Evaluating the effect of local monitoring on nuclear safety

Evidence from France

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  - Safety standards and operation guidelines
  - Deviations reported by plant managers
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- How do plant managers react to this informational policy?
  1. Does it affect their incentives to exert safety care?
  2. Does it influence their decision to comply with self-reporting guidelines?

An analysis of deterrence and self-reporting (1/2)

- Two identification issues
  - Endogeneity of monitoring intensity
  - A mediation channel identification issue

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- Empirical strategy
  - Empirical evaluation of a principal-agent model
  - Using an IV-method based on a quasi-natural experiment
  - A unique dataset of significant safety events in French nuclear stations

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  - A unique dataset of significant safety events in French nuclear stations
- Results: Managers react to informational incentives
  - Local monitoring does not affect safety care
  - Local monitoring increases compliance with reporting guidelines

An analysis of deterrence and self-reporting (2/2)

- Nuclear power and economic incentives
  - Effect of deterrence measures on compliance (Feinstein, 1989)
  - Effect of deregulation on performance and safety (Davis and Wolfram, 2012; Hausman, 2014)
- Theoretical analysis of self-reporting mechanisms
  - Incentives for self-reporting under public info. disclosure (Zahran et al., 2014)
  - Incentives for self-reporting under imperfect audit (Evans et al., 2009; Gilpatric et al., 2011)
- Environmental enforcement and compliance
  - Effect of inspections on abatement and compliance (Helland, 1998; Lin, 2013)
  - RCT on the effect of deterrence on self-reporting (Duflo et al., 2013; Telle, 2013)

Institutional set-up

Source: World Nuclear Association

Managers operate power stations

declare safety events to authority

one firm, but strong delegation

Authority planned and random audits

small sanctions for reported events

lawsuits and stringent regulations for hidden events

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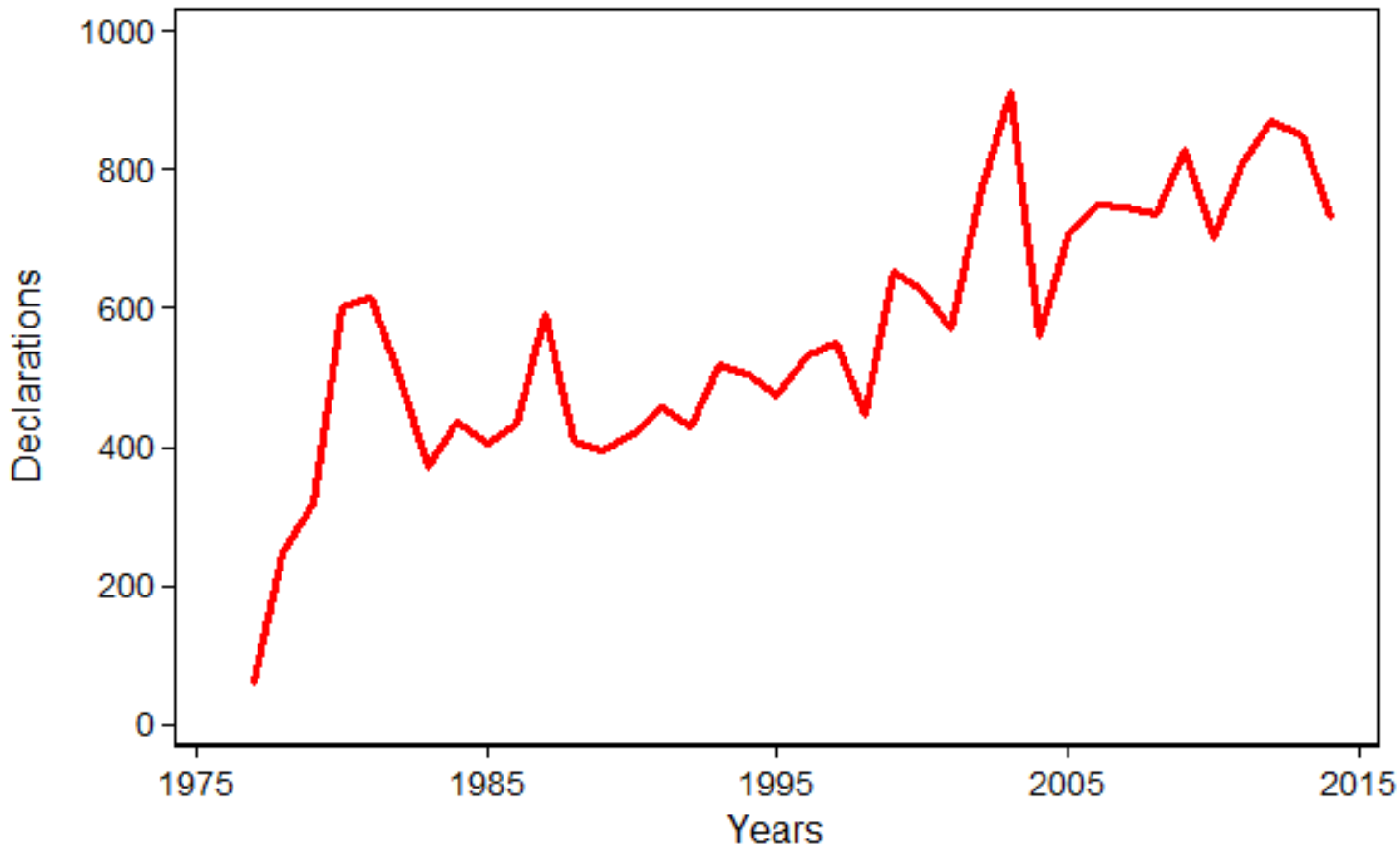
Commissions 2-3 meetings /y with plant managers

