The new modelling approaches and their impact on risk management

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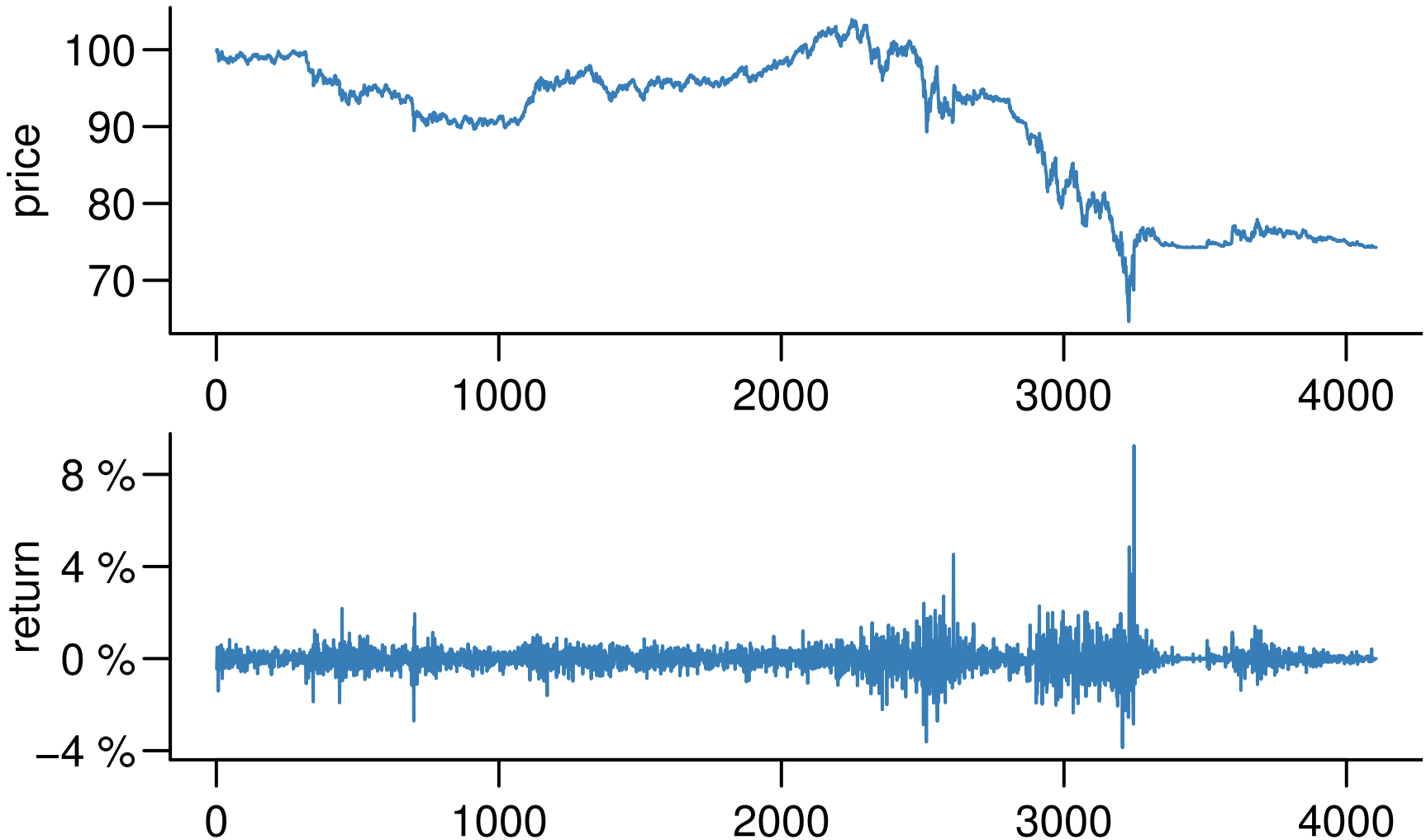
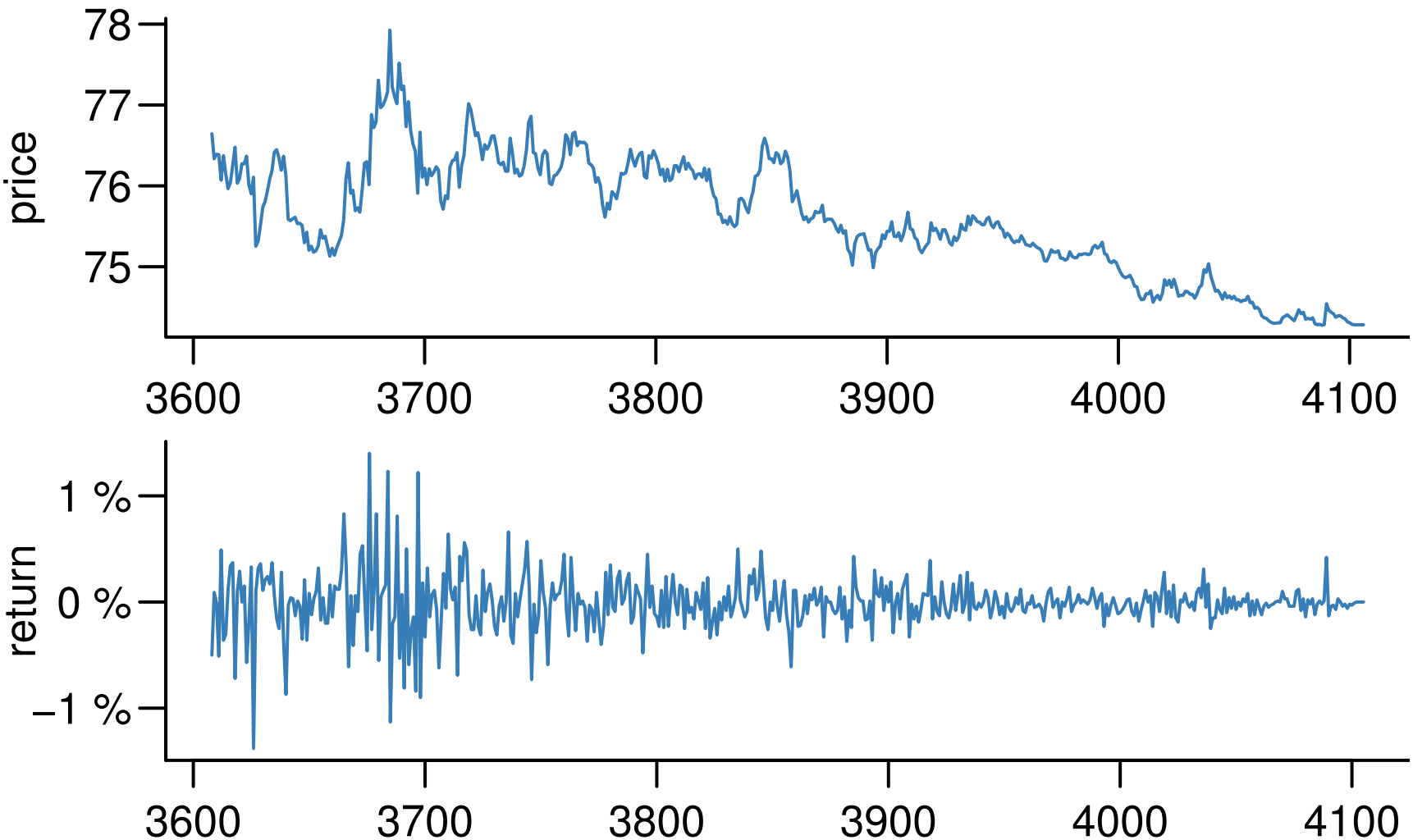
European Supervisor Education Initiative

Some actual price series



Some actual price series (Zoom in)



The two main concepts of market risk

1. Value–at–Risk (*VaR*)
   - Losses exceed the VaR 1% of the time
   - Usually one every hundred days
   - Expressed as 99% of the time losses are smaller than VaR
2. Expected Shortfall (*ES*)
   - On days when losses exceed VaR, how much do we expect to lose
   - Also called "Expected tail loss" or "tail VaR"

- VaR 99% embedded in the Basel I and II regulations from 1996
- To be replaced by ES 97.5% in Basel III (once every 40 days)

And estimated by

with "reputable" models generally accepted by authorities and industry

MA	moving average
EWMA	exponentially weighted moving average
GARCH	normal innovations
t–GARCH	student–t innovations
HS	historical simulation
EVT	extreme value theory

- While other models may be discussed, these six cover the vast amount of use cases
- Estimation period 1,000 days
- Other assumptions give qualitatively similar results

