News Implied Volatility and Disaster Concerns

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Goal

- Measure disaster concerns over a long history
  - Do disaster concerns drive stock market expected returns?
  - Which disaster concerns?
  - Characterize time-series properties of the disaster probability
- Starting point: Options Implied Volatility (VIX) sensitive to disaster concerns, but only available since 1986
- Our approach: quantify disaster concerns using the frequency of words on the front-page of the *Wall Street Journal* available since 1890

Results Summary

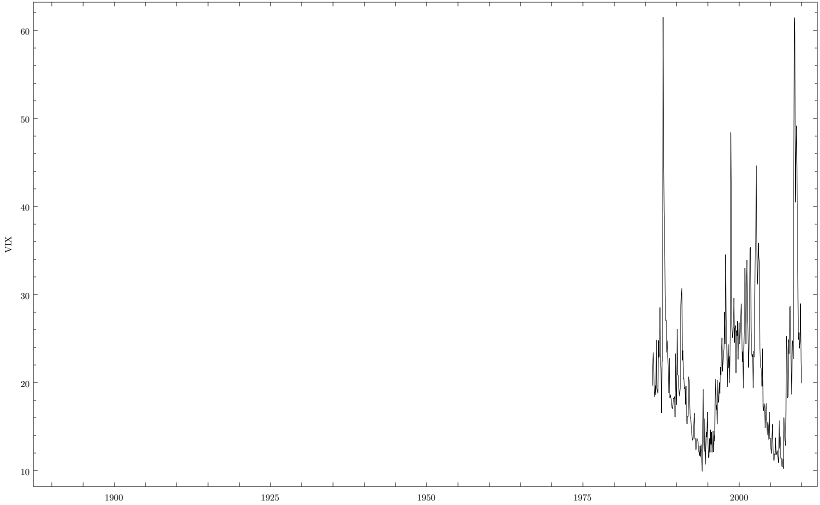
- News-implied volatility (NVIX) captures well the disaster concerns of the average investor over this longer history
  - high during world wars, financial crises, times of policy-related uncertainty, and stock market crashes
- Periods when people are more concerned with a rare disaster, as proxied by news, are either
  - followed by periods of above average stock returns, or
  - followed by periods of large economic disasters
- War-related concerns explain 50% of the time-variation in expected returns implied by NVIX
- Disaster probability is more volatile and less persistent than calibrated in the literature

Rare Disaster Asset Pricing

- Theory: Rietz (1988), Barro (2006), Gabaix (2012), Gourio (2008, 2012), Wachter (2013)
  - Disaster probability process is a key unobserved input
- Empirical: Backus, Chernov and Martin (2011), Bollerslev and Todorov (2011), Bates (2012), Kelly (2012)
  - Focus on relatively short samples
  - Silent about the underlying drivers of disaster concerns

News Implied Volatility

VIX (VXO) is available only recently, 1986-present



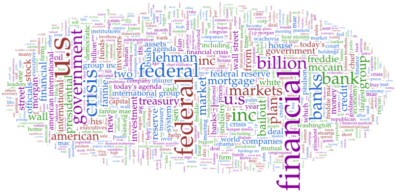
Our Data

We have news, front-page titles and abstracts of the *Wall Street Journal*, 1890-2009

Date	Title	Abstract
2008-09-16	AIG Faces Cash Crisis As Stock Dives 61%	American International Group Inc. was facing a severe cash ...
2008-09-16	AIG, Lehman Shock Hits World Markets ...	The convulsions in the U.S. financial system sent markets ...
2008-09-16	Business and Finance	Central banks around the world pumped cash into money ...
2008-09-16	Keeping Their Powder Dry: Draft Boards ...	The Selective Service System has the awkward task of ...
2008-09-16	Old-School Banks Emerge Atop New ...	Banks are heading "back to basics – to, if you like, the core ...
2008-09-16	World-Wide	Thailand's ruling party chose ousted leader Thaksin's ...

$$VIX_t - \overline{VIX} = w_0 + \mathbf{w} \cdot \mathbf{x}_t + v_t$$

September 2008:



Raw word frequencies

Weighted word frequencies

News Implied Volatility

Support Vector Regression Avoids Overfitting

- SVR regression estimates $\mathbf{w}$, a $K \gg T$ vector of coefficients

$$VIX_t - \overline{VIX} = w_0 + \mathbf{w} \cdot \mathbf{x}_t + \upsilon_t \qquad t = 1 \ldots T \tag{1}$$

