Analyzing the Risk of Transporting Crude Oil by Rail

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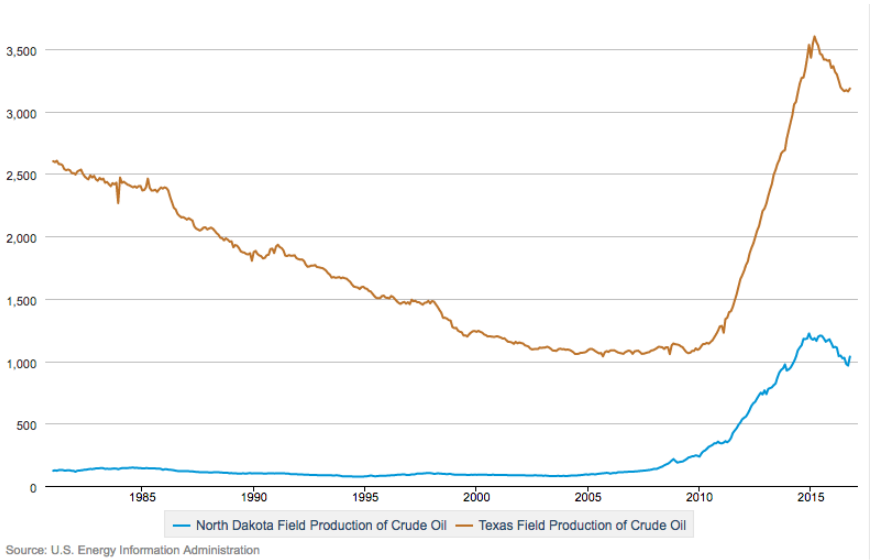
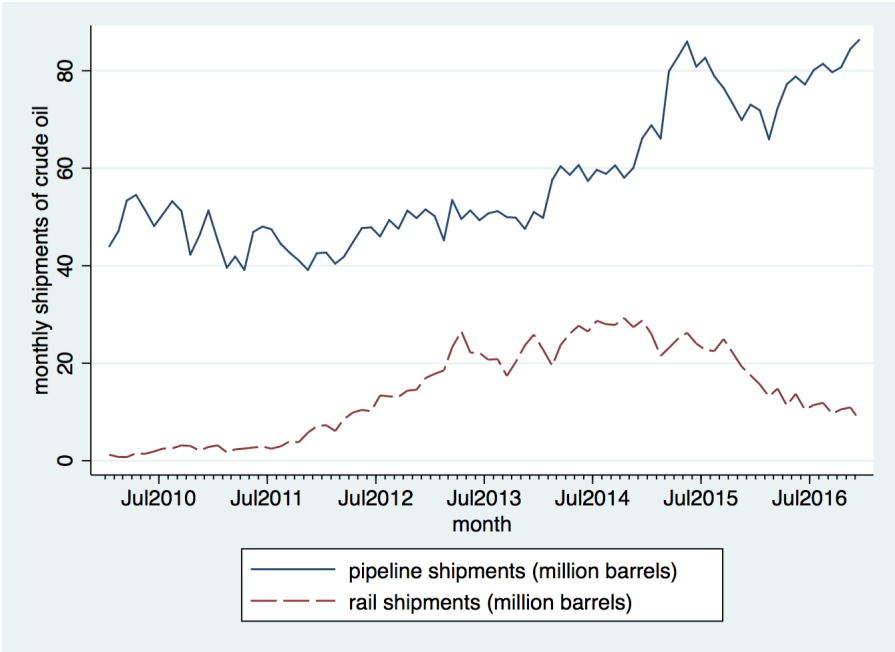
Tight oil production boom: time frame





- fracking boom really shows up in 2010
- pipeline transport didn't change much, rail picked up slack

Delivery issues: pipelines

A building burns after it was set alight by protesters, North Dakota, U.S., February 22, 2017. © Terray Sylvester / Reuters