Risk for the next day $(t+1)$

Portfolio value is 1,000

Model	VaR	ES
HS	*14.04*	20.33

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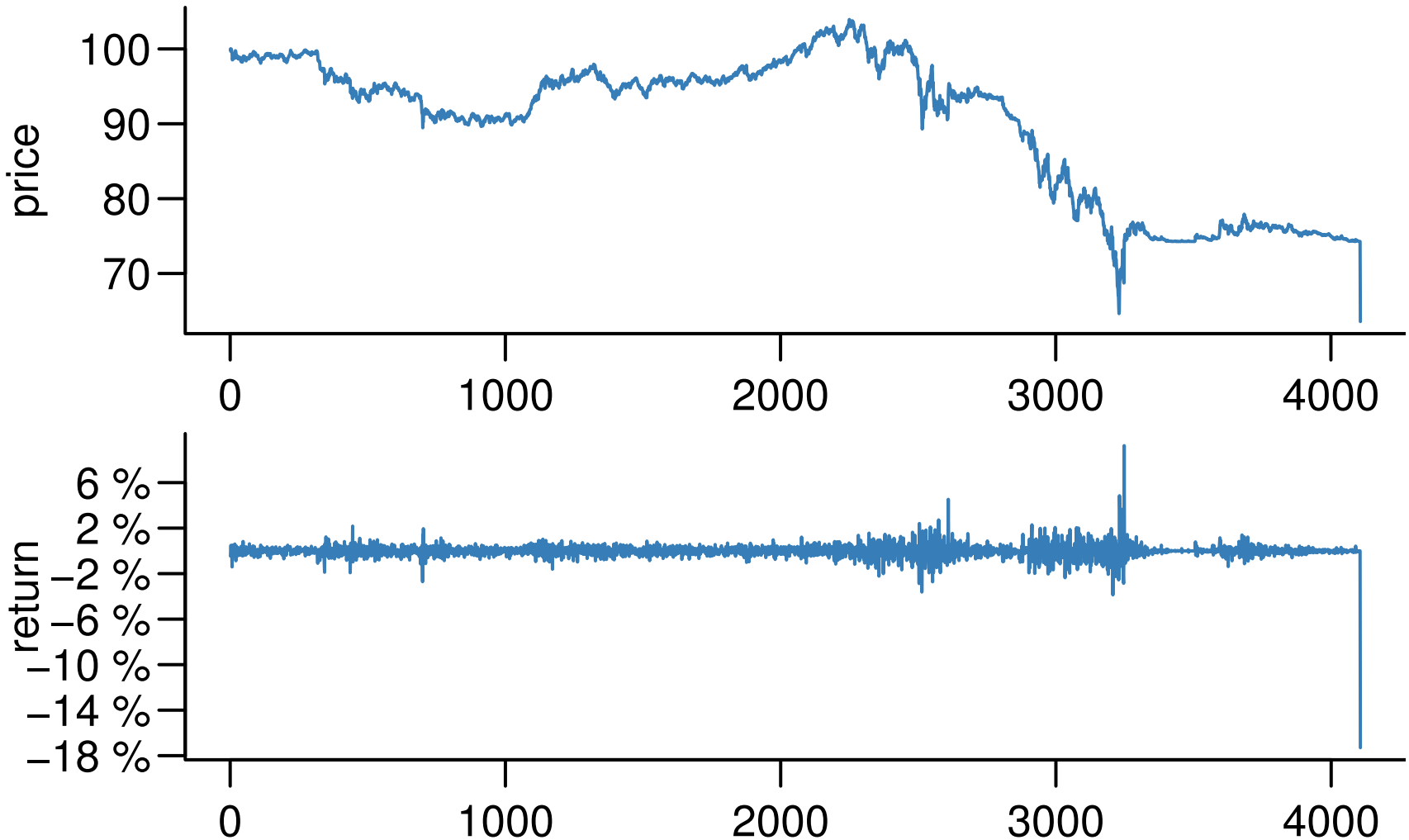
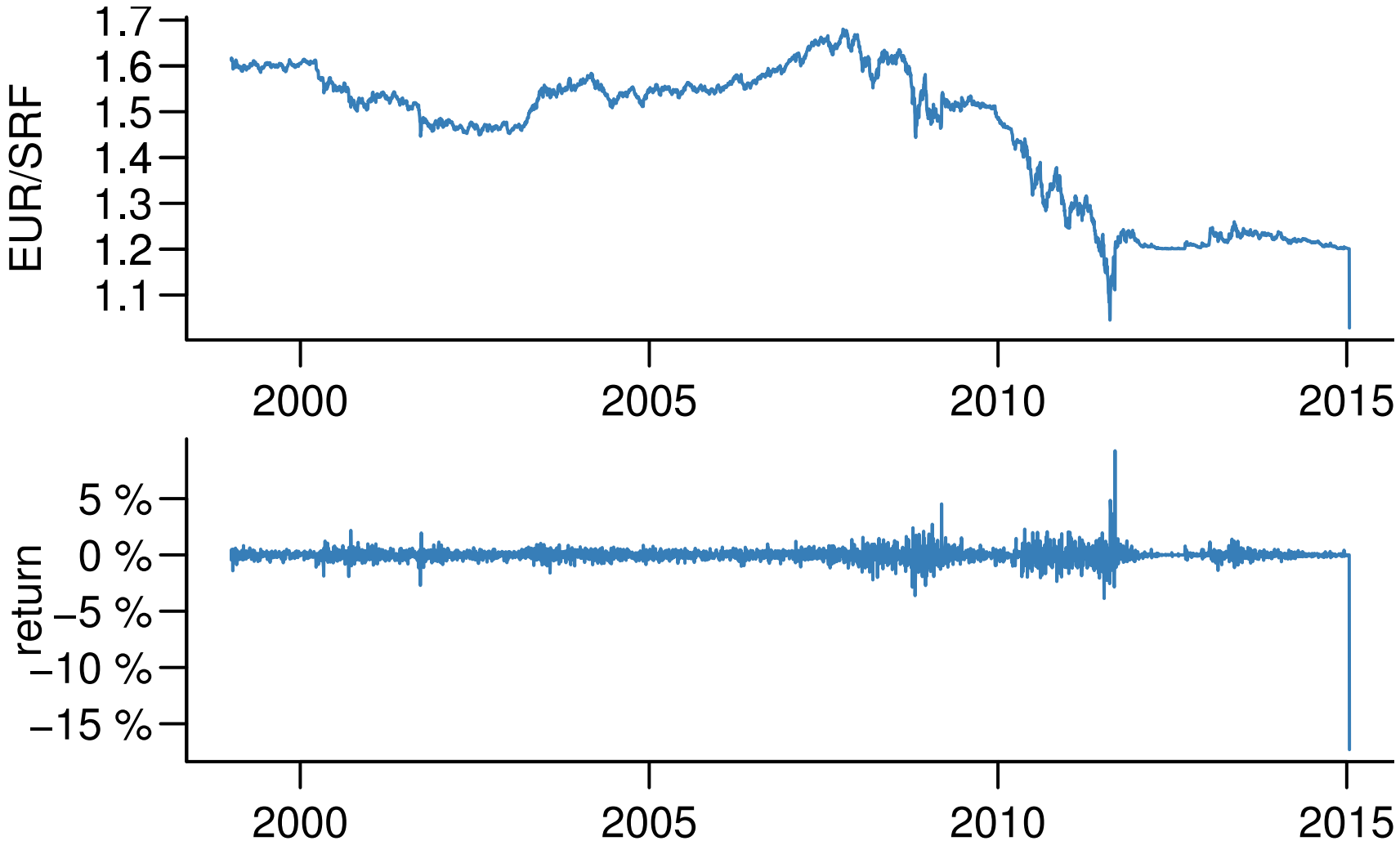
EWMA	*1.59*	1.82
GARCH	1.71	1.96
tGARCH	2.10	2.89
EVT	13.90	24.41
Model risk	*8.85* $= {}^{14.04}/_{1.59}$	13.43 $= {}^{24.41}/_{1.59}$

Lets add one more day...



€/CHF


EUR/SRF
1.7
1.6
1.5
1.4
1.3
1.2
1.1
2000
2005
2010
2015
return
5 %
0 %
−5 %
−10 %
−15 %
2000
2005
2010
2015

How frequently do the Swiss appreciate by 15.5%?

measured in once every X years

Model	frequency

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EWMA	never

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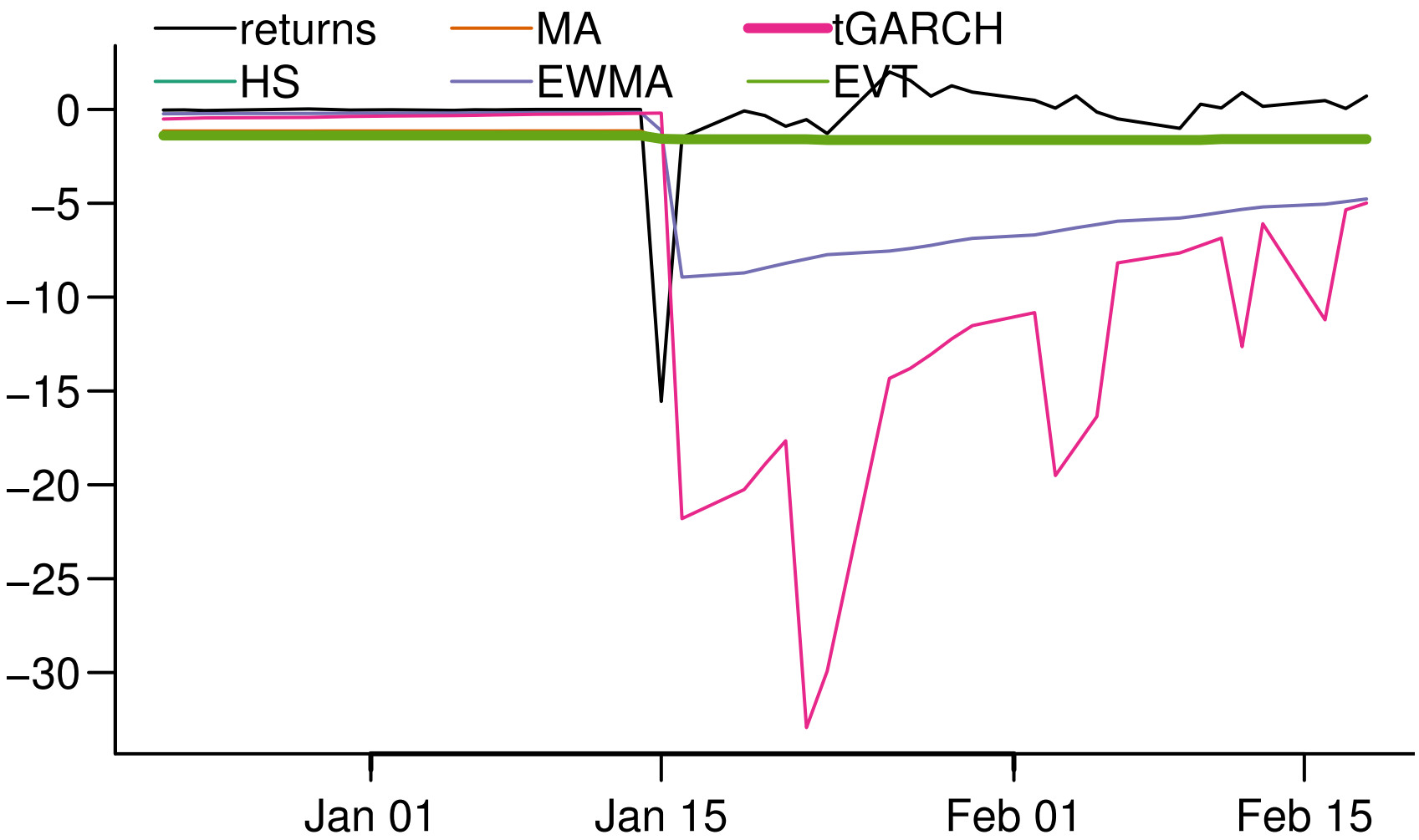
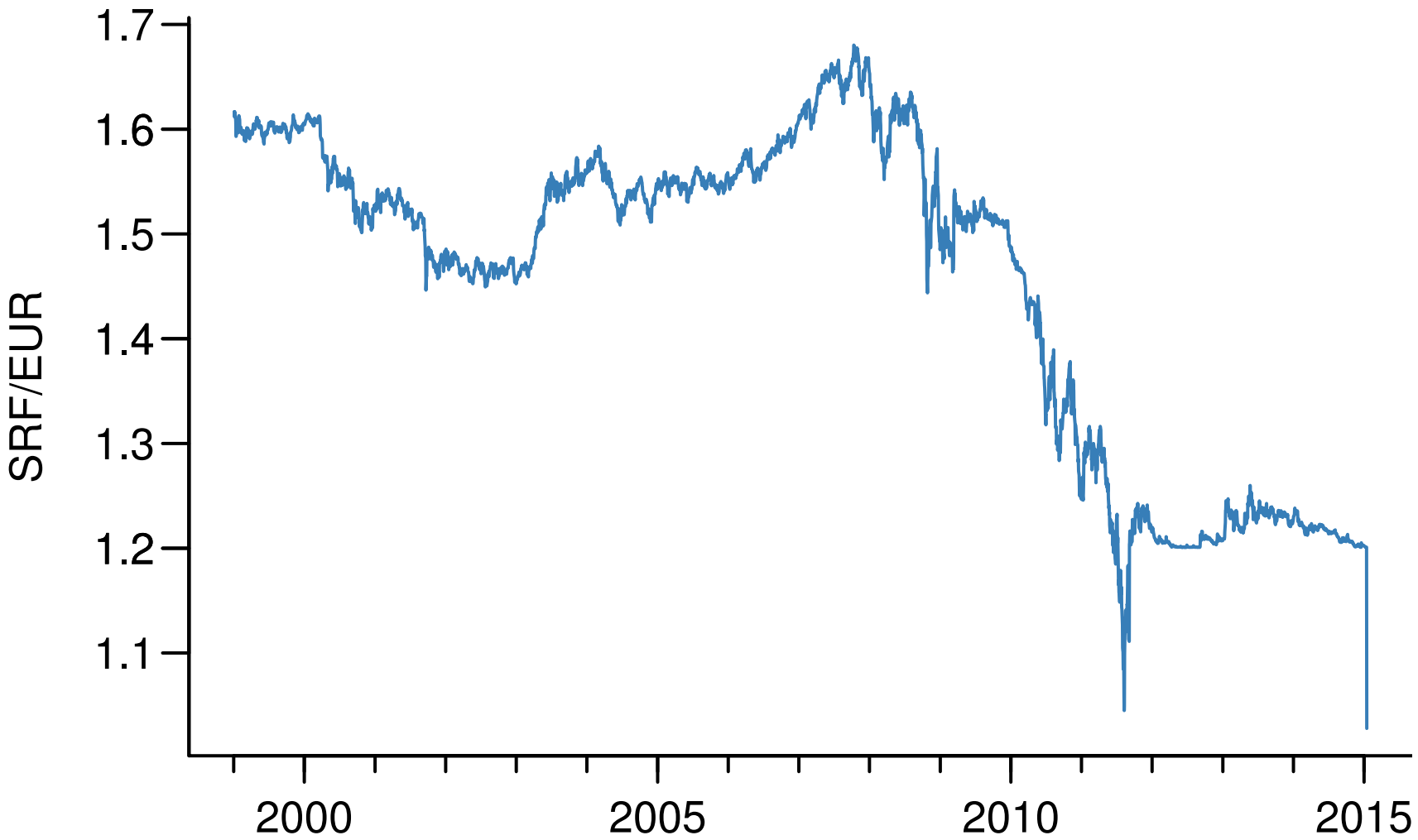
Even more interesting after the event



But is the event all that extraordinary?

just eyeballing it seems not that much



Should we care?

- I am often told that nobody manages FX risk with such methods
- But still they are a part of Basel III market risk
- Some countries use them for pension fund regulations
- The accuracy, or lack thereof, is representative for many other situations and methodologies

Could we do better?

