Measuring Safety under Varying Transparency

Evidence from French Nuclear Incidents

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Introduction

- A need to monitor nuclear safety
  - Safe operation of present nuclear plants
  - Implement socially desirable policies (new builds, shut-downs...)
- Is safety the probability of inflicting harm to people or goods?
  - not compatible with the nuclear risk
  - not used in practice
- Raises important questions
  - How to monitor safety over time?
  - with new reactor designs? new regulations?

The paper

Observation Nuclear accidents are too scarce to measure safety

Questions Do incidents carry information regarding safety?
Can they shed light on safety variations?

Method Count-data regression on a partition of nuclear incidents

Results Safety decreases with age, improvements observed
Effect of age small when compared to technology
Propensity to declare matters

Literature review

- The economic analysis of the nuclear risk
  - using scarce accident data (Rabl, 2013; Rangel, 2014)
  - using larger datasets (Hofert, 2011; Wheatley, 2016a,b))
- The assessment of safety using incident data
  - Airline and auto. industry (Rose, 1990; Dionne, 1992)
  - Nuclear safety (Feinstein, 1989; Hausman, 2014)
- Declaration distortions and audit mechanisms
  - Audit mechanisms (Macho-staddler, 2006)
  - Lab. experiments (Cason, 2016)

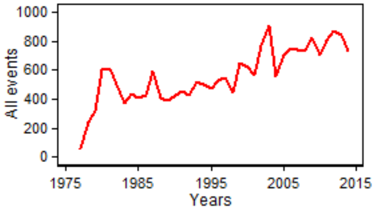
The context

- France (1997-2014)
  - 1 firm (EDF), 19 station operators, 58 reactors
  - 1 technology, 3 types of reactors, 6 designs

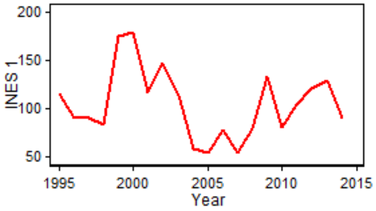
- Operators have to declare safety incidents
  - Declaration criteria set by the safety regulator
  - Subject to mild audit mechanism (no clear sanctions)

- The dataset
  - 19.000 events declared between 1973 and 2014 in French reactors
  - Over 30 descriptive variables: date, causes, real or potential consequences, affected systems, declaration criteria...

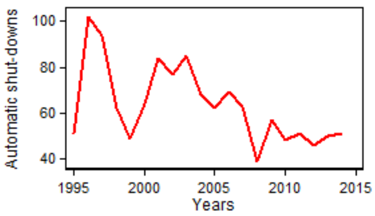
Global trends



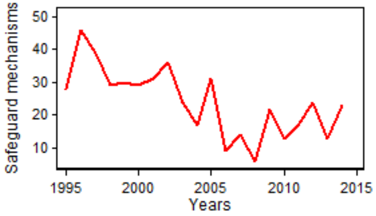
Source: IRSN. Commons duplicated, generic excluded. N = 20 978 ever



Source: IRSN. Commons duplicated, generic excluded. INES1 = 2 736 event



Source: IRSN. 1996-2014. N = 1 272 events



Source: IRSN. 1996-2014. N = 502 events

Propensity to declare

Does an increasing number of declarations imply decreasing safety?

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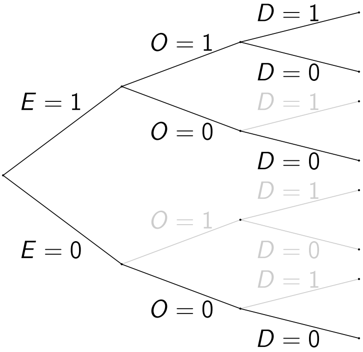

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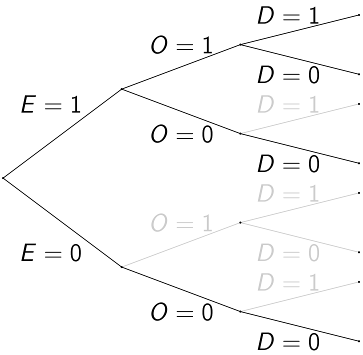

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- Data: $(E, O, D) = (1, 1, 1)$

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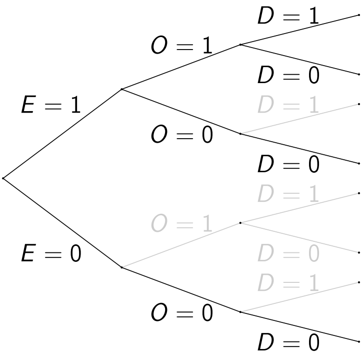

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  - better transparency

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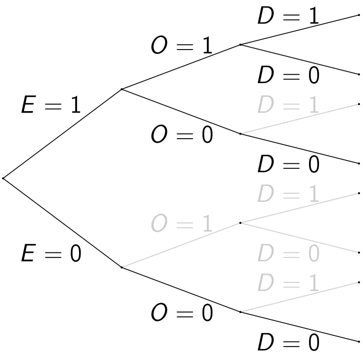

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- How to relate variations in annual counts of events per reactor to their safety levels?