July 6, 2013: Lac-Mégantic, Quebec

More incidents

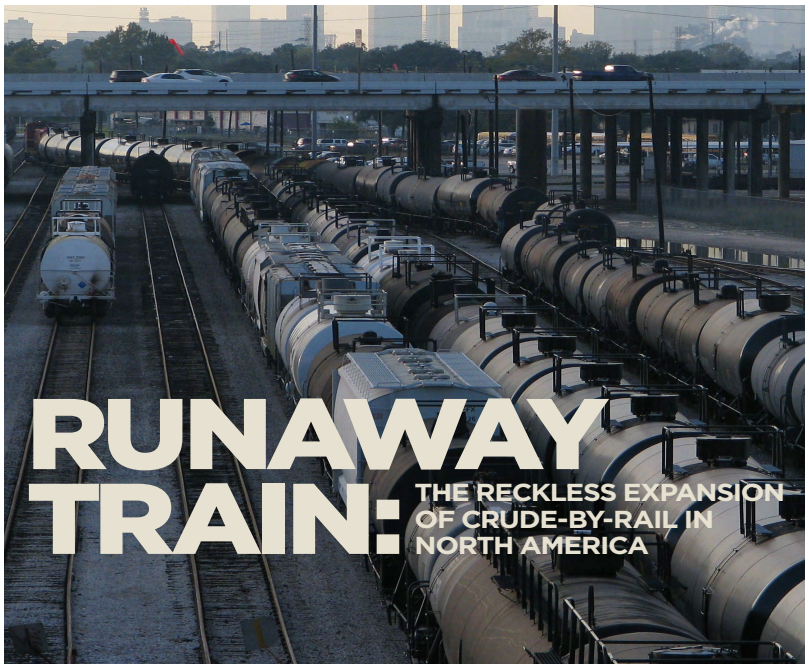
L: Casselton, ND (12/30/13)

R: Lynchburg, VA (4/30/14)

L: Mount Carbon, WV (2/16/15)

R: Galena, IL (3/5/15)

Pushback



- leads to new set of rail regulations
  - strengthening of rail cars
- Question: does increased rail traffic carrying crude raise chance of serious incident?
  - if so, how: more draws with fixed *pr* of trouble? increased *pr*?
  - wear and tear on tracks?
    - if so, from crude? from all shipments?

Sources

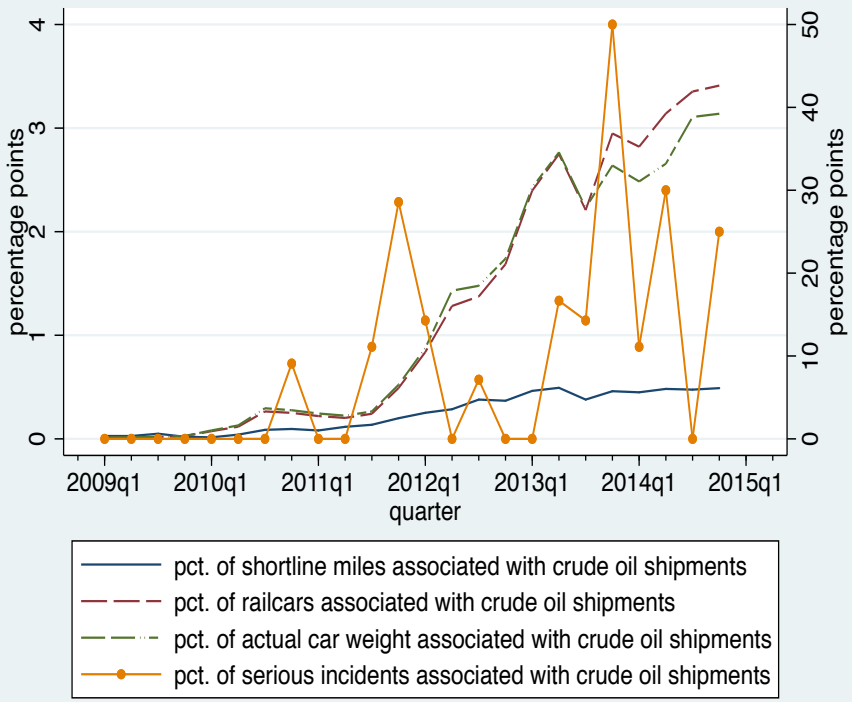
- Incidents
  - PHMSA reports
    - any (self-reported) “incident” (restrict to crude oil)
    - can be minor (common) or serious (infrequent)
    - observations collected for 1 Jan 2009 – 31 Dec 2014
    - info: amt. oil released, total econ. damages, origin state, destination state
- Rail Traffic
  - DOT waybill sample
    - most large carrier shipments
    - detailed information on rail shipments, 2009 - 2014
    - retained all shipments carrying oil, originating in US
- merged these sets
  - aggregated to monthly observations
    - “obs’n”: number of oil cars shipped in month t from location j to location k
    - number of incidents (0 – 8)
    - number of serious incidents (0/1)
    - amount of oil spilled; total costs