- If one considers who owns the Swiss National Bank
- And some factors, perhaps
  - SNB dividend payments
  - Money supply
  - Reserves
  - Government bonds outstanding
- Yes, we can do much much better than the models used here

example is from `www.voxeu.org/article/what-swiss-fx-shock-says-about-risk-models`

Motivation

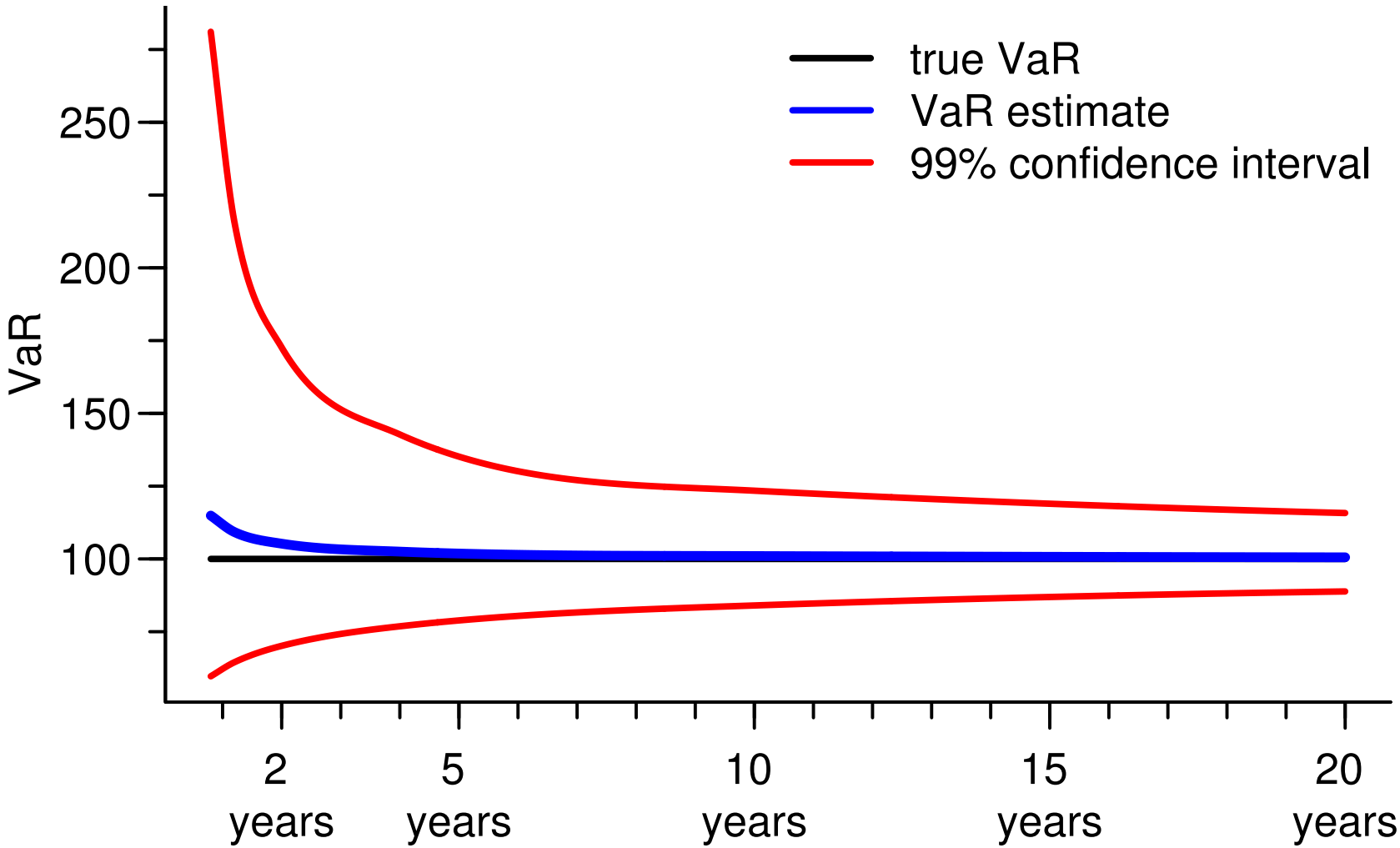
- Consider the various market risk forecasting methods
- A lot of papers exist on the asymptotic properties of various methods
- Or comparing method A to method B
- We could not find any paper on how the various methods work in small samples
- That is, in practice

CRSP stocks 99% risk

	VaR		ES	
N	standard error	99% conf. bound	standard error	99% conf. bound
300	(0.21)	[0.65,1.49]	(0.16)	[0.63,1.28]
1,000	(0.13)	[0.74,1.35]	(0.14)	[0.69,1.35]
5,000	(0.07)	[0.84,1.20]	(0.09)	[0.80,1.24]

Finite sample properties of VaR

$\alpha = 3$



VaR and ES simulation results

		VaR		ES	
sample size	α	se	99% conf. interval	se	99% conf. interval
300 days	2.5	0.33	[0.61,2.46]	0.56	[0.42,3.42]
300 days	5	0.18	[0.72,1.70]	0.22	[0.61,1.82]
4 years	2.5	0.15	[0.74,1.51]	0.31	[0.59,2.27]
4 years	5	0.09	[0.82,1.29]	0.12	[0.75,1.40]
50 years	2.5	0.04	[0.91,1.11]	0.09	[0.84,1.31]
50 years	5	0.02	[0.94,1.07]	0.03	[0.92,1.10]

Is ES really better than VaR?

yes, I know it is subadditive

- VaR is also subadditive unless tails are *superfat*
  - (tail index < 2)
- In practice, ES is VaR times a constant
  - Affected by tail thickness and sample size
  - VaR(99%) (Basel II) is approximately the same as ES(97.5%) (Basel III)
- ES is less precisely estimated than VaR
- With the distributions and probabilities considered here, VaR is preferred to ES
- Except, it is easier to manipulate VaR than ES

Manipulation

- The uncertainty creates considerable room for financial institutions to deliberately manipulate control processes like back testing
- Happens because ex-post verification can only look at outcomes not the accuracy of risk measurements
- e.g. the Basel traffic light methodology
- Under which, and with VaR, they are incentivized to increase tail risk
- Harder to do with ES

Conclusion

- VaR beats ES
  - Only reason to prefer ES is when concerned with manipulation
- Minimum sample size thousand days, preferably more
- At lower sample sizes, might as well use a random number generator

Model risk of risk forecast models

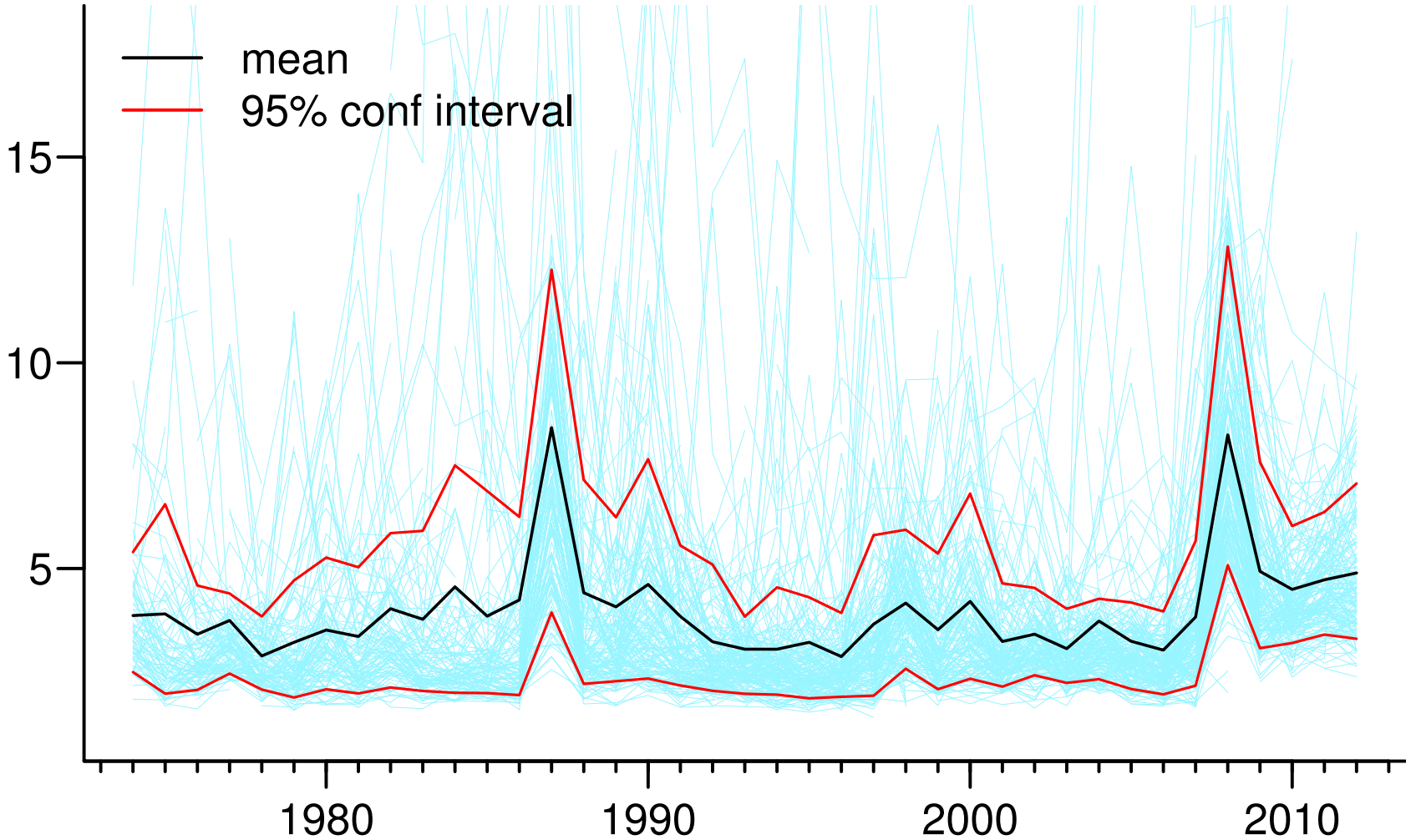
Every model is wrong — Some models are useful

The risk of loss, or other undesirable outcomes like financial crises arising from using risk models to make financial decisions

- Infinite number of candidate models
- Infinite number of different risk forecasts for the same event
- Infinite number of different decisions, many ex ante equally plausible
- Hard to discriminate

Model risk — Across all assets

Annual maximum



What drives risk?

- 2008 happened because of decisions made years earlier
- In 2003 all the signs pointed to risk being low
- The authorities and the private sector thought we were safe
- And so it was perfectly OK to take extra risk
- But
- "*Stability is destabilizing*" (Minsky)

The unknown unknowns

- The US stock market goes down by $200 billion in one day and nobody cares
- Potential subprime losses of less than $200 billion, and OMG, its the end of civilization
- The risk we know we prepare for — *known unknowns*
- The risk we don't know is the dangerous type
- The *unknown unknowns* are most damaging

Risk is endogenous

Danielsson–Shin (2002)