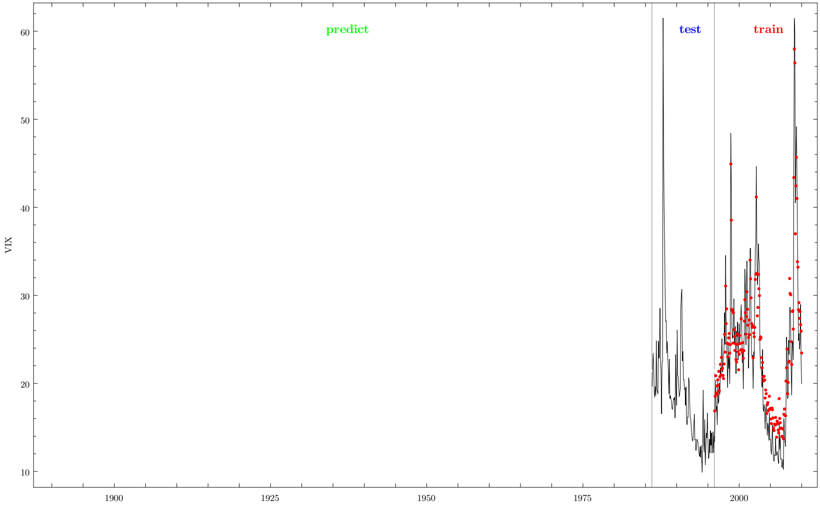
- $\mathbf{w}$ is restricted to be a weighted-average of regressors
- Only the weights α_t of *support vectors* are non-zero

$$\hat{\mathbf{w}}_{SVR} = \sum_{t \in train} \alpha_t \mathbf{x}_t \tag{2}$$

- Support vectors are word usage vectors of months that are "important" in the train sample
  - Benefit: Reduces an infeasible problem $O(K)$, to a feasible one $O(T)$
  - Benefit: Method has been shown to predict well out-of-sample
  - Cost: SVR cannot concentrate on $\mathbf{x}_t$ subspaces or do standard inference

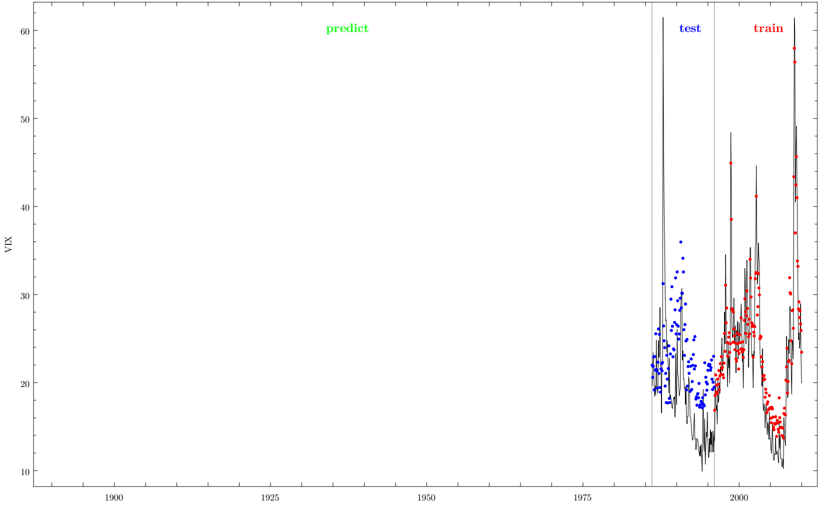
News Implied Volatility

Support Vector Regression: $VIX_t - \overline{VIX} = w_0 + \mathbf{w} \cdot \mathbf{x}_t + \upsilon_t$



