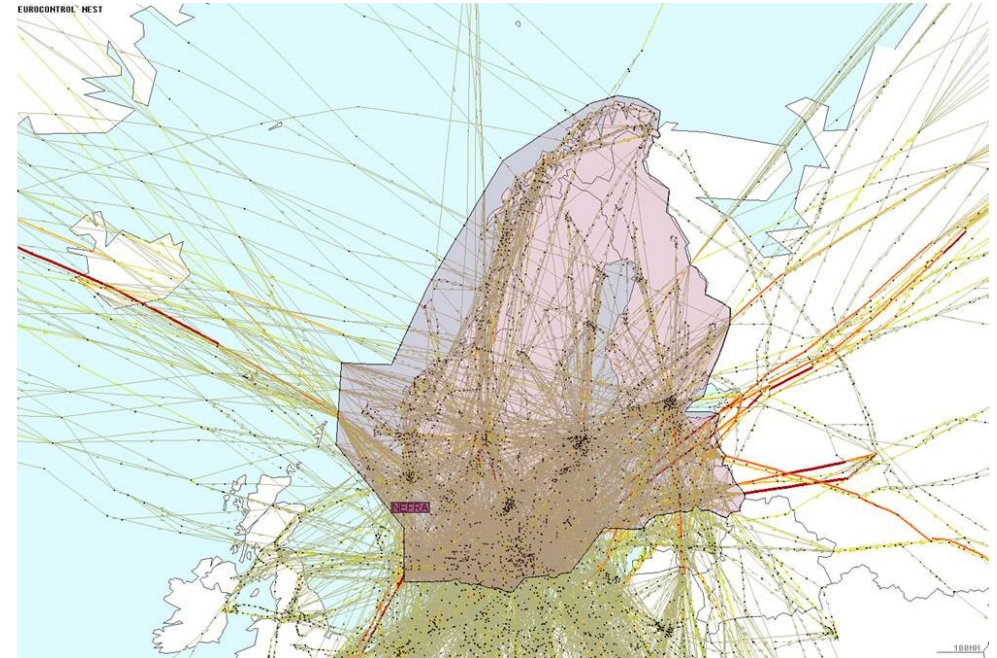


Case study - scope

- NEFRA - Northern Europe Free Route Airspace
 - Finland, Estonia, Latvia, Norway, Denmark, Sweden
- Established in 2013

Milestones:

- November 2015: NEFAB FRA (FI-EE-LV + NO)
- June 2016 - cross-border (NEFAB + DK/SE)
- May 2017 – cross-border with NO
- Current state of play - seamless FRA above FL285





Case study – indicators and data

Proxies of safety performance:

- **Situations of Interest (Sols)**, i.e. changes in the number of potential safety-related events (separation minima infringements)
- **Risk exposure index** – index combining safety and operational/trajectory information by taking into account potential separation losses and their characteristics (severity)

Data:

- Current Tactical Flight Model (CTFM) (M3 in NEST terminology) flight trajectories
- Conflict module in NEST used to find potential separation losses
- Separation criteria - 5NM for lateral and 1000ft for vertical separation
- For Sol to be recorded both vertical and horizontal separation need to be breached



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Methodology

- Time series analysis
 - daily Sols between 16/10/2014 and 20/07/2016
- Steps:
 - Find structural breakpoints in time series data and associate it with FRA implementation; quantify the immediate impact (Causal Impact);
 - Choose relevant month for year-on-year comparisons to observe the evolution over longer period.