- Risk is *exogenous* or *endogenous*

  exogenous Shocks to the financial system arrive from outside the system, like with an asteroid

  endogenous Financial risk is created by the interaction of market participants

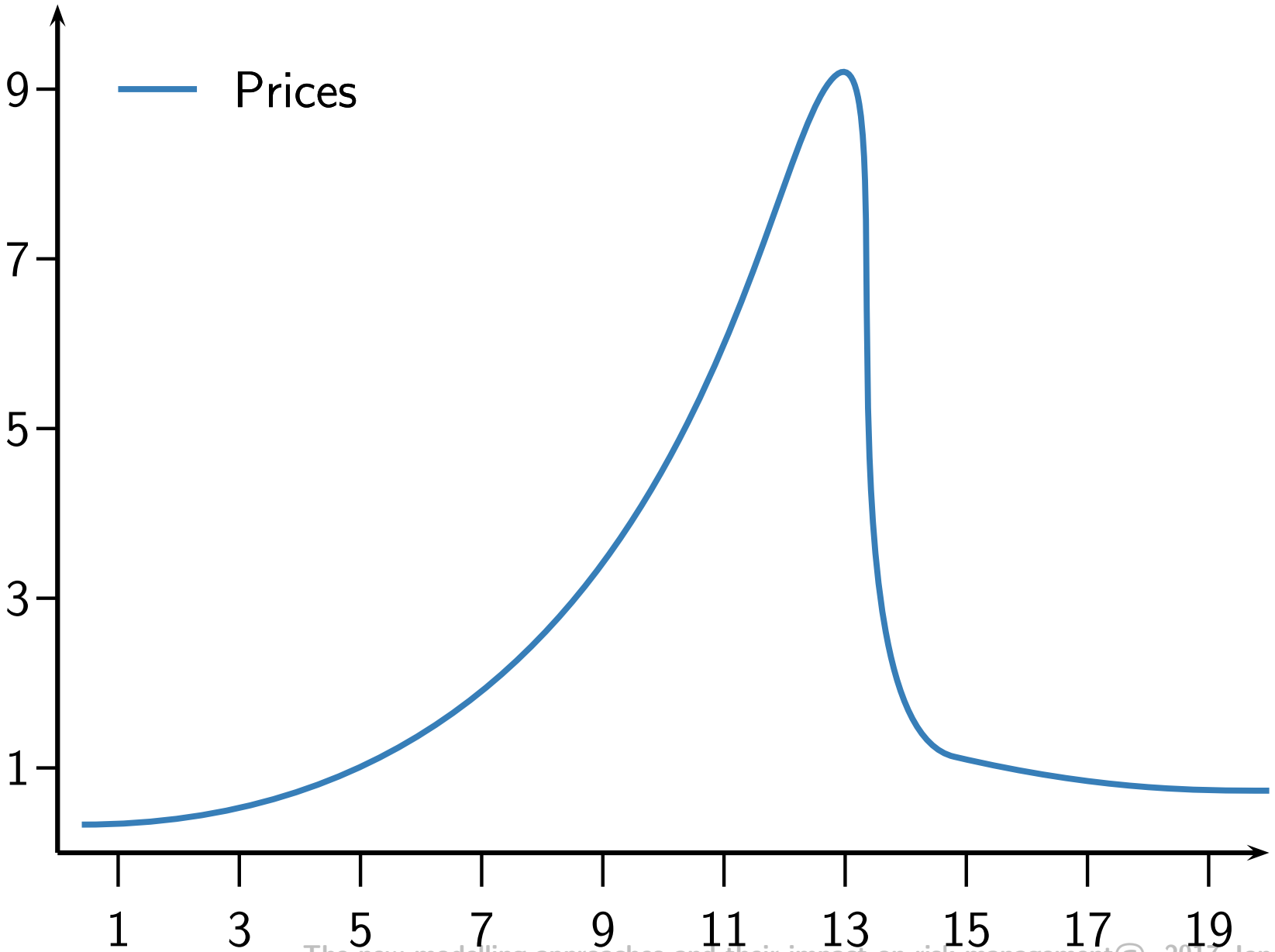
"The received wisdom is that risk increases in recessions and falls in booms. In contrast, it may be more helpful to think of risk as increasing during upswings, as financial imbalances build up, and materialising in recessions."
Andrew Crockett, then head of the BIS, 2000

- Market participants are guided by a myriad of models and rules, many dictate myopia
- Prices don't follow random walks in adverse states of nature
- Because that is when the constraints bind
- Endogenous risk is created by the interaction of human beings
- All with their own objectives, abilities, resources, biases
- *All large market outcomes are endogenous*

Two faces of risk

- When individuals observe *and* react — affecting their operating environment
- Financial system is not invariant under observation
- We cycle between virtuous and vicious feedbacks
  - *perceived risk* — as reported by risk models
  - *actual risk* — hidden but ever present

Endogenous bubble



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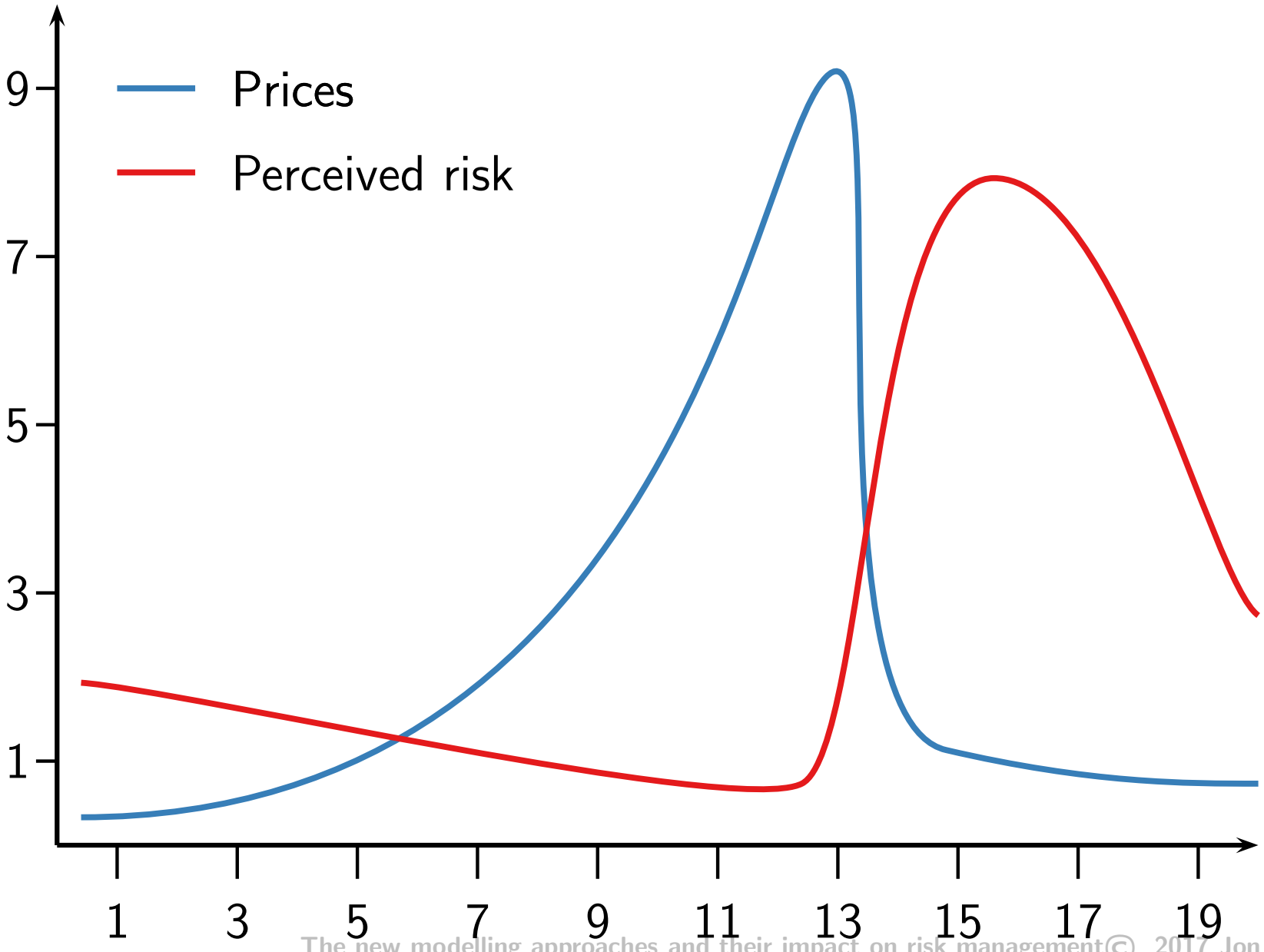

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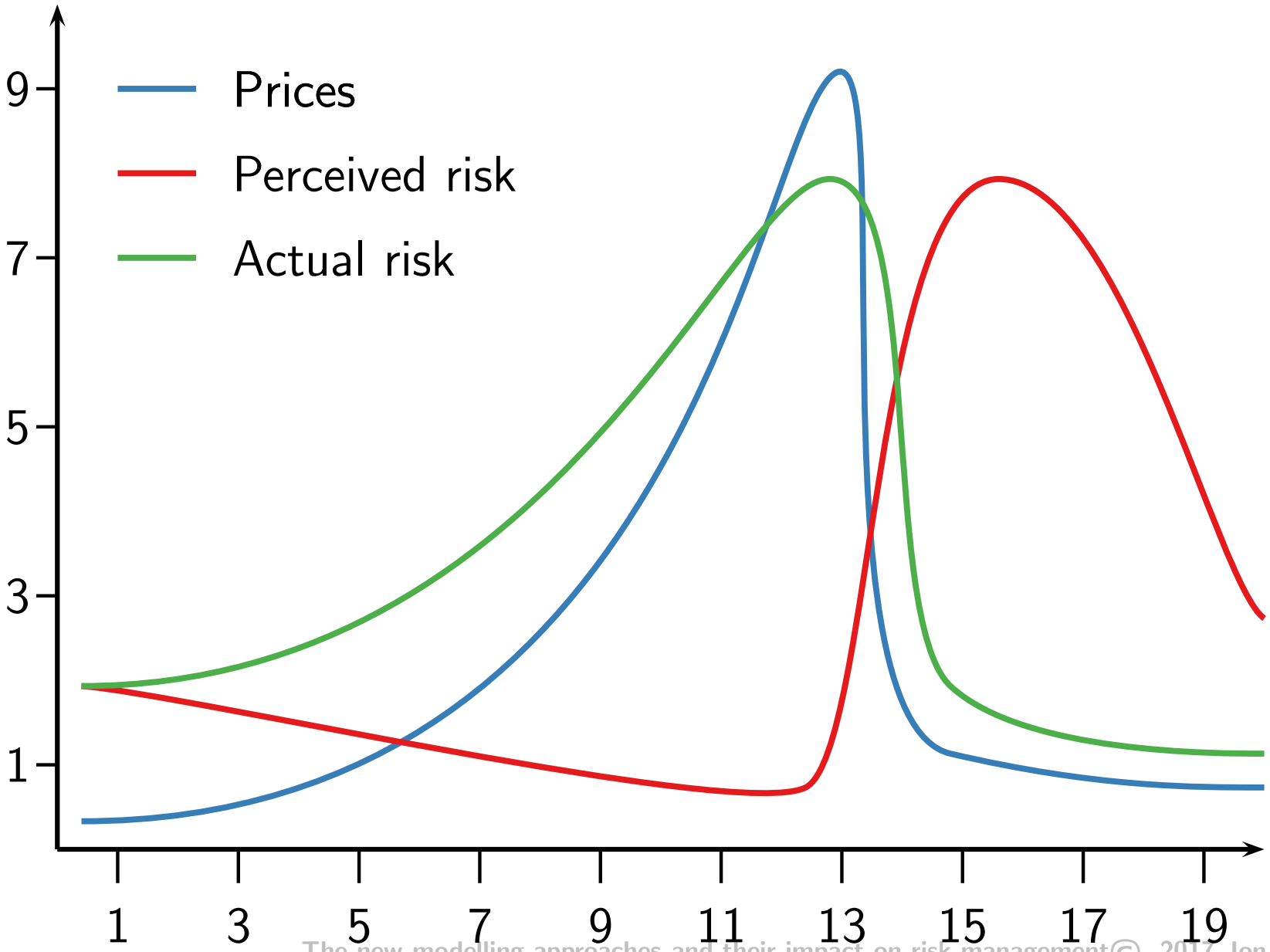
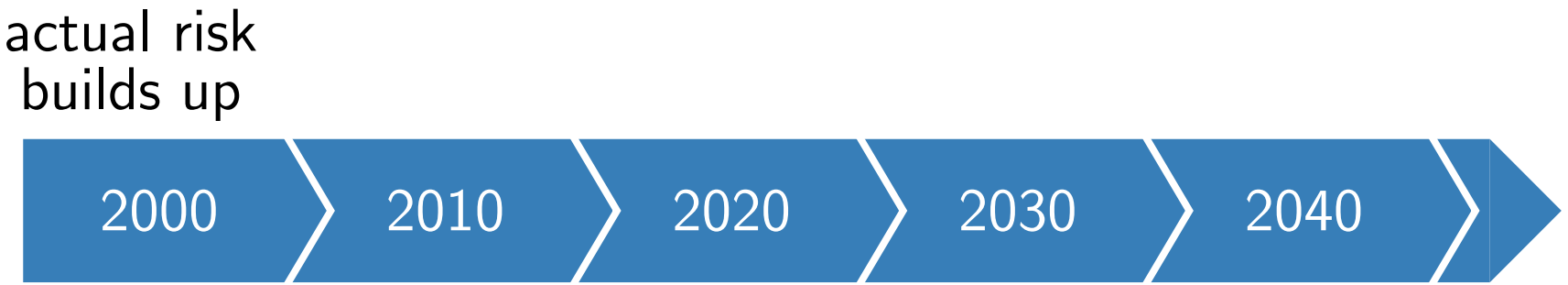


How often do systemic crises happen?