Considerations

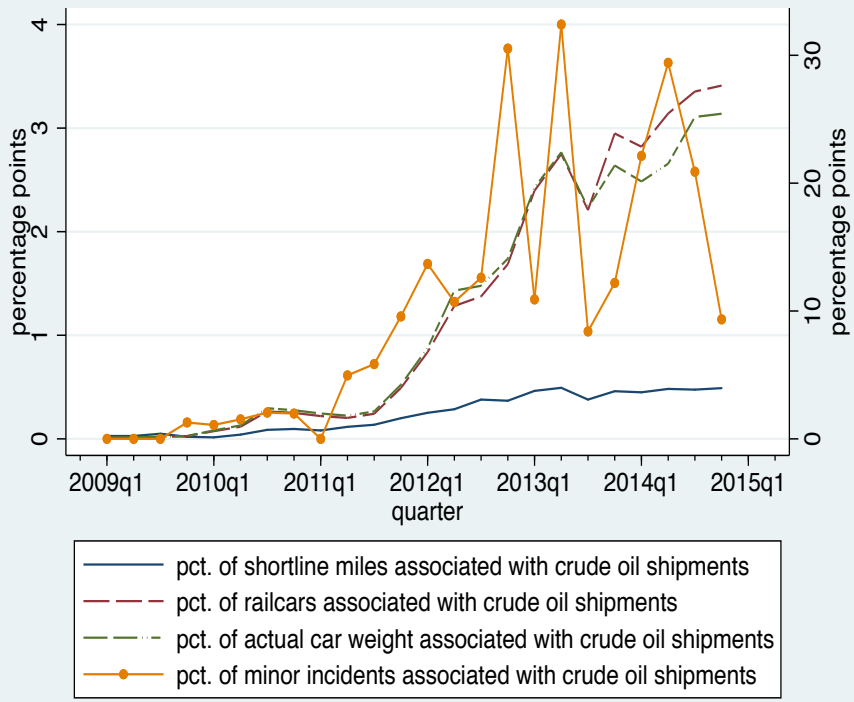
- oil-by-rail traffic grows steadily during sample period
  - in several states – at different paces, at different times
- heterogeneity in time and amt. of expansion, shipping destination
  1) focus on origin-destination state pairs
  2) focus on routes (origin-destination FIPS pairs)
- potential for effects to differ in relation to time of year
  - use monthly dummies?
- how to measure rail activity (cars, miles, weight, weight x miles)
  - possible link to “sloshing”
  - issues raised above