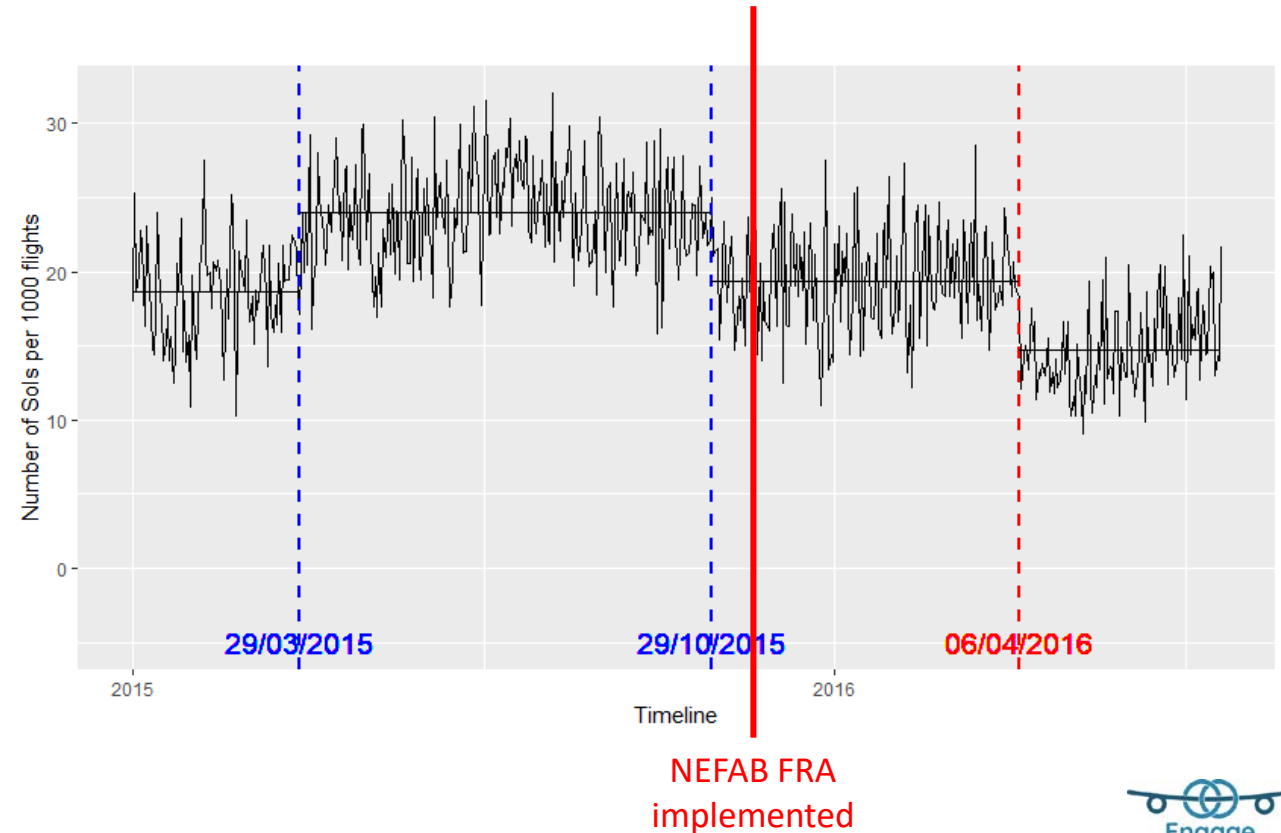
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Structural breakpoints – results

- Level breakpoints* identified:
 - 29 March 2015
 - 29 October 2015
- } *IATA scheduling seasons*
- **06 April 2016** - followed by notable decrease in Sol rate, despite the regular increase in traffic demand
 - FRA effects more visible during the periods of higher traffic demand



* An abrupt change in the mean or other time series' parameter at a certain point in time. May be of several types: level, trend, polynomial etc.