- Ask the IMF–WB systemic crises database (only OECD)
- Every 43 years (17 for UK)
- Best indication of the target probability for policymakers
- However, most indicators focus on much more frequent events
- Typically every month to every five months

The 43 year cycle of systemic risk



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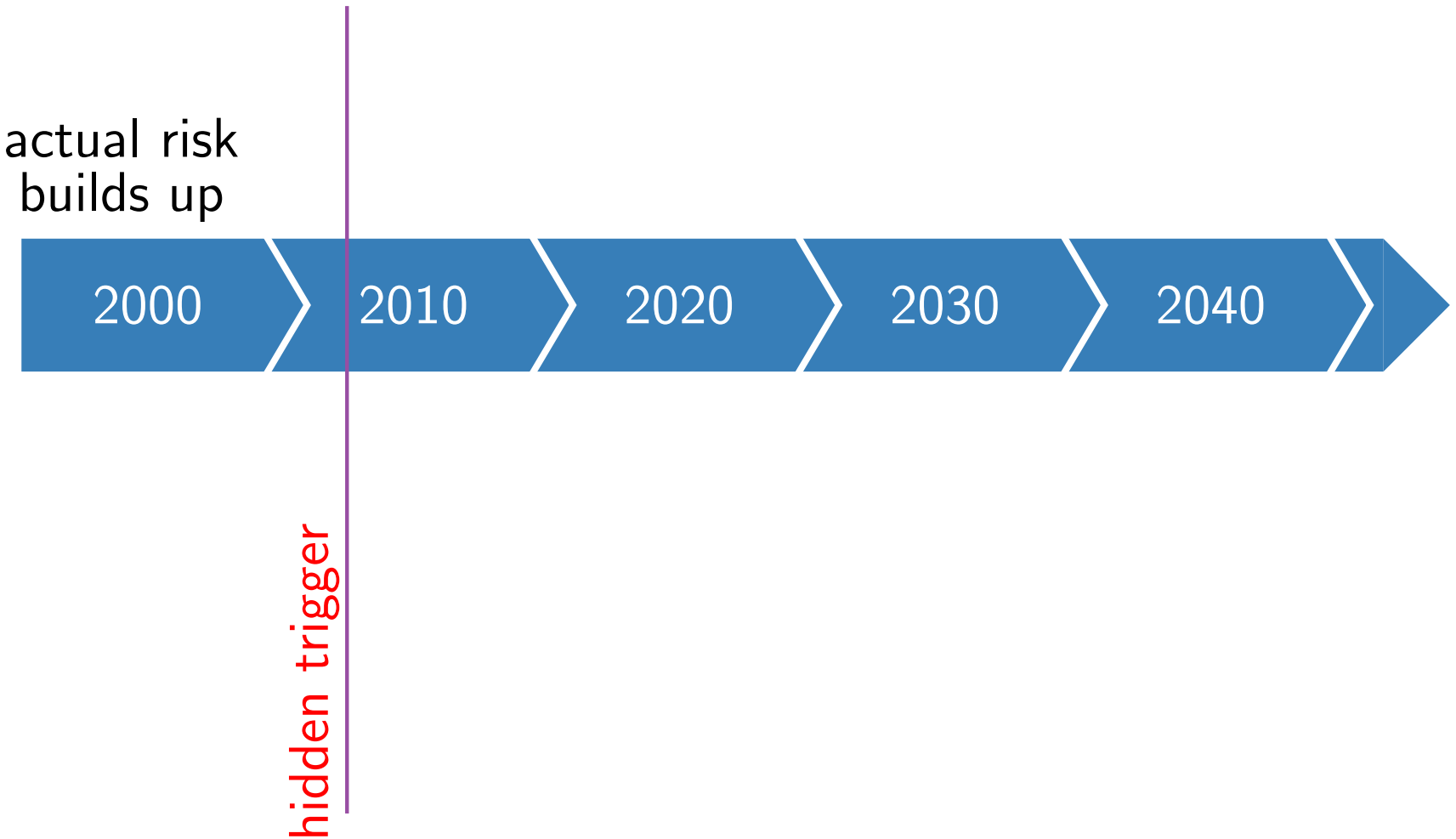

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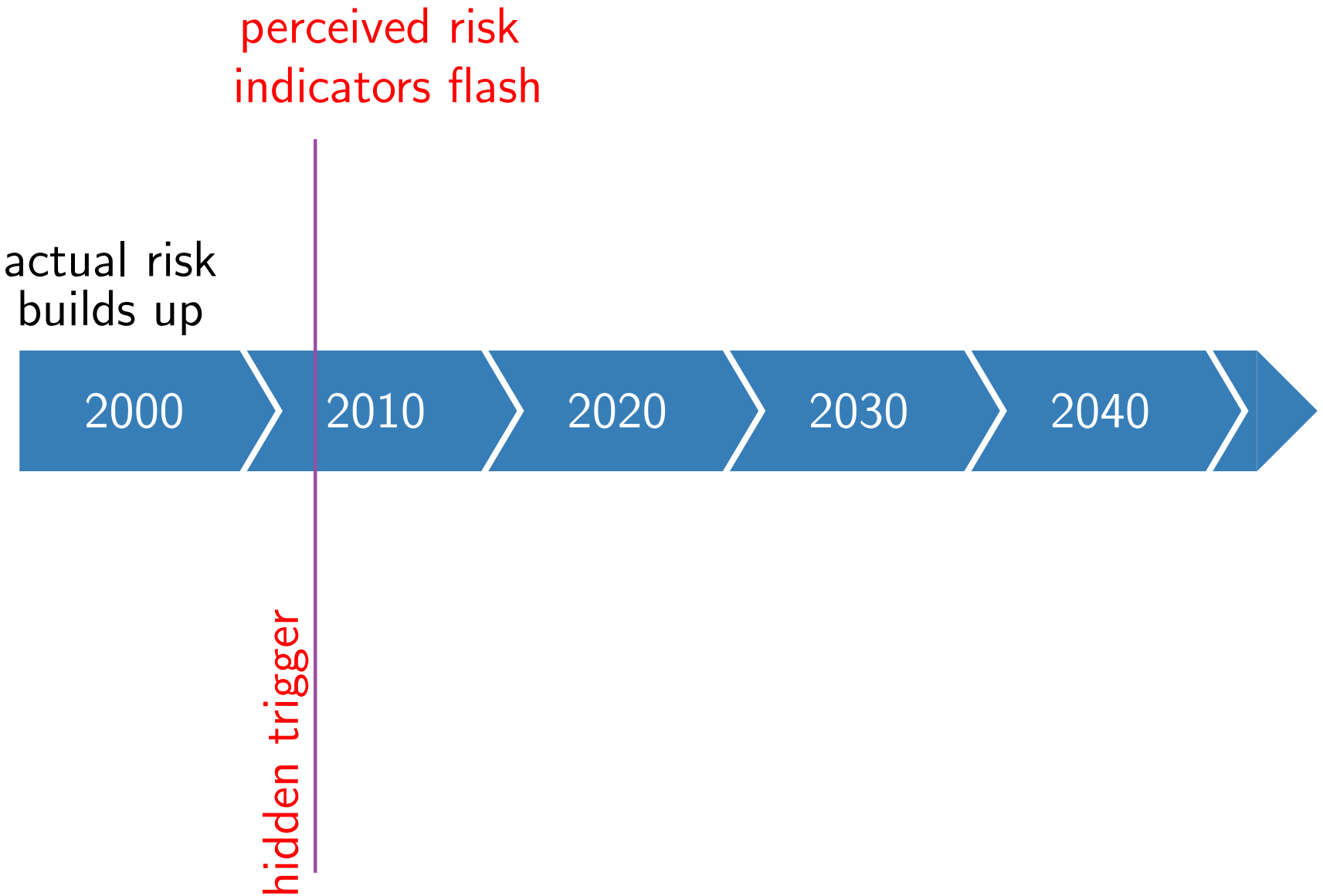

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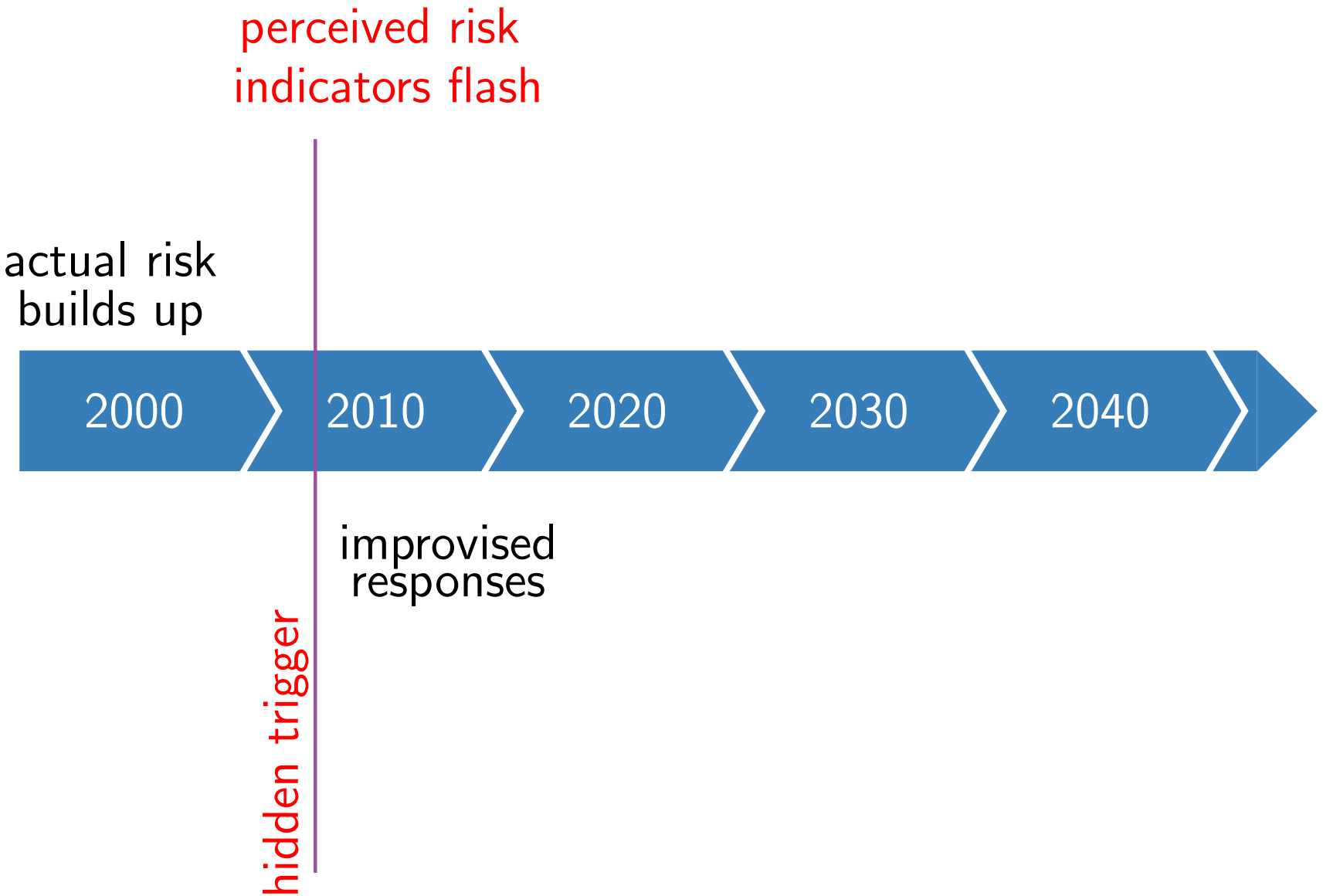