Rail traffic vs. incidents

serious



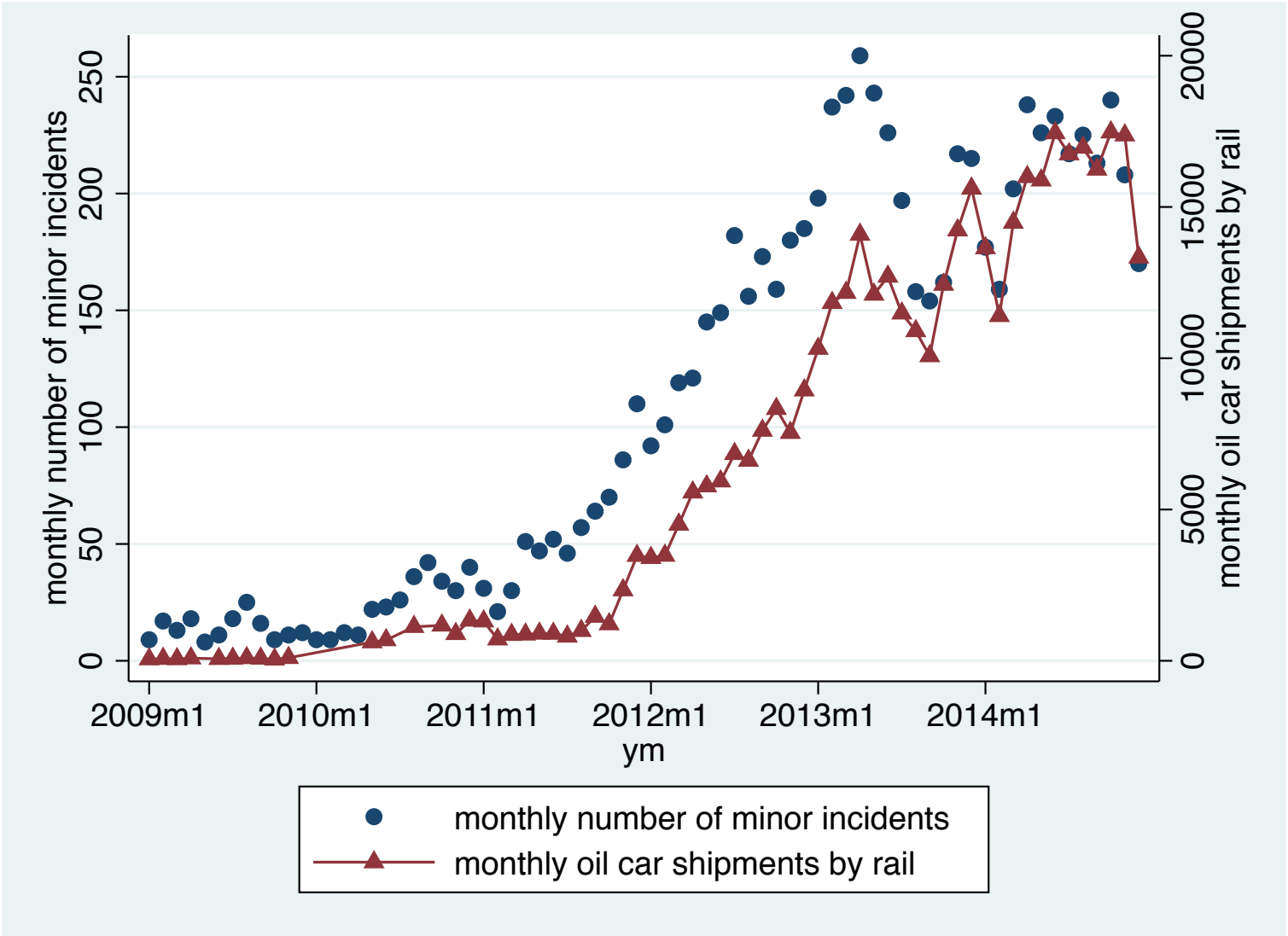
minor



Annual Rail Shipments Of Crude Oil Originating in US

		rail cars carrying oil		distance (thousand miles)		weight (thousand tons)	
year	oil shipments	total	per shipment	total	per shipment	total	per shipment
2009	167	942	5.6	170.8	1.023	1738.1	10.408
2010	294	9554	32.5	375.2	1.276	18613.8	63.312
2011	665	15818	23.8	843.9	1.269	29473.1	44.320
2012	1762	74525	42.3	2096.8	1.190	124203.0	70.490
2013	2508	147940	59	3001.8	1.197	223371.0	89.063
2014	2508	186954	74.5	3242.2	1.293	266733.1	106.353
Total	7904	435708	55.1	9730.7	1.231	664132.1	84.025

Minor Rail Incidents vs. Rail Oil Traffic



Approach

- Monthly observations: January 1, 2009 – December 31, 2014
- very few "serious" incidents $\Rightarrow$ use two-step approach:
  1. estimate relation between minor incidents and serious incidents
     - Logit analysis: probability of serious incident as function of accumulated number of recent minor incidents (3, 6, 9, 12 mos.)
  2. estimate relation between rail traffic and number of minor incidents
     - Logit model (incident: yes/no)
     - Count model (Poisson; Negative Binomial)
  3. estimate relation between rail traffic and
     i) quantity of oil released
     ii) economic damages

Logit Analysis of Serious Incidents, 1

	(1)	(2)	(3)	(4)
# minor incidents, past 3 mos.	0.363**	0.363**	0.305*	0.310***
	(0.168)	(0.165)	(0.166)	(0.052)
# minor incidents, past 6 mos.	-0.218	-0.219	0.003	
	(0.197)	(0.192)	(0.092)	