Hire independent experts for impact assessments

Communicate with local populations

But very heterogeneous budgets (5 - 200 k€/y)

Significant safety events



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

Two identification issues

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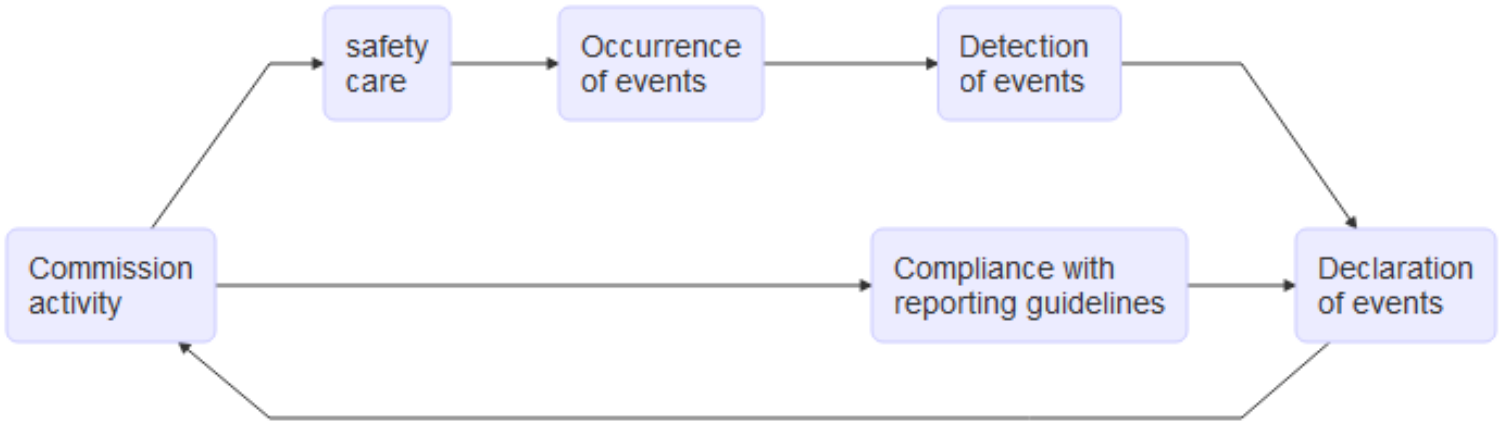

An IV-method based on a quasi-natural experiment

- Monitoring intensity is endogenous
  - Indirect measurement of monitoring intensity: commission budgets
  - Instrument: department-level budget forecast errors

$$INSTR_{R,t} = Real\ op.\ budget_{R,t} - Forecast\ op.\ budget_{R,t}$$

- Strength of the instrument:
  - Forecast error: failure to predict tax revenue
  - May lead to reappraisal of departmental expenditures