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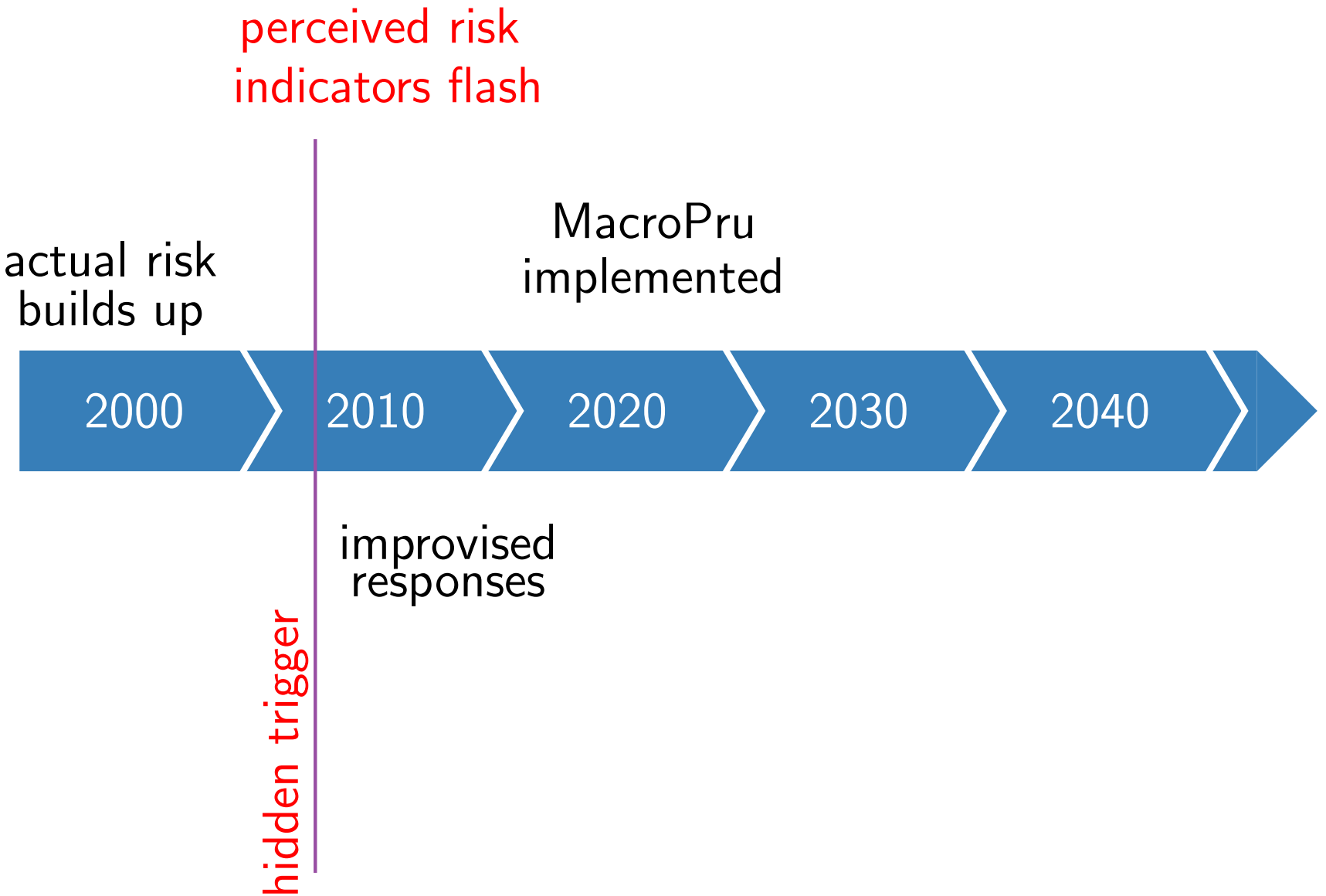

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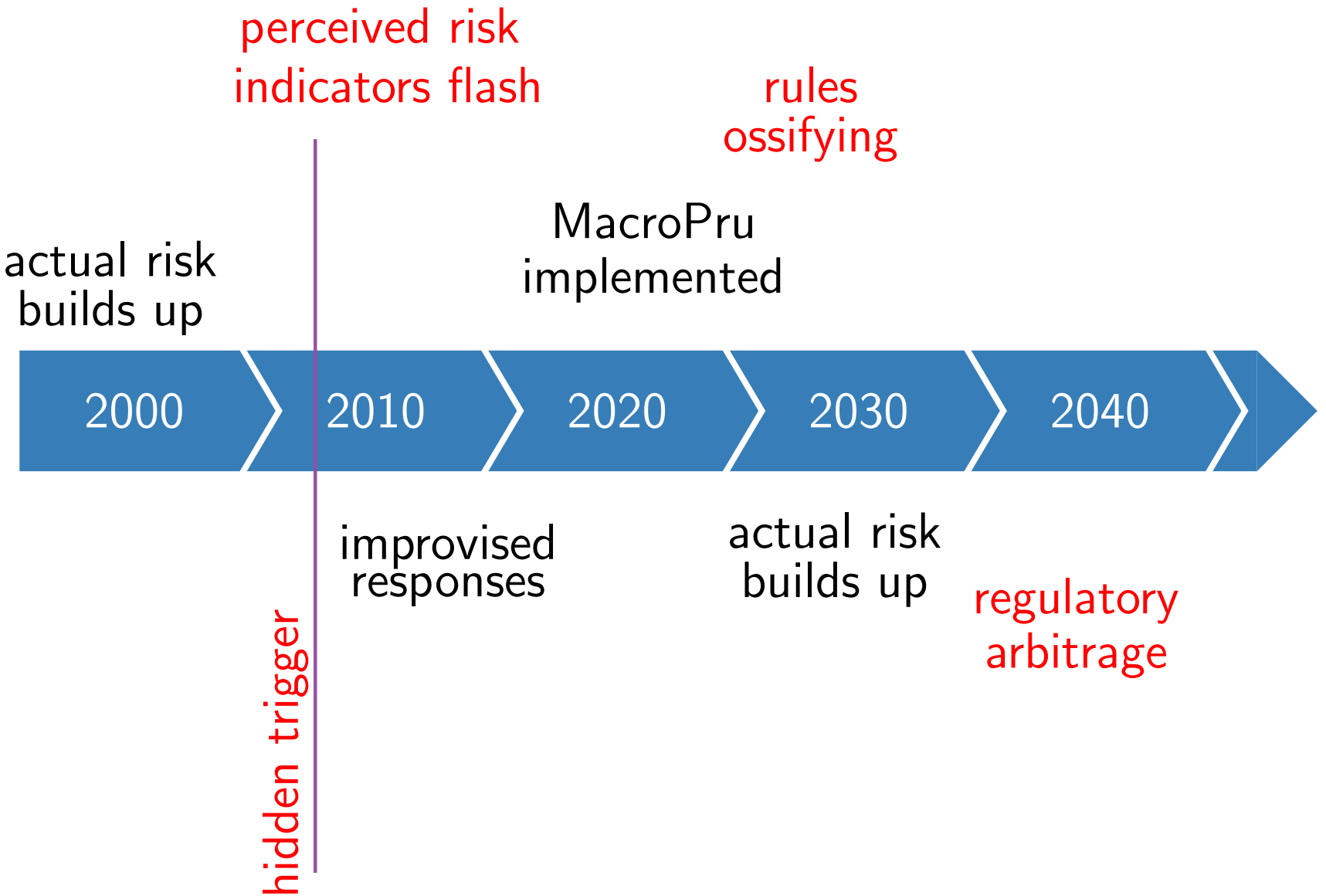

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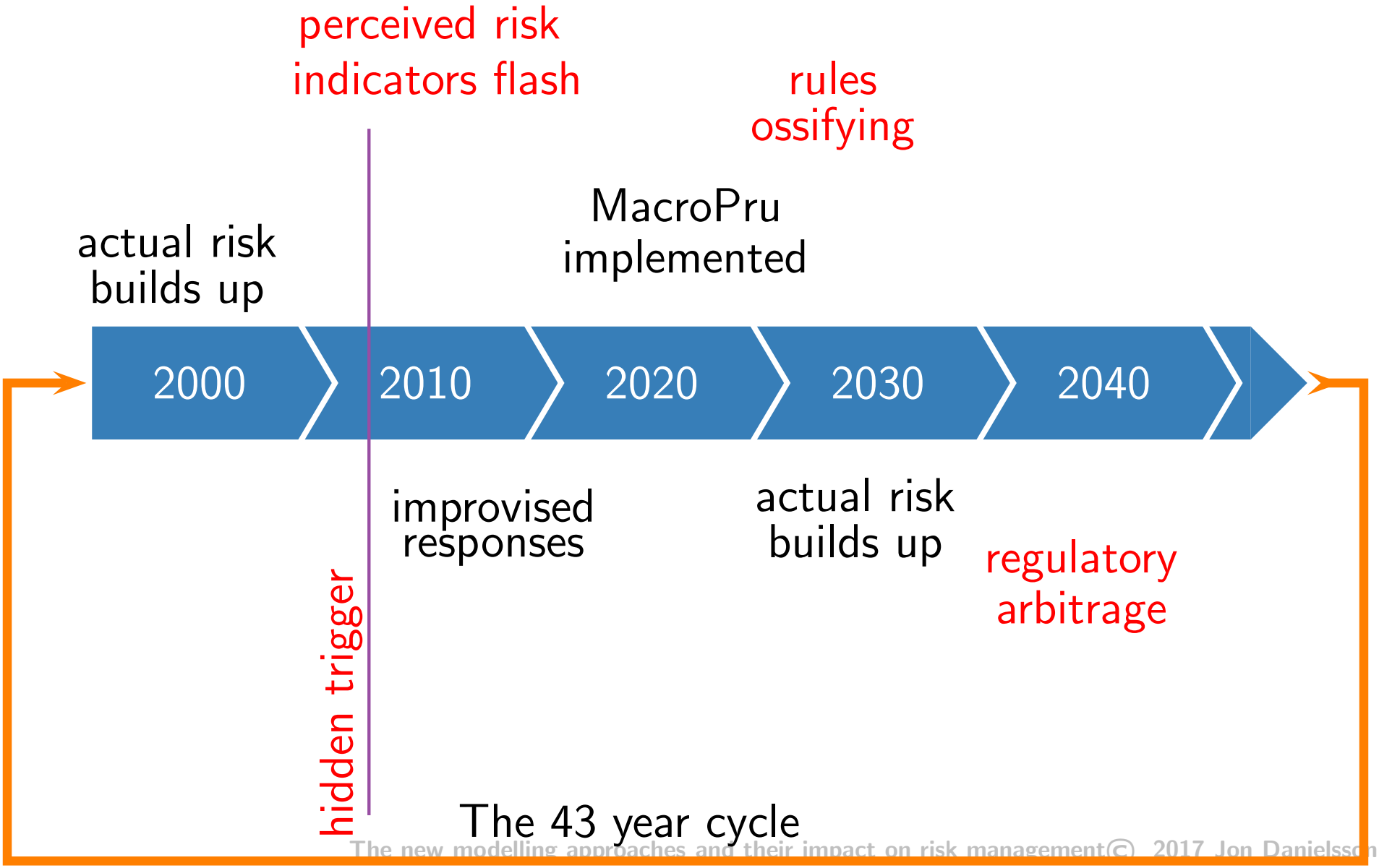