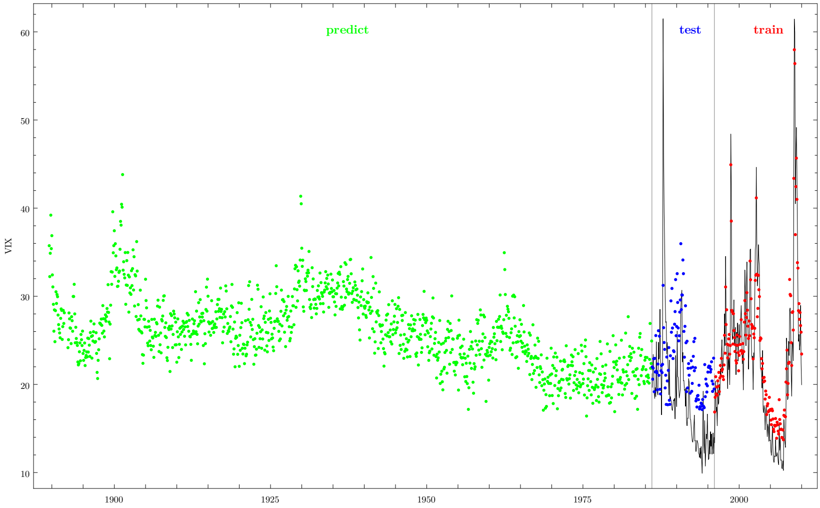
News Implied Volatility

Out-of-sample Fit: $R^2\,(test) = 0.34,\ RMSE\,(test) = 7.52$



News Implied Volatility

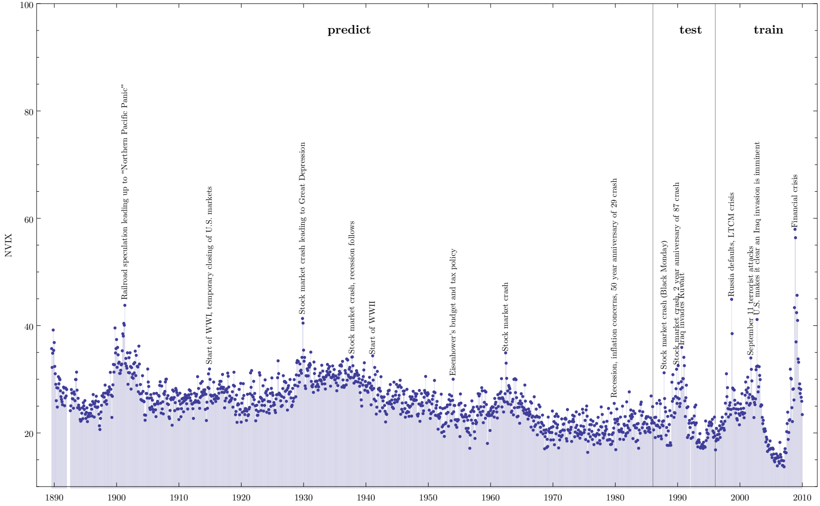
Fig. 1: NVIX captures well the fears of the average investor over this long history



See NVIX interactive chart with word clouds on my website

Is NVIX a Reasonable Proxy for Disaster Concerns?

Fig. 2: NVIX is particularly high during stock market crashes, times of policy-related uncertainty, world wars and financial crises



Alternative Text-based Analysis Approaches

- We use Support Vector Regression (SVR) to overcome the large dimensionality of the words space
- Our approach lets the data speak
- Kogan et al (2009) use SVR to predict firm-specific volatility using 10-Ks
- Two alternative approaches suggested by previous literature:
  1. Create topic-specific compound search statement and count the resulting number of articles
     - e.g. Baker et al (2013) searches for articles containing the term 'uncertainty' or 'uncertain', the terms 'economic' or 'economy' and one additional term such as 'policy', 'tax', etc.
  2. Classifies words into word lists that share a common tone and count all occurrences of words in the text belonging to a particular word list
     - e.g. Loughran and McDonald (2011) develops a negative word list, along with five other word lists, that reflect tone in financial text and relate them to 10-Ks filing returns

Disaster Probabilities, Implied Vol, and Expected Returns

- Economic environment with time-varying disaster probability
  - Link between VIX *squared* and disaster probabilities:

$$VIX_t^2 \approx p_t(1-b_c)^{-\gamma}\left(A + B \times \sigma^2_{e,t}\right) + \sigma^2_{e,t} \tag{3}$$

  - Excess returns are approximately linear in disaster probabilities

$$log\frac{E[R^e_{t+1}|p_t]}{E[R^f_{t+1}|p_t]} \approx \gamma\Sigma_{c,d} + p_t\left(\left(1-b_c\right)^{-\gamma} b_d - b_d\right) \tag{4}$$

- Peso problem: direct estimates of (4) are highly sensitive to frequency and size of the realized disasters in the sample

Disaster Probabilities, Implied Vol, and Expected Returns

- A more informative approach is to decompose the test in two:

1. Test if NVIX predicts returns in paths without disasters

$$log\frac{E[R^e_{t+1}|p_t, I^D_{t+1}=0]}{E[R^f_{t+1}|p_t, I^D_{t+1}=0]} \approx \gamma\Sigma_{c,d} + (1-b_c)^{-\gamma} b_d p_t \qquad (5)$$
$$= \beta^R_0 + \beta^R_1 VIX^2_t$$

   only depends on disaster concerns and not disaster realizations

2. Test if disaster probabilities actually predict disasters

$$E_t[I^D_{t\to t+1}] = p_t = \beta^D_0 + \beta^D_1 VIX^2_t \qquad (6)$$

- The rare disaster story imposes a cross-equation restriction between coefficients β^R_1 and β^D_1
- This approach requires judgment in identifying disasters
  - Call month t a disaster if stock market crashes and followed by large drop in economic activity (Fig. 3)

Return Predictability

Tbl 3: $\sigma\left(NVIX_t^2\right)$ change means 4 pp higher annualized excess return next month

$r^e_{t\to t+\tau} = \beta_0^R + \beta_1^R NVIX_t^2 + \epsilon_{t+\tau}$ if $I^{D,r}_{t\to t+\tau} = 0$				
Sample Period	1896-2009		1896-1995	
τ	β_1^R $t(\beta_1^R)$	R^2 T	β_1^R $t(\beta_1^R)$	R^2 T
1	0.19**	0.41	0.19*	0.36
	[2.04]	1322	[1.90]	1145
3	0.21***	1.55	0.20**	1.14
	[3.13]	1306	[2.45]	1131
6	0.16***	1.89	0.16**	1.55
	[2.71]	1284	[2.19]	1112
12	0.14**	2.55	0.15**	2.49
	[2.34]	1248	[2.01]	1082
24	0.08*	2.12	0.09	2.24
	[1.70]	1176	[1.49]	1022

Disaster Predictability

Tbl 4: $\sigma\left(NVIX_t^2\right)$ increases next month disaster probability from 0.58% to 1.2%

$I^{D,D}_{t\to t+\tau} = \beta^D_0 + \beta^D_1 NVIX^2_t + \epsilon_t$				
Sample Period	1896-2009		1938-2009	
τ	$\beta^D_1(\times 100)$ $t(\beta^D_1)$	R^2 T	$\beta^D_1(\times 100)$ $t(\beta^D_1)$	R^2 T
1	0.35**	0.67	0.29	1.11
	[1.97]	1367	[1.10]	863
3	0.23**	0.89	0.10	0.37
	[2.09]	1367	[0.85]	863
6	0.21*	1.46	0.04	0.10
	[1.75]	1367	[0.51]	863
12	0.21	2.77	0.01	0.03
	[1.58]	1367	[0.27]	863
24	0.14	2.26	-0.05	0.72
	[1.10]	1367	[1.04]	863
N_D	8		2	

Robustness

- Results are robust to (Table 5)
  - Realized volatility control
  - Expected volatility control
  - Truncation correction
- Similar and significant return predictability post Great Depression when *including* disasters (Table 6)

Which Concerns?

- NVIX predicts future excess returns and disasters consistent with the model
- But could potentially be because NVIX is measuring other forms of uncertainty unrelated to disaster risk
- Our text-based measure allows us to study which concerns drive risk premia
  - Content analysis

Categories Total Variance Share

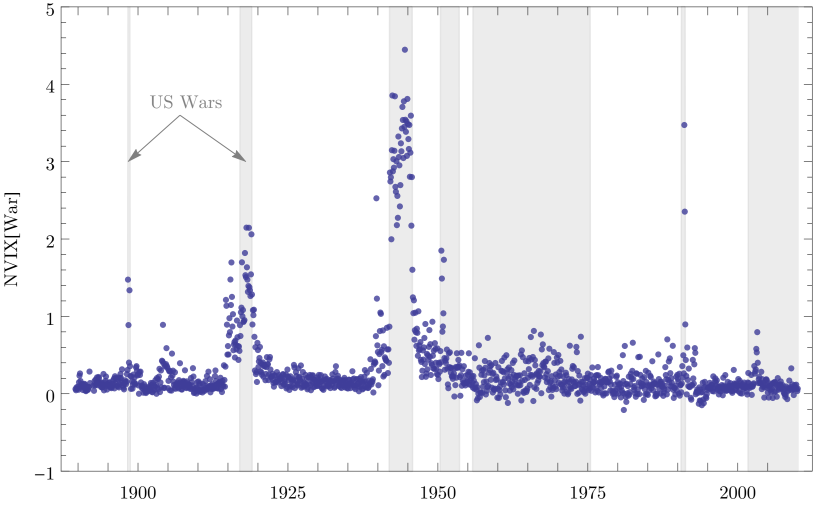
Tbl 10: *Stock Market* words explain half the variation in NVIX, *War* words explain 6%