- Validity of the instrument:
  - Excl. Restriction: no direct financing from dept. to nuclear plants
  - Exogeneity
    - Negligible commission budgets
    - Unanticipated error: no forward looking-behaviour

Monitoring and firm behaviour

- We study a manager's best-response to a change in monitoring
  - Manager solves $\max_{E,z} B(E) - \alpha z E - q\beta E \int_z^{1+d} (u-z) f(u) du$
  - E: number of detected safety events
  - z: rate of compliance with declaration guidelines
  - d: rate of non-detection
  - α: **sanction** for reporting and $q\beta$: **expected penalty** for non-reporting

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Comparative statics and testable hypotheses...

- Increases in $\alpha \Rightarrow$ decreases in z, E and zE
- Increases in $q\beta \Rightarrow$ increases in z and decreases in E

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... leading to two empirical questions

1. Does local monitoring affect **perceived sanctions** or **expected penalties**?
2. What is the effect of local monitoring on **safety care** and **compliance**?

An empirical strategy in 3 steps

1. A test for variations in **perceived sanctions**
   - Focus on a subgroup of safety events
   - Perfectly detected and declared ($z = 1$, $d = 0$)
     - Automatic shut-downs
     - Unplanned uses of safeguard systems

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   - Two reliability measures related to safety care
     - Production loss due to unplanned maintenance extensions
     - Production loss due to fortuitous stops

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3. A test for variations in **reporting behaviours**
   - Observed reporting behaviours zE
   - Interpretation conditioned on previous results

The data

- Self-reporting of safety events (1972-2015)
  - 19.000 significant safety events from 58 reactors
  - Information on time, reactor status, event cause and consequences...
  - Source: ASN, IRSN
- Indirect measure of local monitoring intensity (2007-2015)
  - Local commission budget (unbalanced panel)
  - Qty of independent expertise conducted
  - Descriptive data (frequency of meeting, composition of commissions...)
  - Source: the commissions' annual activity reports
- Reactor-level production performance data (2007-2015)
  - Total production, duration of maintenance activities
  - Load factor, specific rates of unplanned outages
  - Source: EDF and ASN
- Department-level budget data 2005-2015
  - Source: open data from collectivités-local.gouv.fr

Empirical framework

$$Y_{R,t} = \beta_{budget} budget_{C,t} + \beta \cdot X_{R,t} + \delta_t + \gamma_R + \epsilon$$

- Monitoring and **perceived sanctions**
  - $Y_{R,t}$ = Counts of automatic shut-downs (ASD)
  - $Y_{R,t}$ = Counts of unplanned uses of safeguard systems (SFG)
- Monitoring and **safety care**
  - $Y_{R,t}$ = Losses due to unplanned prolonged maintenance (K_{ipr})
  - $Y_{R,t}$ = Losses due to fortuitous stops (K_{if})
- Monitoring and **reporting behaviours**
  - $Y_{R,t}$ = Counts of significant events (ALL)

- Specification:
  - Control variables: Electrical production, maintenance and age
  - Year and reactor fixed effects
  - GMM-IV estimator, robust SE

Perceived sanctions and reliability

	Sanctions		Reliability	
VARIABLES	ASD	SFG	Kipr	Kif
budget	0.00463	-0.0276**	-0.000106	-0.000322
age	-0.0859*	0.0419*	-0.00134	0.00122
production	-0.285**	-0.202**	-0.0104*	-0.0158**
maintenance	-0.00252	-0.00149	0.000289***	-0.000282**
Year-FE	Yes	Yes	Yes	Yes
Reactor-FE	Yes	Yes	Yes	Yes
Observations	234	234	234	234
KP rk LM	8.197	8.197	8.197	8.197
KP rk Wald	10.05	10.05	10.05	10.05

*** p<0.01, ** p<0.05, * p<0.1

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- data suggests small increases in perceived sanctions
- data indicates no evidence of increases in reliability (and safety care)