Identification strategy

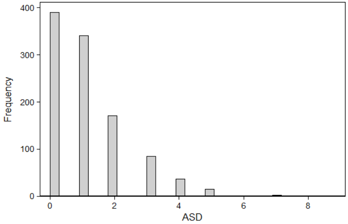
Selection Systematically Detected and Declared (SDD) events:
Automatic shut-downs (ASD)
Safeguard systems (SFG)

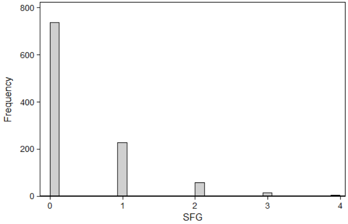
Identification Variations necessarily due to safety
ASD and SFG subject to constant criteria

Covariates Technology, reactor age, calendar time
Station Size, maintenance days
First-of-a-kind, first-of-a-site

Descriptive statistics

Variable	Definition	Mean	Std. Dev.
ASD	Automatic shut-downs declared per R.Y	1.138	1.242
SFG	Unplanned use of safeguard mechanisms per R.Y	0.391	0.701
ALL	All events declared per R.Y	12.290	5.094





Model specifications

$$\mathbb{E}(Y|\mathbf{X}) = \exp\left(\beta \cdot \mathbf{X} + \gamma \cdot \mathbf{AGE} + \sum_{t=1998}^{2014} \mu_t \cdot \mathbb{1}_t \times \mathbf{AGE} + \sum_g \omega_g \cdot \mathbb{1}_g \times \mathbf{AGE}\right) + \epsilon$$

- Model specifications
  - Poisson vs. Neg. Bin. (NB1 & NB2)
  - Clustered std. errors at site and reactor level
  - No reactor fixed-effects
- Robustness checks
  - Several definitions of age
  - Several technology groups

Results: negative binomial for ASD and SFG

Variables	ASD	SFG
RSize	-0.036	-0.18***
AGE	0.14***	0.16***
1300 MW	0.82**	1.26**
1450 MW	2.38***	2.49***
1300×AGE	-0.029**	-0.012
1450×AGE	-0.15***	-0.099*
FoaS	-0.034	-0.39
FoaK	-0.090	-0.086
FoaS×AGE	-0.0079	0.0056
FoaK×AGE	0.014	0.021
$\mathbb{1}_{1998}\times$AGE	-0.024*	-0.024
$\mathbb{1}_{1999}\times$AGE	-0.035***	-0.035
$\mathbb{1}_{2000}\times$AGE	-0.040***	-0.047**

Site-clustered standard errors
1,042 observations

Variables	ASD	SFG
$\mathbb{1}_{2001}\times$AGE	-0.030**	-0.049**
$\mathbb{1}_{2002}\times$AGE	-0.038***	-0.042**
$\mathbb{1}_{2003}\times$AGE	-0.036***	-0.073***
$\mathbb{1}_{2004}\times$AGE	-0.054***	-0.10***
$\mathbb{1}_{2005}\times$AGE	-0.059***	-0.071**
$\mathbb{1}_{2006}\times$AGE	-0.058***	-0.13***
$\mathbb{1}_{2007}\times$AGE	-0.063***	-0.11***
$\mathbb{1}_{2008}\times$AGE	-0.094***	-0.16***
$\mathbb{1}_{2009}\times$AGE	-0.071***	-0.095**
$\mathbb{1}_{2010}\times$AGE	-0.081***	-0.12***
$\mathbb{1}_{2011}\times$AGE	-0.082***	-0.11***
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ommitted intercept
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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1,042 observations

- Older reactors declare more ASDs
- Small compared to β_{P1450}
- New types declare more ASDs, but are less affected by AGE

Results: negative binomial for ASD and SFG

- The effect of AGE decreases over time
- For a given year: more ASD in older reactors
- Differences across age flatten over time

Variables	ASD	SFG
$\mathbb{1}_{2001} \times$AGE	-0.030**	-0.049**
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Transparency (1/2)

Transparency What about the rest of the dataset?