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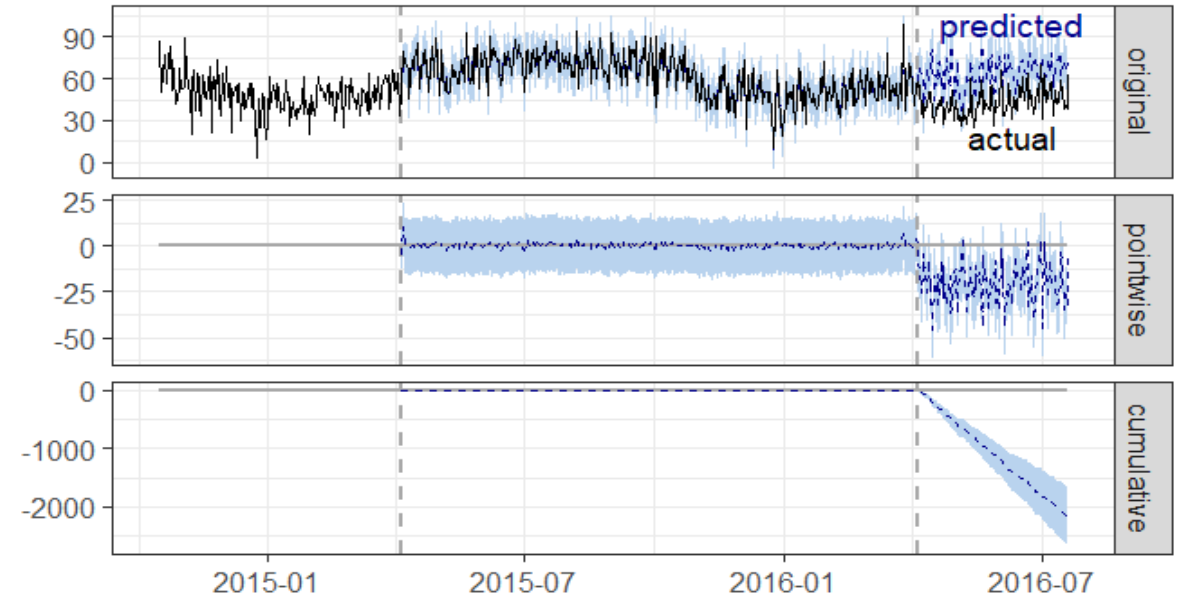


Causal Impact - results

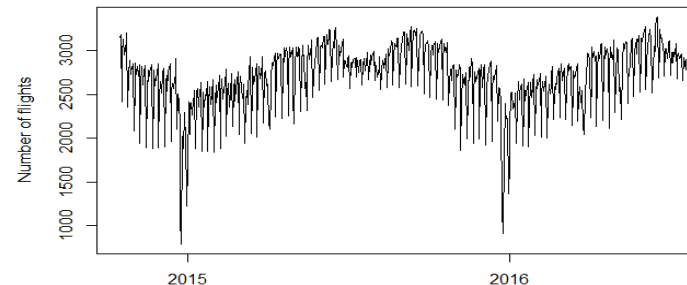
- **Pre-period:** 1 year preceding 06/04/2016
- **Post-period:** 06/04/2016 – 20/07/2016

- Regressor correlation: $\text{pearsonr}=0.75$
- Best fit ($R^2=0.86$) obtained with frequency parameter set at 364 days (yearly seasonality)

- Common validation techniques (e.g. k-fold cross validation) not appropriate for time series;
- Additional Causal Impact analysis entirely in pre-period conducted to test the model.



Indicator: Number of Sols



Regressor: Daily traffic demand



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Causal Impact - results

- During the post-implementation period, the target indicator had an average value of approx. 43.32
- On the contrary, in the absence of FRA implementation we would have expected an average (daily) response of 63.83



-20.51 or -32%

	Average	Cumulative
Actual	43	4592
Prediction (s.d.)	64 (2.5)	6766 (261.9)
95% CI	[59, 68]	[6250, 7259]
Absolute effect	-21 (2,5)	-2174 (261.9)
95% CI	[-25, -16]	[-2667, -1658]
Relative effect	-32% (3.9%)	
95% CI	[-39%, -25%]	



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Year-on-year comparison (2015-2018)

Reference month: July

Summary 2015 → 2018:

- Number of flights: + 13.5% ↑
- Number of flight hours: + 13.8% ↑
- Number of Sols: ↓ -26%
- Sol rate per 1000 flights: ↓ -35%