# minor incidents, past 9 mos.	0.134	0.141		
	(0.204)	(0.104)		
# minor incidents, past 12 mos.	0.005			
	(0.133)			
constant	-4.190***	-4.190***	-4.117***	-4.116***
	(0.318)	(0.314)	(0.296)	(0.296)

Dependent variable: indicator for serious incident, state pairs; 504 observations. Robust standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Logit Analysis of Serious Incidents, 2

	(1)
# minor incidents, 3 months lagged	1.336***
	(0.432)
# minor incidents, 4 months lagged	1.196**
	(0.599)
# minor incidents, 8 months lagged	1.559***
	(0.384)
# minor incidents, 11 months lagged	1.255**
	(0.530)
constant	-8.129***
	(0.549)

Dependent variable: indicator for serious incident, FIPS pairs; 10,477 observations. Perfectly collinear regressors dropped. Robust standard errors in parentheses.

Alternative specifications for minor incidents: Miles (1, 2, 3) and Weight (4, 5, 6)

	(1)	(2)	(3)	(4)	(5)	(6)
10^6 Miles (Crude)	9.842**	10.004**	11.559**			
	(4.563)	(4.427)	(4.857)			
10^6 Miles (All)	12.380**	11.510**	10.566*			
	(5.743)	(5.594)	(5.617)			
10^6 Tons (Crude)				0.119*	0.124*	0.117*
				(0.070)	(0.068)	(0.071)
10^6 Tons (All)				0.031	0.024	0.028
				(0.053)	(0.051)	(0.054)
constant	-1.060***	-0.965***	-1.137**	-0.587*	-0.489	-0.705*
	(0.327)	(0.334)	(0.442)	(0.303)	(0.310)	(0.429)

All regressions include fixed effects for origination-destination state pairs; $N = 913$.
Regressions 3, 6 include monthly fixed effects; 2, 5 include winter dummy