Local monitoring increases reporting

VARIABLES	ALL	ALL	log(ALL)	log(ALL)
budget	0.0571**	0.132*	0.00353*	0.00862
age	0.178	-0.473**	0.0209	-0.0417**
production	-1.137*	-0.942	-0.0835**	-0.0723
maintenance	0.0124	0.0135	0.00113	0.00117
Status	9.356***		0.641***	
multiple	-2.353**		-0.172*	
meet	7.510**		0.514**	
Saint-Laurent	-1.949		-0.217	
size	1.554**		0.109**	
FOAS	-0.481		-0.0552	
FOAK	-0.556		0.0264	
1300MW	9.189***		0.681***	
1450MW	20.20***		1.552***	
Year FE	Yes	Yes	Yes	Yes
Reactor FE	No	Yes	No	Yes
Observations	234	234	234	234
KP rk LM	17.32	8.197	17.32	8.197
KP rk Wald	26.86	10.05	26.86	10.05

*** p<0.01, ** p<0.05, * p<0.1

Results: Local monitoring enhances compliance

Empirical results

1. Increased monitoring intensity weakly increases perceived sanctions
2. Increased monitoring intensity increases reporting
3. Increased monitoring does not significantly affect safety care

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- $3 \Rightarrow$ penalties increase with monitoring intensity

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Conclusions

- More local monitoring increases compliance
- A 1.000€ increase in budget leads to a 1% increase in reporting

Additional results

- Strength of the instrument
  - Highly significant first stage
  - KP - F stat $>$ 10 in all regressions
  - but some KP - F stat $<$ Stock-Yogo 15% stat
- Evidence of a negative OLS bias
  - Consistent with reverse causality
- Robustness checks
  - Count estimators with control function approach (Wooldridge, 2015)
  - GMM with exponential link

A weaker interpretation

- What if we relax the assumption that detection is constant in safety care?
  - The operator can exert effort to improve safety, or to improve his detection abilities
- Most interpretations still hold:
  - Monitoring intensity weakly increases perceived sanctions
  - Monitoring intensity does not increase safety care
- The interpretation of final conclusion is weakened:
  - Increased monitoring intensity leads to better **transparency**
  - transparency = detection + compliance

Takeaways

- Managers react to informational incentives
  - they seem not to increase safety care
  - they act more transparently
- Transparency has positive externalities through learning
  - Local informational policies can be beneficial for safety
  - In France: cheap investment when compared to standard regulation
- Policy implications
  - In France: a law defining the funding of the commissions exist but is not applied, it probably should be.
  - More generally: informational policies may be effective complements to command-and-control safety regulation, especially to enforce compliance.

Thank you for your attention !

Presentation materials and references :

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

References I

Davis, L. W. and Wolfram, C. (2012). Deregulation, consolidation, and efficiency: Evidence from US nuclear power. *American Economic Journal: Applied Economics*, 4(4):194–225.

Duflo, E., Greenstone, M., Pande, R., and Ryan, N. (2013). Truth-telling by third-party auditors and the response of polluting firms: Experimental evidence from India. *The Quarterly Journal of Economics*.

Evans, M. F., Gilpatric, S. M., and Liu, L. (2009). Regulation with direct benefits of information disclosure and imperfect monitoring. *Journal of Environmental Economics and Management*, 57(3):284–292.

Feinstein, J. S. (1989). The Safety Regulation of U.S. Nuclear Power Plants: Violations, Inspections and Abnormal Occurences. *Journal of Political Economy*, 97:115–154.

Gilpatric, S. M., Vossler, C. A., and McKee, M. (2011). Regulatory enforcement with competitive endogenous audit mechanisms. *The RAND Journal of Economics*, 42(2):292–312.

References II

Hausman, C. (2014). Corporate incentives and nuclear safety. *American Economic Journal: Economic Policy*, 6(3):178–206.

Helland, E. (1998). The enforcement of pollution control laws: Inspections, violations, and self-reporting. *Review of Economics and Statistics*, 80(1):141–153.

Lin, L. (2013). Enforcement of pollution levies in china. *Journal of Public Economics*, 98:32–43.

Telle, K. (2013). Monitoring and enforcement of environmental regulations: Lessons from a natural field experiment in norway. *Journal of Public Economics*, 99:24–34.

Wooldridge, J. M. (2015). Control function methods in applied econometrics. *Journal of Human Resources*, 50(2):420–445.

Zahran, S., Iverson, T., Weiler, S., and Underwood, A. (2014). Evidence that the accuracy of self-reported lead emissions data improved: A puzzle and discussion. *Journal of Risk and Uncertainty*, 49(3):235–257.