Indicator	Year (*July only)			
	2015	2016	2017	2018
Mean No of aircraft per day	2851	2928	3095	3235
Mean Flight Hours per day	1604	1638	1747	1823
Mean flight hours per flight	0,563	0,560	0,564	0,564
Total no of Sols	2098	1351	1511	1556
No of Sols per 1000 flights	26,28	16,48	17,43	17,18



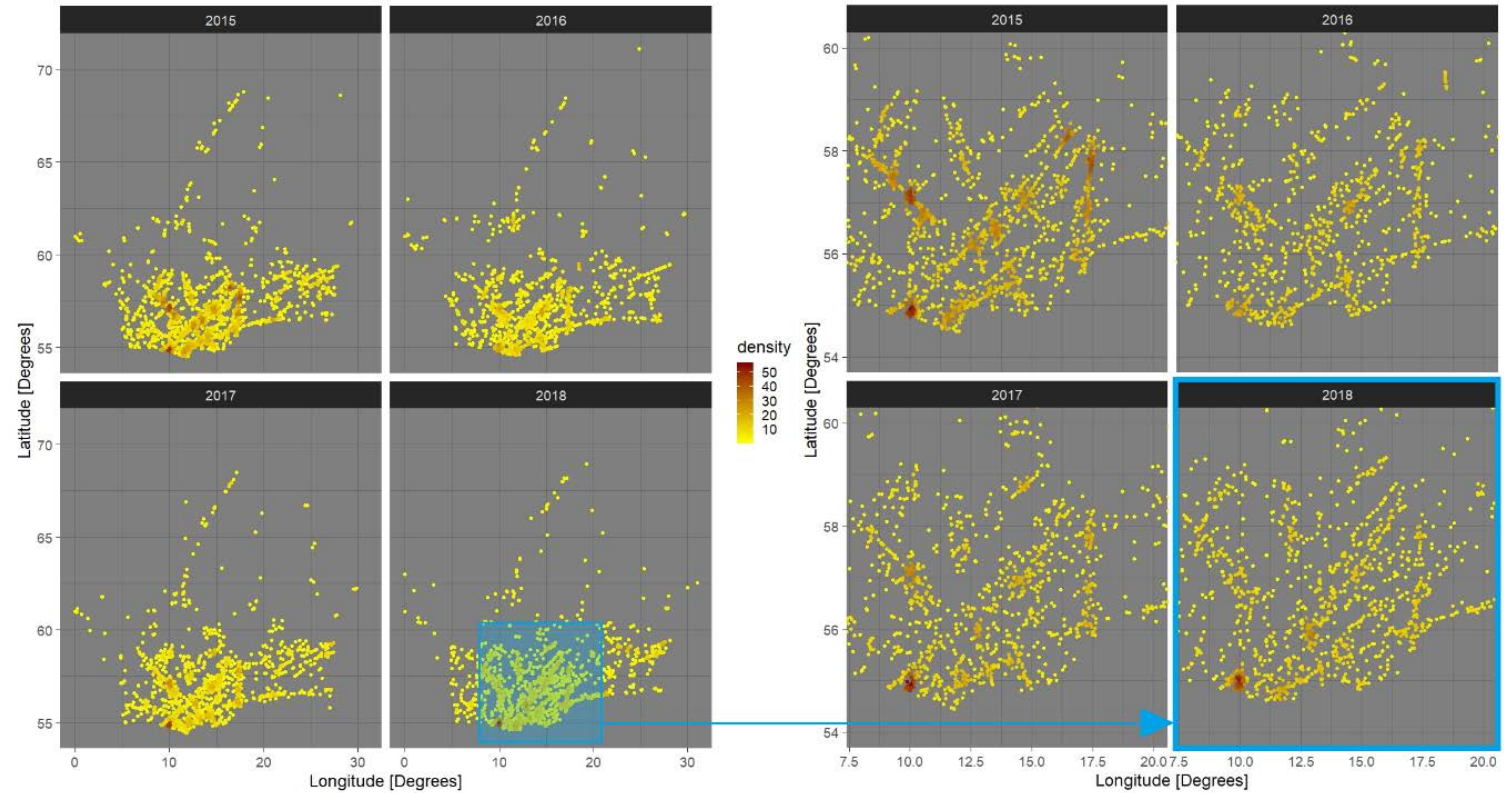
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Sol density