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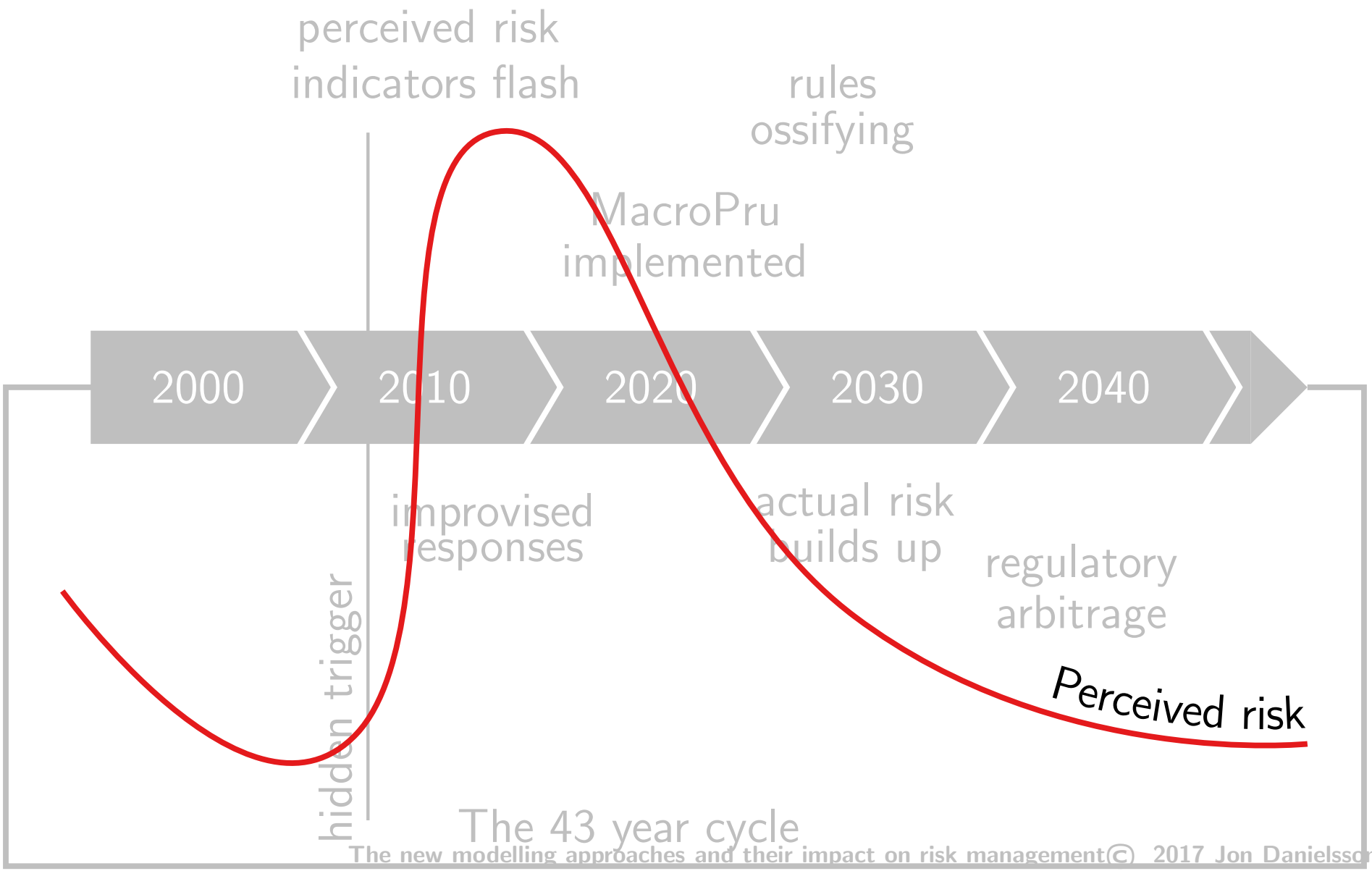

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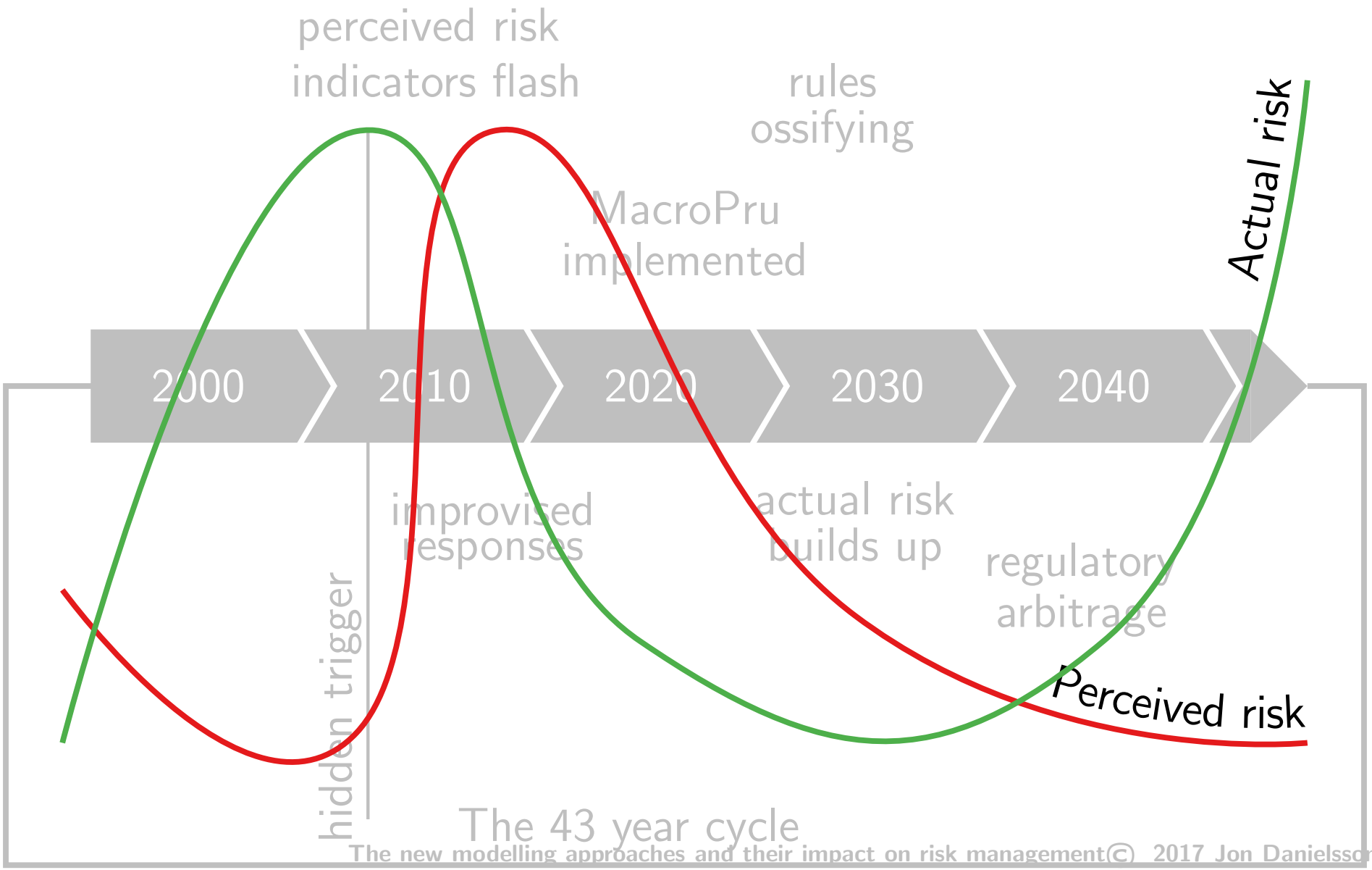


The potential for procyclical macropru

VoxEU.org (2016) Jon Danielsson, Robert Macrae, Dimitri Tsomocos, Jean-Pierre Zigrand

- Minsky — stability is destabilizing
- Homogenization of the financial system
- Measurement
  - Most current indicators of systemic risk only identify perceived risk
  - Reacting with lag to indicators measured with a lag
  - Out of cycle response

"Learning from History: Volatility and Financial Crises"

(2017)

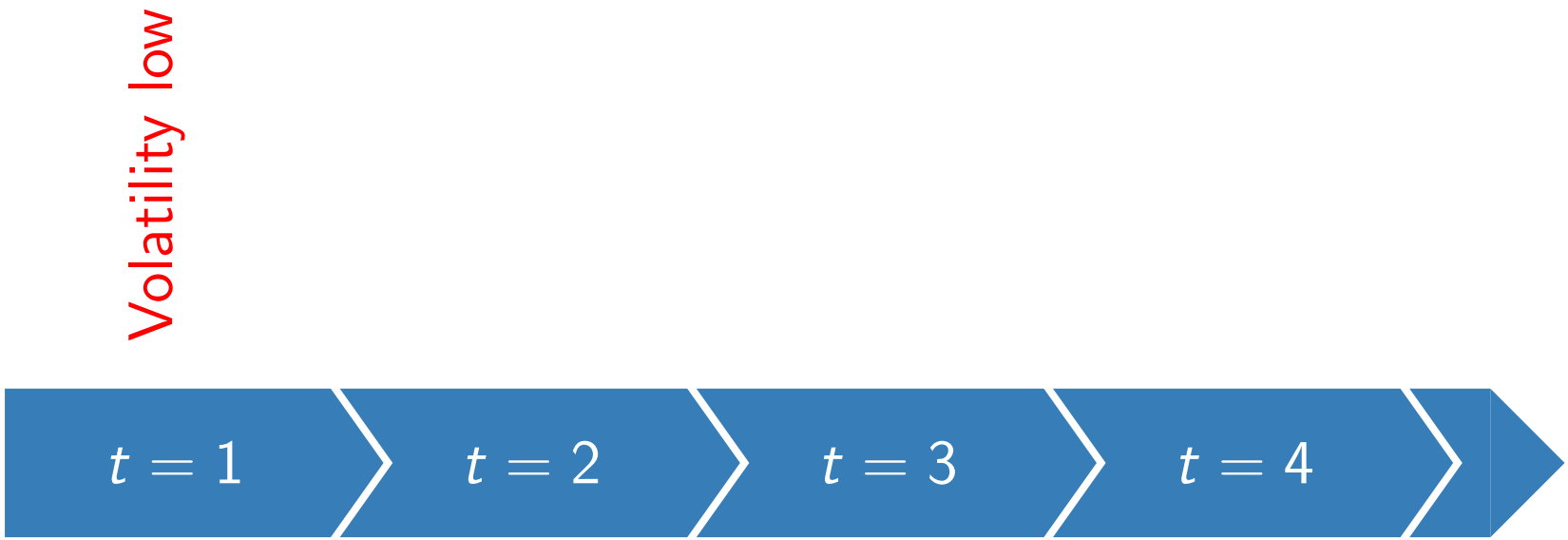
with Marcela Valenzuela (University of Chile)

Ilknur Zer (Federal Reserve)

Crises volatilities

"Volatility in markets is at low levels, both actual and expected, ... to the extent that low levels of volatility may induce risk-taking behavior ... is a concern to me and to the Committee."
Federal Reserve Chair Janet Yellen, 2014.

The volatility — crisis cycle



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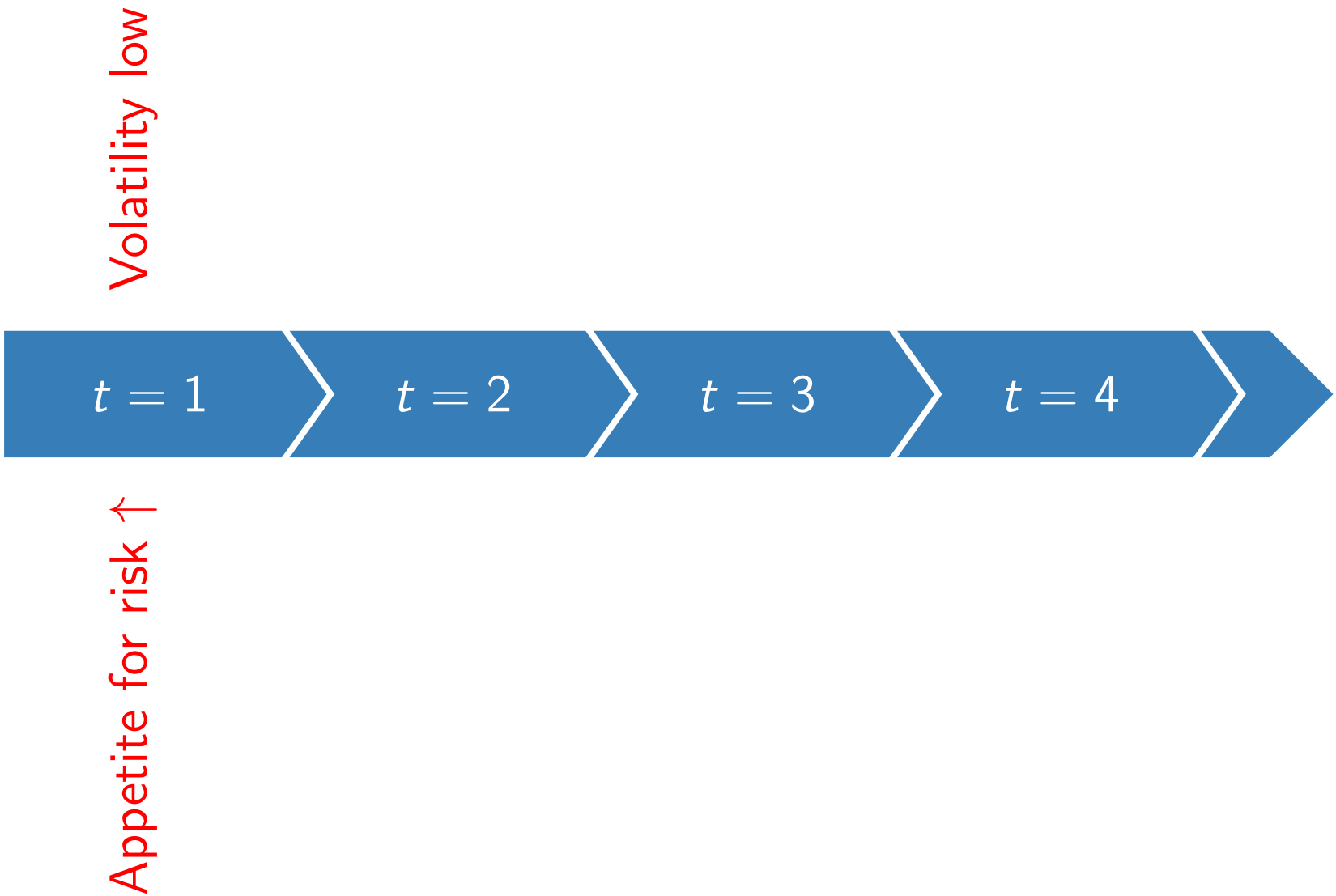