Logit Analysis based on routes

	(1)	(2)	(3)	(4)
10^3 Tons, Crude	-02.19	-2.24	-8.56*	-8.55*
	(0.00770)	(0.00770)	(4.52)	(4.48)
10^3 Miles, Crude	0.149**	0.149**	0.0971*	0.0972*
	(0.0648)	(0.0649)	(0.0542)	(0.0543)
10^6 Ton-Miles, Crude	2.05	-1.36	4.42*	0.530
	(4.02)	(6.23)	(2.37)	(0.281)
10^3 Cars, Crude	-4.34**	-4.33**	-1.09	-1.07
	(1.79)	(1.79)	(1.40)	(1.41)
10^6 Ton-Miles, All Shipments		3.43		3.87**
		(4.79)		(1.57)
constant			4.21***	4.22***
			(0.29)	(0.29)
N	873	873	2977	2977

Regressions based on origination-destination FIPS pairs. Robust standard errors in paren's.

Regressions 1, 2 (resp., 3, 4) use fixed (resp., random) effects based on FIPS pairs.

Alternative specifications for minor incidents, including Wheat shipments

	(1)	(2)	(3)	(4)
10^3 cars crude	0.322***	0.244*	0.312***	0.242*
	(0.082)	(0.132)	(0.078)	(0.124)
10^3 cars wheat	0.020	-0.080	0.114	-0.001
	(0.831)	(0.843)	(0.818)	(0.834)
10^3 cars all		0.088		0.078
		(0.112)		(0.106)
constant	-0.756*	-0.850**	-0.535*	-0.626**
	(0.417)	(0.425)	(0.293)	(0.309)

All regressions include fixed effects for origination-destination state pairs.; N = 913.

Monthly dummies (regressions 1, 2) or winter dummy (regressions 3, 4)

Alternative specifications for serious incidents

Count (All)	-0.190		0.029	-0.174
L1.Count (All)	0.027		0.152	0.031
L2.Count (All)	0.175		0.323**	0.180
Count (Crude)	0.775**			0.938**
L1.Count (Crude)	-0.078			0.251
L2.Count (Crude)	0.450			0.773**
10^3 Cars (Crude)		2.008**	2.011**	1.696
10^3 Tons (Crude)		-1.043**	-1.342**	-1.339**
N	2247	2486	2178	2178

All regressions use fixed effects logit analysis of serious incidents, all liquid shipments.

Coeff's for winter dummy; cars, tons, miles (all); miles (crude) insign. and not shown.

Rail Shipments and (a) Oil Spilled, (b) Total Damages

	(1)	(2)	(3)	(4)
10^3 cars	0.412***	0.409***	0.513***	0.511***
Jan		-0.491		-0.654
Feb		-0.388		-0.433
March		-0.504		-0.521
April		0.095		-0.036
May		0.045		-0.059
July		-0.240		-0.376
August		-0.315		-0.657
September		-0.158		-0.341
October		-0.330		-0.273
November		0.051		0.207
December		-0.271		-0.348
constant	-2.876***	-2.685***	-4.830***	-4.561***

LHS vbl: amount of oil spilled (1, 2; $N = 872$) or damages (3, 4; $N = 863$).

Impact on expected damages

- above results can be used to infer the expected impact of a one unit increase in rail traffic