- Classify words into five broad categories
- Rely on Princeton's widely used WordNet project

Category	Variance Share, %	n-grams	Top n-grams
Government	2.59	83	tax, money, rates
Intermediation	2.24	70	financial, business, bank
Natural Disaster	0.01	63	fire, storm, aids
Stock Market	51.67	59	stock, market, stocks
War	6.22	46	war, military, action
Unclassified	37.30	373988	u.s, washington, gold

NVIX due to War-related Words

Fig 4b: Captures well not only whether the US was engaged in war, but also the degree of concern about the future prevalent at the time



Which Concerns?

Risk premia decomposition strongly supports the time-varying rare disaster risk model

- Risk premia decomposition (Table 11):
  - *War* words explain 54% of risk premia variation
  - *Government* words explain 21%
  - Other categories are insignificant
- About half the variation in risk premia is unequivocally about disaster concerns

Disaster Probability Process

- "Is this calibration reasonable? This crucial question is hard to answer, since the success of this calibration is solely driven by the large and persistent variation in the disaster probability, which is unobservable." (Gourio, 2008)
- Our predictability regression coefficients imply
  - Expected disaster sizes (risk-neutral) consistent with standard calibrations (Barro, 1996; Gourio, 2012; Wachter, 2013)
  - Disaster probability less persistent and more volatile than standard calibrations (Gourio, 2012; Wachter, 2013)

Risk-Neutral Disaster Size

- Ratio of predictability coefficients β_τ^R and β_τ^D recovers the expected risk neutral size of disasters

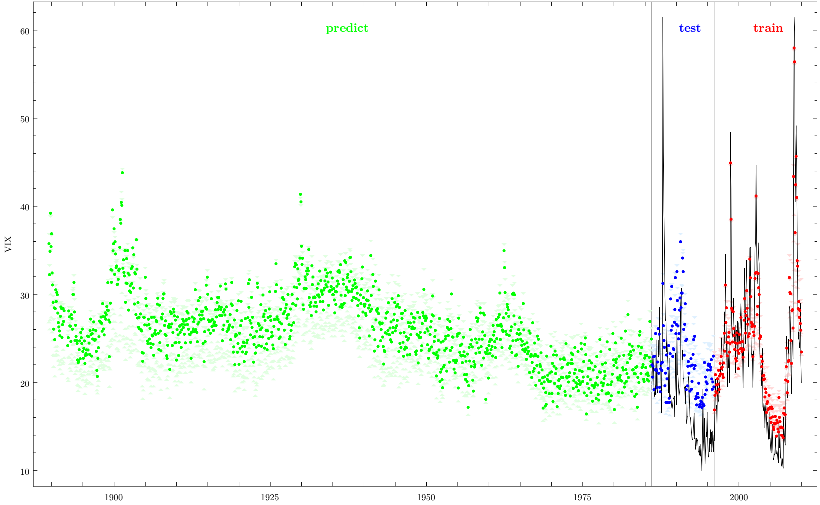
$$\frac{\beta_\tau^R}{\beta_\tau^D} = \left| b^d (1 - b^c)^{-\gamma} \right|$$

Conclusion

- We propose a text-based method to extend options-implied measures of uncertainty back to 1890
  - NVIX is plausibly related with concerns about rare disasters
  - Out-of-sample fit is stable over the long sample
- NVIX predicts returns and large economic disasters
  - Predictability results largely driven by war related concerns
  - Provide guidance for future calibrations
- Strong evidence in new data for an asset pricing model with time-varying disaster concerns
- A step forward in applying text analysis to big data to answer difficult economic questions
  - Content analysis is promising avenue for future research

News Implied Volatility

Fig. 1: Estimation is not sensitive to randomizations of the *train* subsample



Measurement Error

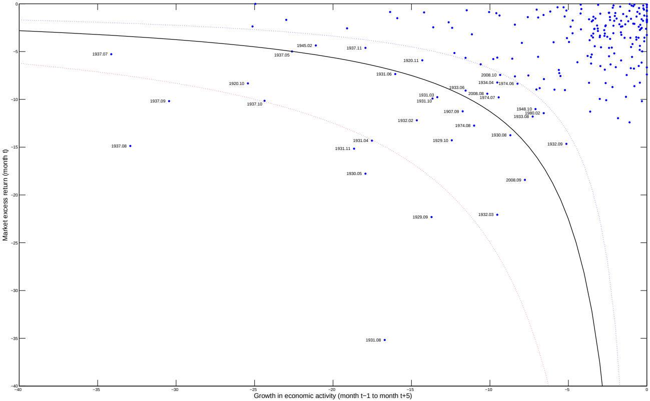
Table 2: Our predictive ability over the long sample is quite stable