Strategy Adapted from Rose (1990)

Run similar regressions on two datasets

One characterized by subjective declarations

If similar results, subjectivity can be neglected

Adaptation New dependant variable: all events declared per R.Y

Compare to previous results

Results no longer significant

Transparency (2/2)

Variables	ASD	ALL
RSize	-0.036	0.0057
AGE	0.14***	0.014
1300 MW	0.82**	0.067
1450 MW	2.38***	0.35
1300×AGE	-0.029**	0.0048
1450×AGE	-0.15***	0.011
FoaS	-0.034	0.042
FoaK	-0.090	-0.19*
FoaS×AGE	-0.0079	-0.0028
FoaK×AGE	0.014	0.013**
$\mathbb{1}_{1998}$×AGE	-0.024*	-0.014**
$\mathbb{1}_{1999}$×AGE	-0.035***	0.011*
$\mathbb{1}_{2000}$×AGE	-0.040***	0.0071

Site-clustered standard errors
1,042 observations

Variables	ASD	ALL
$\mathbb{1}_{2001}$×AGE	-0.030**	0.00084
$\mathbb{1}_{2002}$×AGE	-0.038***	0.015**
$\mathbb{1}_{2003}$×AGE	-0.036***	0.020**
$\mathbb{1}_{2004}$×AGE	-0.054***	-0.0037
$\mathbb{1}_{2005}$×AGE	-0.059***	0.0051
$\mathbb{1}_{2006}$×AGE	-0.058***	0.0076
$\mathbb{1}_{2007}$×AGE	-0.063***	0.0068
$\mathbb{1}_{2008}$×AGE	-0.094***	0.0047
$\mathbb{1}_{2009}$×AGE	-0.071***	0.0093
$\mathbb{1}_{2010}$×AGE	-0.081***	0.0017
$\mathbb{1}_{2011}$×AGE	-0.082***	0.0070
$\mathbb{1}_{2012}$×AGE	-0.088***	0.0083
$\mathbb{1}_{2013}$×AGE	-0.082***	0.0072
$\mathbb{1}_{2014}$×AGE	-0.082***	0.0014

ommitted intercept
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Conclusion and policy implications

- Safety decreases slightly with age, progress over time
  - Impact is small when compared to technology groups
  - Impact is decreasing over time
  - Robust across two different categories of events
  - Yet, test does not allow to neglect propensity to declare

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- Safety decreases slightly with age, progress over time
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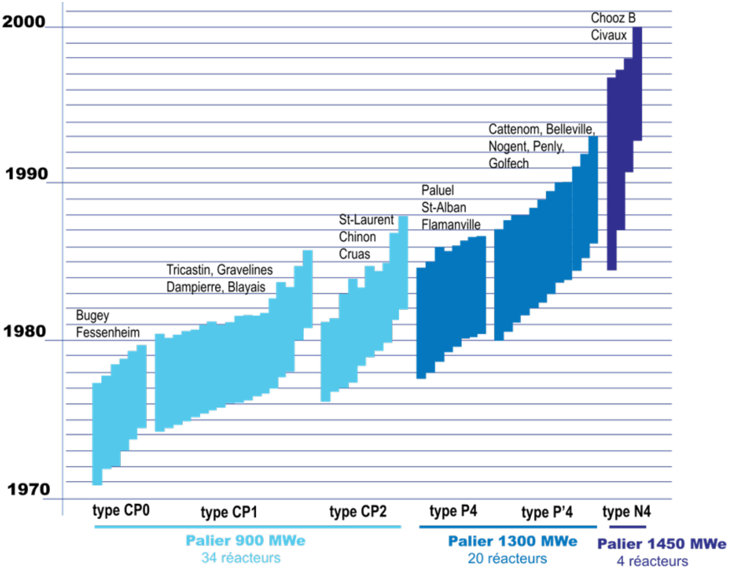
  - Impact is decreasing over time
  - Robust across two different categories of events
  - Yet, test does not allow to neglect propensity to declare
- Current research and policy implications
  - An alternative way to monitor nuclear safety
  - Importance of technology in debates regarding safety
  - Follow up: What policy to increase transparency?

Thank you for your attention !

References and additional information

- www.cerna.mines-paristech.fr/nuclearpower/
- www.cerna.mines-paristech.fr/bizet/

The French nuclear fleet



Some examples

Operation Discipline	Installation Conformity	Maintenance Interventions	Event Severity	Safety Analysis
Domain Exits	Safeguard system failures	Preparedness defaults	Unplanned use of safeguard systems	Learning failures
Group1 events	Qualification losses	Execution failures	Entries in SAM	Inappropriate declarations
Recuperation failures	Trial failures	Surveillance failures	Transitory states	
Operation failures	Maintenance scheme failures	Requalification defaults	Common cause failures	
Surveillance defaults			Triggering events	
Configuration failures			Remarkable events (IRSN)	
Control failures				
Gusts of events				

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