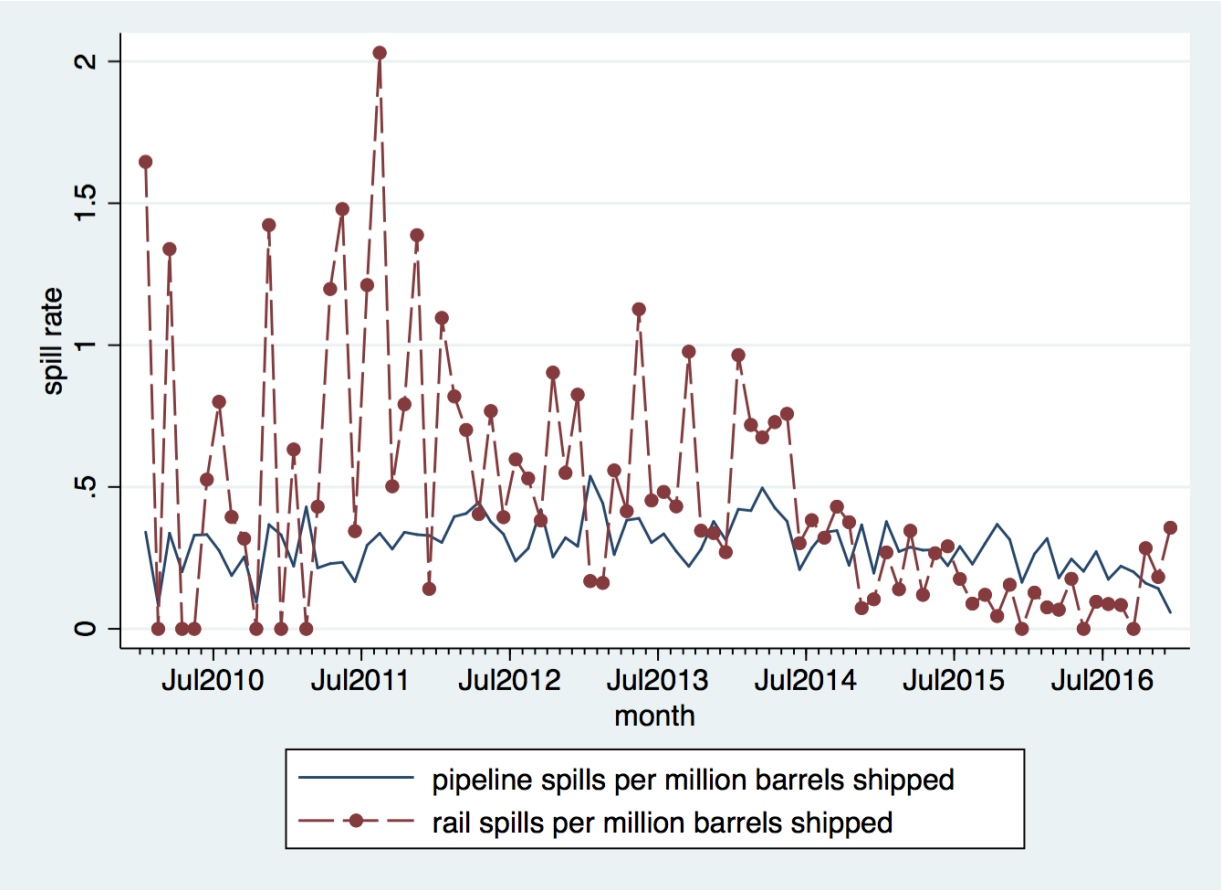
$$\mathcal{E}(D) = \exp(\hat{\beta}\,\overline{x}),$$

  - one unit = 1,000 rail cars
  - $\hat{\beta} = 0.511$ is the estimated coefficient on rail traffic
  - the average value of dollar damages is \$3,375
- thus, the expected value of total economic damages is