- We assume the choice of words by the press provides a good and stable reflection of the concerns of the average investor
- Measurement error would bias our predictability results to zero
- Compare measurement error in *test* vs. *predict* subsamples
- Repeat exercise using *realized volatility* as dependent variable

Subsample	Period	$RMSE$ SVR	Obs.
train	1996–2009	3.35	168
test	1986–1995	9.60	119
predict	1890–1985	10.91	1150

- Modest increase in measurement error moving back in time

Economic Disasters Identification (Fig. 4)



- We call month t a disaster month if $r_t^m < 0$ and $r_t^m \times \Delta y_{t-1,t+5} \geq \kappa$
- Requires that big stock market drops be followed by large drops in economic activity

Alternative stories

Tbl 5: Results not driven by time-varying volatility or truncation

$$r^e_{t\to t+\tau} = \beta_0^R + \beta_1^R NVIX_t^2 + \beta_2 X_t + \epsilon_t \text{ if } I^{D,r}_{t\to t+\tau} = 0$$

	Realized Variance		Expected Variance		Truncation	
τ	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T	$\beta_1^R - \gamma$ / $t(\beta_1^R - \gamma)$	R^2 / T
1	0.14	0.68	0.11	0.79	0.15*	0.41
	[1.33]	1322	[1.13]	1319	[1.65]	1322
3	0.17***	1.99	0.17**	1.97	0.18***	1.55
	[2.58]	1306	[2.42]	1303	[2.66]	1306
6	0.15**	2.05	0.13**	2.31	0.13**	1.89
	[2.36]	1284	[2.12]	1281	[2.24]	1284
12	0.11*	3.11	0.10*	3.57	0.11*	2.55
	[1.93]	1248	[1.69]	1245	[1.89]	1248
24	0.08	2.24	0.07	2.37	0.06	2.12
	[1.53]	1176	[1.42]	1173	[1.22]	1176

Post Depression Sample *including* Disasters

Tbl 6: Similar and significant return predictability post Great Depression

$$r^e_{t\rightarrow t+\tau} = \beta_0 + \beta_1^R NVIX_t^2 + \beta_2 X_t + \epsilon_t$$

Sample:	1938-2009				1896-2009			
Disasters	Excluded		Included		Excluded		Included	
τ	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T
1	0.20	0.46	0.10	0.48	0.14	0.68	0.03	0.39
	[1.52]	857	[0.80]	863	[1.33]	1322	[0.26]	1367
3	0.23***	2.18	0.08	0.22	0.17***	1.99	0.03	0.32
	[2.81]	853	[0.65]	863	[2.58]	1306	[0.35]	1367
6	0.21***	3.16	0.13*	1.10	0.15**	2.05	0.05	0.48
	[3.02]	847	[1.72]	863	[2.36]	1284	[0.77]	1367
12	0.15**	2.84	0.12**	1.85	0.11*	3.11	0.02	0.15
	[2.22]	835	[2.15]	863	[1.93]	1248	[0.34]	1367
24	0.10*	2.43	0.12**	3.59	0.08	2.24	0.01	0.08
	[1.74]	811	[2.43]	863	[1.53]	1176	[0.17]	1367

Disaster Threshold Sensitivity

Tbl 7: Exactly as expected, including disasters biases downward

$$r^e_{t\to t+\tau} = \beta_0 + \beta_1^R NVIX_t^2 + \epsilon_t \text{ if } I^{D,r}_{t\to t+\tau} = 0$$