- 2015: the impact of the traditional ATS route structure clearly visible
- Over time, Sols are becoming more spread and “hotspots” are becoming less dense



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Risk exposure index

- Combines safety and operational/trajectory information by taking into account potential separation losses and their characteristics (severity)

$$\text{risk exposure index} = \frac{\text{SV severity} * \text{SV duration}}{\text{flhrs}}$$

$$\text{SV severity} = Sc * (70 * SVc + 20 * SVo + 10 * SVp)$$

$$Sc = \frac{\text{minsep} - \text{actsep}}{\text{minsep}} \quad \text{SV duration} = \text{time}_e - \text{time}_b$$

- The severity is defined by duration, magnitude of separation minima breach and type of separation loss in terms of geometry

Variable	Definition	Variable	Definition
Sc	Separation breach index	SV	Number of potential Separation Violations (SV)
minsep	Minimum separation parameter	SVc	SV when aircraft are converging
actsep	Actual separation distance	SVo	SV when aircraft are opposite
time _e	Time when contact ends	SVp	SV when aircraft are parallel
time _b	Time when contact begins	flhrs	Flight seconds (flight hours*3600)



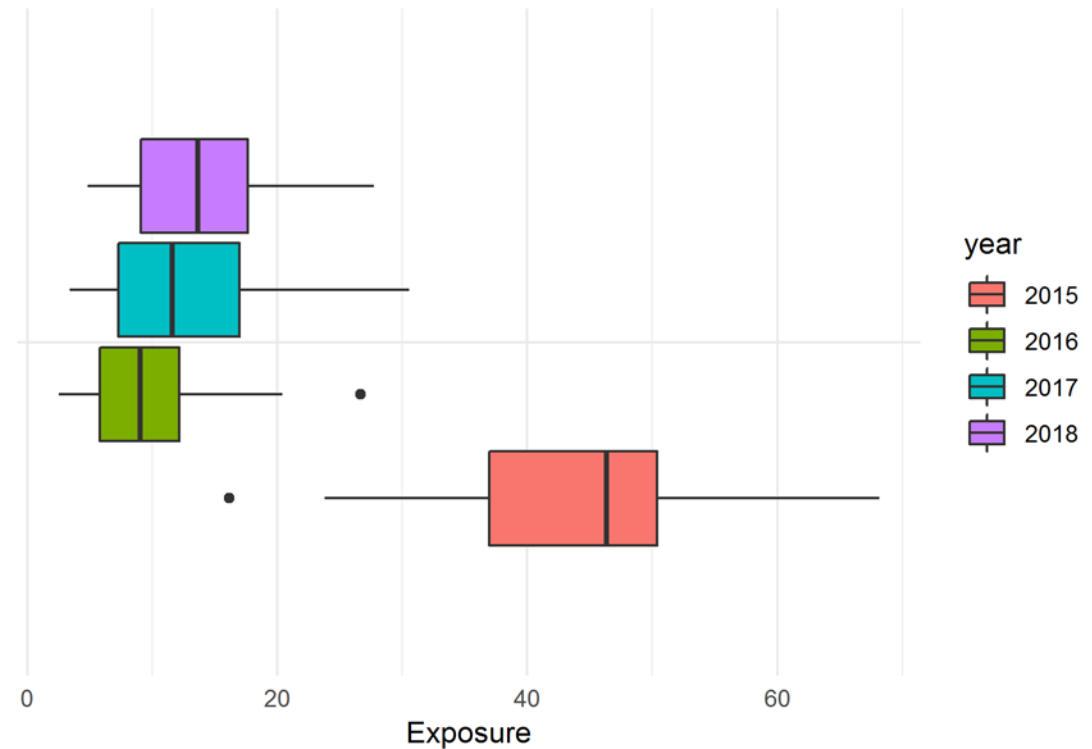
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Risk exposure index - results