$$0.511 \times \$3,375 \approx \$1725$$

- less than \$2 per additional car

Spill rates: rail vs. pipeline deliveries



Spill rates: rail vs. pipeline deliveries

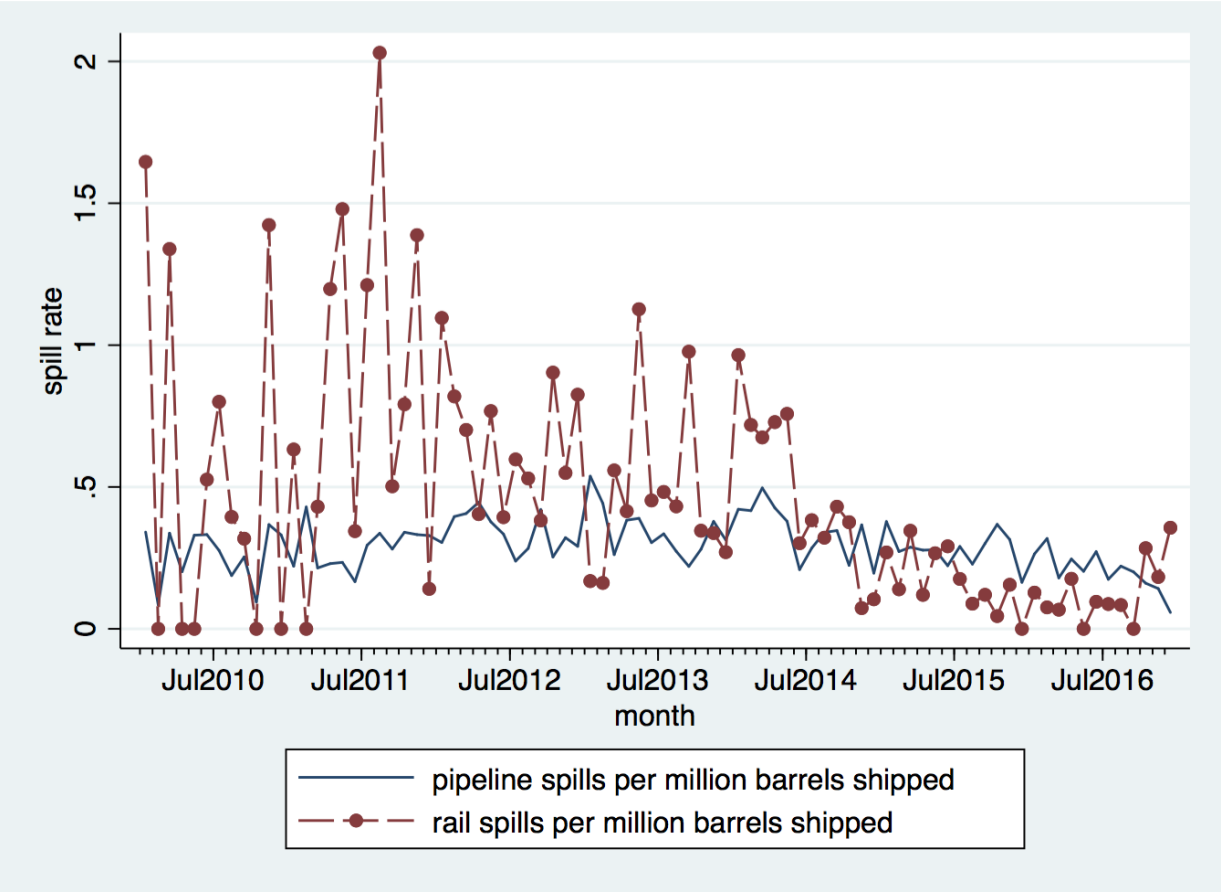


Table 1: Summary Statistics for Oil Spills

mode	N	mean	median	std. dev.	max
rail	75	4152	0.570	32558	281989
pipeline	84	411.1	7.590	1140	8193

Conclusion

- statistically important, negative relation b/w accumulated minor incidents over recent months and frequency of serious events
- statistically important (pos.) rel'n b/w rail traffic & pdf over minor incidents
  - adding 100,000 rail cars shipping oil $\Rightarrow \approx$ 1 add'n'l incidents / month
  - each add'n'l 3 recent minor incidents $\Rightarrow$ one add'n'l serious event
- largest fixed effects linked to routes originating in North Dakota
- statistically important positive rel'n b/w rail traffic and pdf over costs
  - implies impact on expected costs: marginal impact of one-unit increase in rail shipments $\approx$ \$1725
  - costs reported in database include
    - lost product and damaged capital (private costs)
    - costs from response, closure of main transportation arteries (social costs)
  - costs *do not* include
    - social costs associated with environmental damages from oil spills
    - property damages resulting from serious events (*e.g.*, spill-induced fires)
    - value of lost life