Threshold	$\kappa = 0.5\%$		$\kappa = 1\%$		$\kappa = 1.5\%$		$\kappa = 2\%$		$\kappa = 2.5\%$	
τ	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T	β_1^R / $t(\beta_1^R)$	R^2 / T
1	0.05	0.04	0.16*	0.32	0.19**	0.41	0.19**	0.42	0.21**	0.55
	[0.52]	1348	[1.77]	1335	[2.04]	1322	[2.04]	1311	[2.39]	1296
3	0.08	0.23	0.19***	1.30	0.21***	1.55	0.20***	1.48	0.23***	1.96
	[0.81]	1339	[2.88]	1322	[3.13]	1306	[3.04]	1291	[3.42]	1268
6	0.11*	0.95	0.16***	1.79	0.16***	1.89	0.14**	1.52	0.15**	1.75
	[1.83]	1327	[2.67]	1305	[2.71]	1284	[2.44]	1263	[2.52]	1230
12	0.12**	1.92	0.14**	2.60	0.14**	2.55	0.12**	2.00	0.12**	2.06
	[2.44]	1312	[2.40]	1278	[2.34]	1248	[2.11]	1215	[2.04]	1175
24	0.10**	3.29	0.10*	2.70	0.08*	2.12	0.07	1.68	0.06	1.25
	[2.44]	1288	[1.95]	1230	[1.70]	1176	[1.48]	1130	[1.27]	1067
N_D	7		14		21		27		34	

News Implied Volatility

Intuition behind Support Vector Regression

Ideal example with only two concerns: Wars and Financial crises

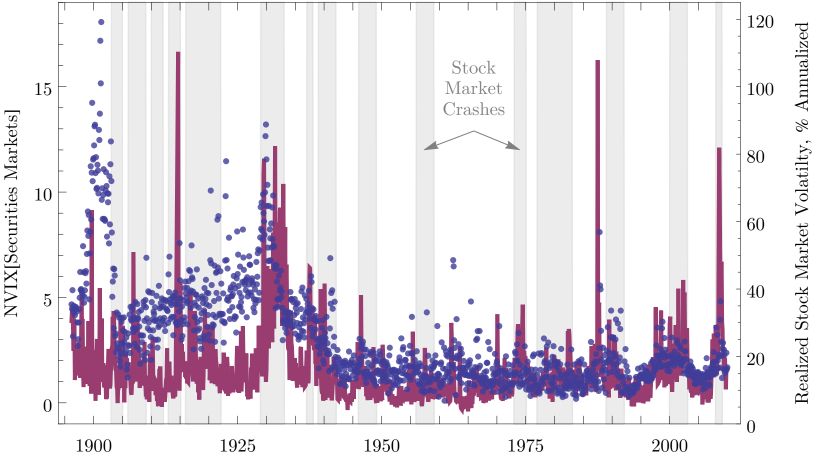
- Month j VIX is abnormally high and investors are exclusively concerned about a war
- Month i VIX is abnormally high and investors are exclusively concerned about a financial crises
- SVR uses word usage x_i and x_j as support vectors
- SVR decomposes VIX in the other months as weighted average of months i and j concerns

Word Categorization

- Classify n-grams into five broad categories of words: *Government*, *Intermediation*, *Natural Disasters*, *Stock Markets* and *War*
- Rely on Princeton's widely used WordNet project
- We select a few root word senses for each category, then expand to a set of similar words with WordNet:Similarity of at least 0.5
- Construct separate NVIX time-series implied by each category
- Measure the percentage of NVIX variance each category drives over the *predict* subsample