- 2016: Risk exposure index ↓ by ~ 78%
- 2017 and 2018: ↑ by ~ 31% and 7%
- 2015 and 2018 overall: ↓ by ~ 70% (-68.5%)



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Conclusions and further research

- FRA had a positive impact on safety performance in NEFRA despite sustained traffic growth:
 - Sols reduced by $\approx 35\%$
 - risk exposure index reduced by $\approx 70\%$
- Causal Impact methodology has a potential to be used to estimate benefits of FRA implementation (and other operational concepts)
 - Careful selection of regressors is needed and more data is highly desirable
- Extending geographical scope of the analysis (e.g. other or multiple FRAs)
- Using different trajectory information (e.g. ADS-B data)
- Validation of results (e.g. operational feedback from ATCOs and flight crews)
- Analysis can be applied to other key performance areas



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Thank you for your attention!

Questions?

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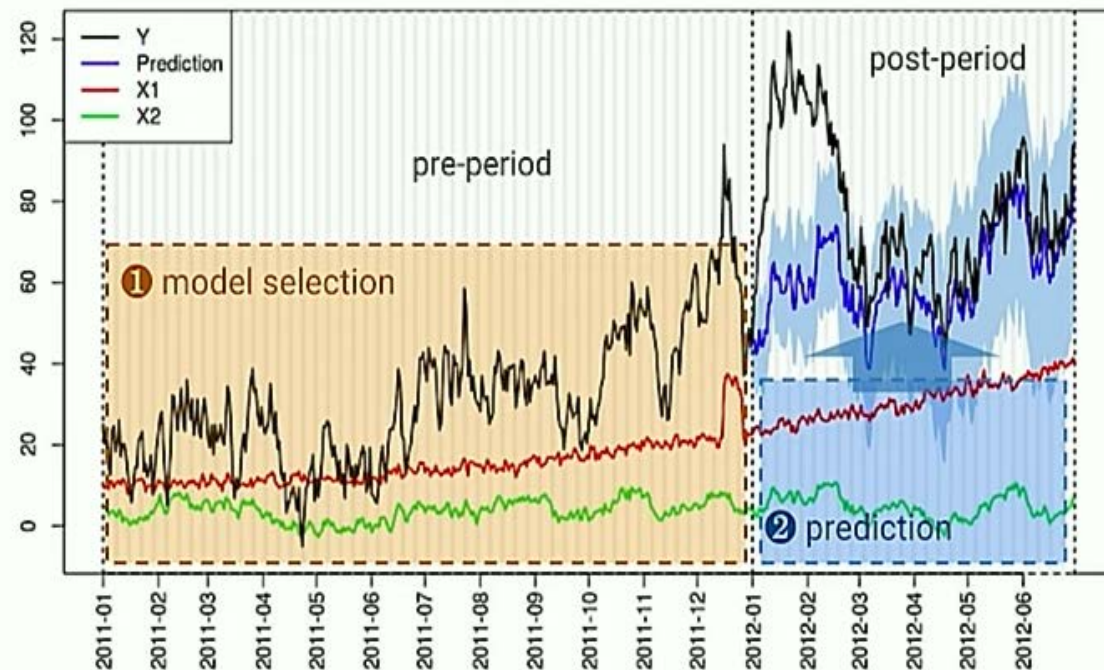


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Annex - Causal Impact assessment

- The BSTS* model is trained on pre-implementation data to determine the relationship between the response variable and a selected regressor.
- The model is then used to predict the values in the post-implementation period (counterfactual), assuming that FRA implementation had never occurred;
- The predicted values in the post-implementation period are later compared with the actual (observed) values of the response variable in order to assess the impact of FRA implementation.



Source: Brodersen, K. H., *Inferring the effect of an event using CausalImpact*. Big Data Spain, November 2016, Madrid

*Bayesian structural time series