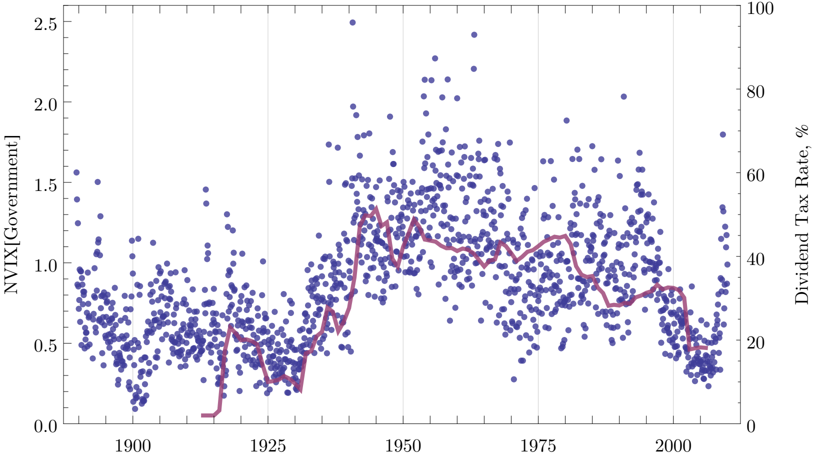
NVIX due to Stock Market-related Words

Fig 4a: Stock Markets component has a lot to do with stock market volatility



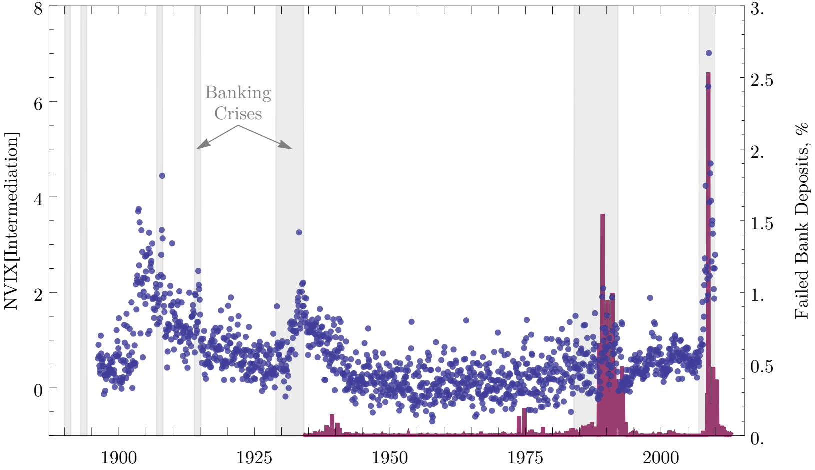
NVIX due to Government-related Words

Fig 4c: Policy-related uncertainty as captured by *Government* component tracks well changes in the average marginal tax rate on dividends



NVIX due to Financial Intermediation-related Words

Fig 4d: Spikes when expected, mostly during financial crises



Which Concerns?

Tbl 11: *War* words explain 54% of risk premia variation, *Government* words explain 21%

$$r^e_{t\to t+\tau} = \beta^R_0 + \sum_{j=1}^{N} \beta^R_j X^j_t + \epsilon_{t+\tau} \text{ if } I^{D,r}_{t\to t+\tau} = 0$$

τ	Gov't	War	Finance	Stocks	Natural	Residual	R^2/T
1	1.62	2.90**	1.69	2.41	-0.72	2.80	0.65
	[0.99]	[2.40]	[0.68]	[1.48]	[0.63]	[1.37]	1323
3	2.78**	2.76***	2.32	2.65*	-0.25	3.02**	2.41
	[2.41]	[2.84]	[1.30]	[1.92]	[0.32]	[2.28]	1307
6	2.12**	2.99***	1.78	1.49	0.19	2.73**	3.96
	[1.99]	[3.27]	[1.27]	[1.13]	[0.29]	[2.39]	1285
12	1.77*	2.77***	1.54	1.30	0.50	1.92*	5.81
	[1.69]	[3.74]	[1.47]	[1.05]	[0.90]	[1.67]	1249
24	2.16**	1.56**	1.28	1.39	-0.18	0.59	6.62
	[2.29]	[2.33]	[1.62]	[1.31]	[0.46]	[0.65]	1177

Risk-Neutral Disaster Size

Tbl 8: The amount of predictability we detect in expected returns is consistent with a reasonable calibration of rare disasters

(d) Risk Neutral Disaster Size	
1	0.53
3	0.91
6	0.79
12	0.65
24	0.57

- Assuming all time-variation in expected returns detected by VIX is driven by variation in the disaster probability, the above ratio recovers the risk-adjusted disaster size
- Barro and Ursua (2008 AER) estimates imply a risk-neutral disaster size of 0.76

Disaster Probability Persistence

- Ratio of predictability coefficients at different horizons recovers disaster probability persistence ρ_p^D

$$\frac{\beta_{\tau_L}^D}{\beta_{\tau_s}^D} = \frac{1-\rho_p^{\tau_L}}{1-\rho_p^{\tau_S}} \tag{7}$$

- Identical logic applies to the return predictability estimates.
- Simple time-varying disaster risk hypothesis predict same persistence for both specifications

Disaster Probability Persistence

Tbl 8: Persistent but considerably less than assumed in the literature

(a) Implied by Return Predictability Regressions

$\tau_S \backslash \tau_L$	3	6	12	24
1	1.12	0.95	0.94	0.92
3		0.82	0.90	0.89
6			0.94	0.91
12				0.88

(b) Implied by Disaster Predictability Regressions

$\tau_S \backslash \tau_L$	3	6	12	24
1	0.61	0.78	0.90	0.91
3		0.93	0.98	0.95
6			1.01	0.96
12				0.92

- Excluding one/three month ratio, tight range of persistence estimates implied by the return predictability regressions: $\rho_R \in [0.82, 0.95]$,$\rho_p \in [0.78, 0.98]$