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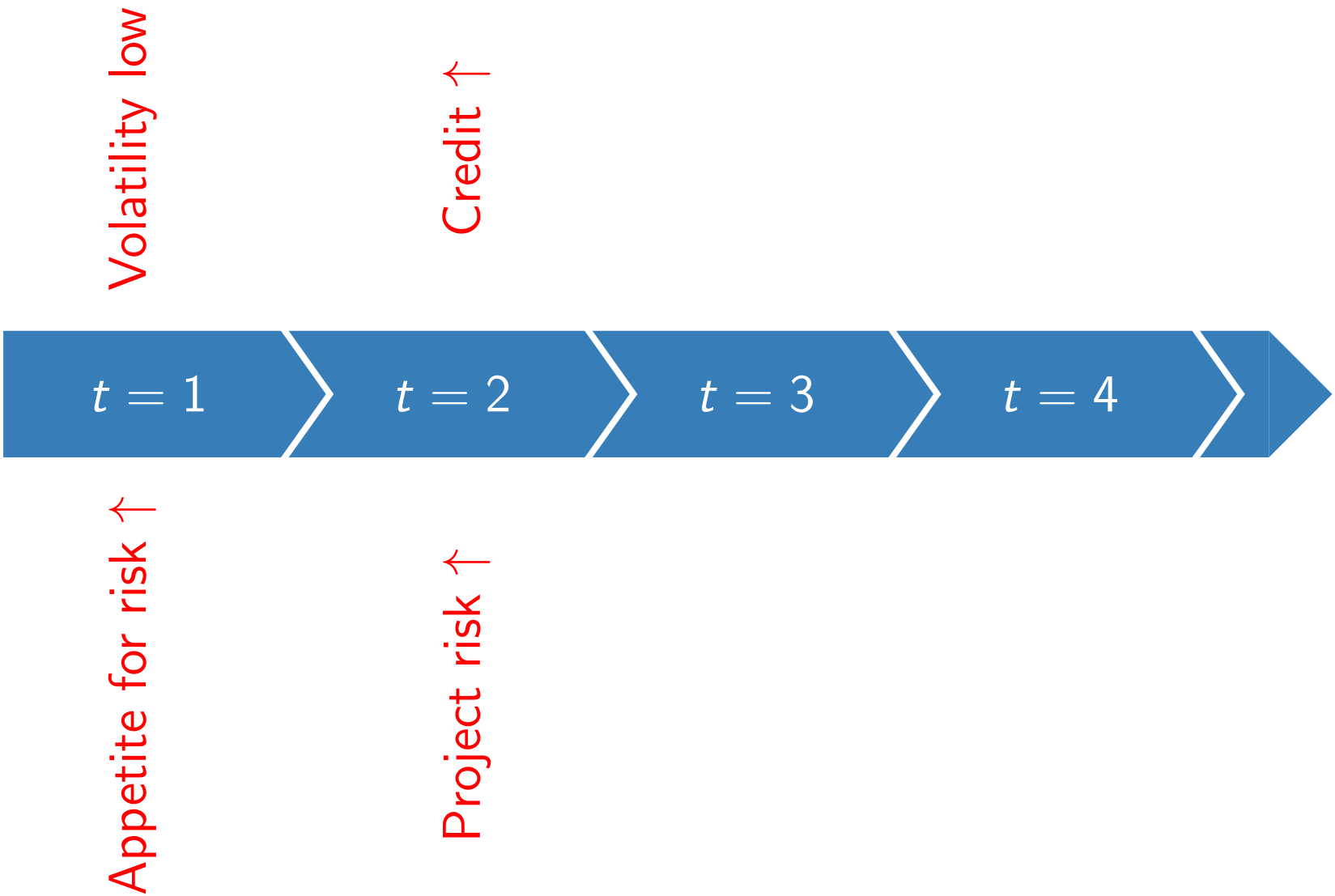

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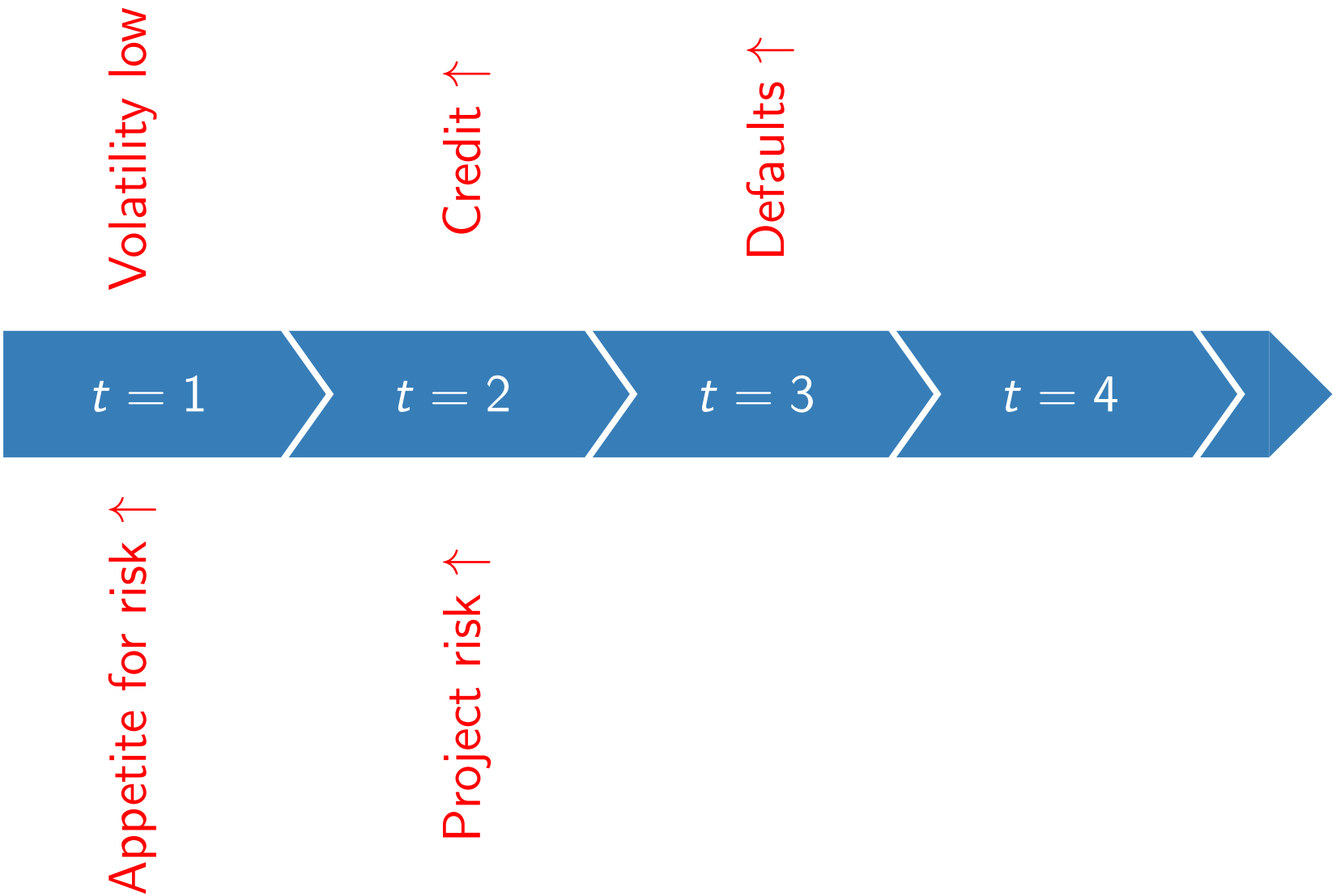

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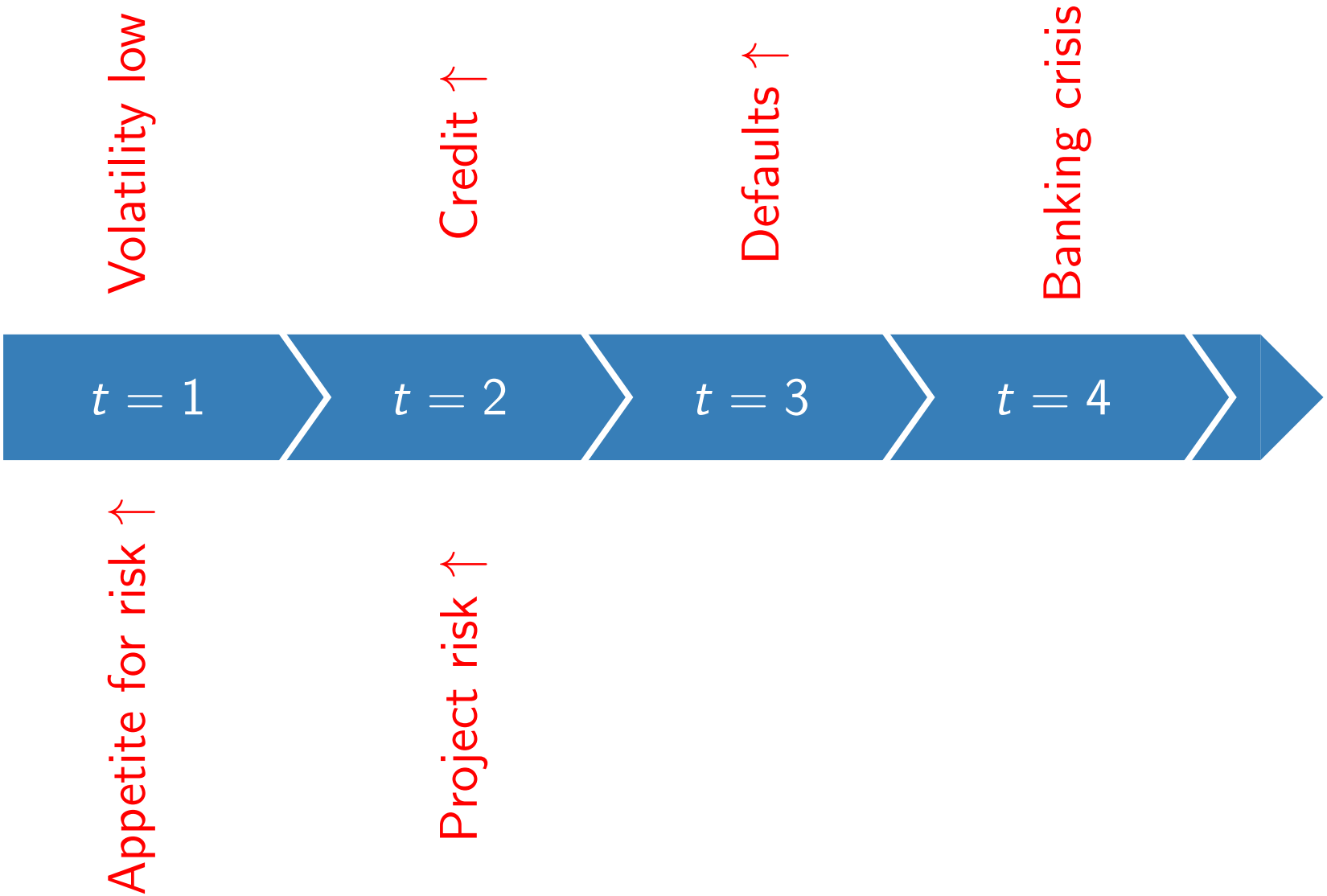

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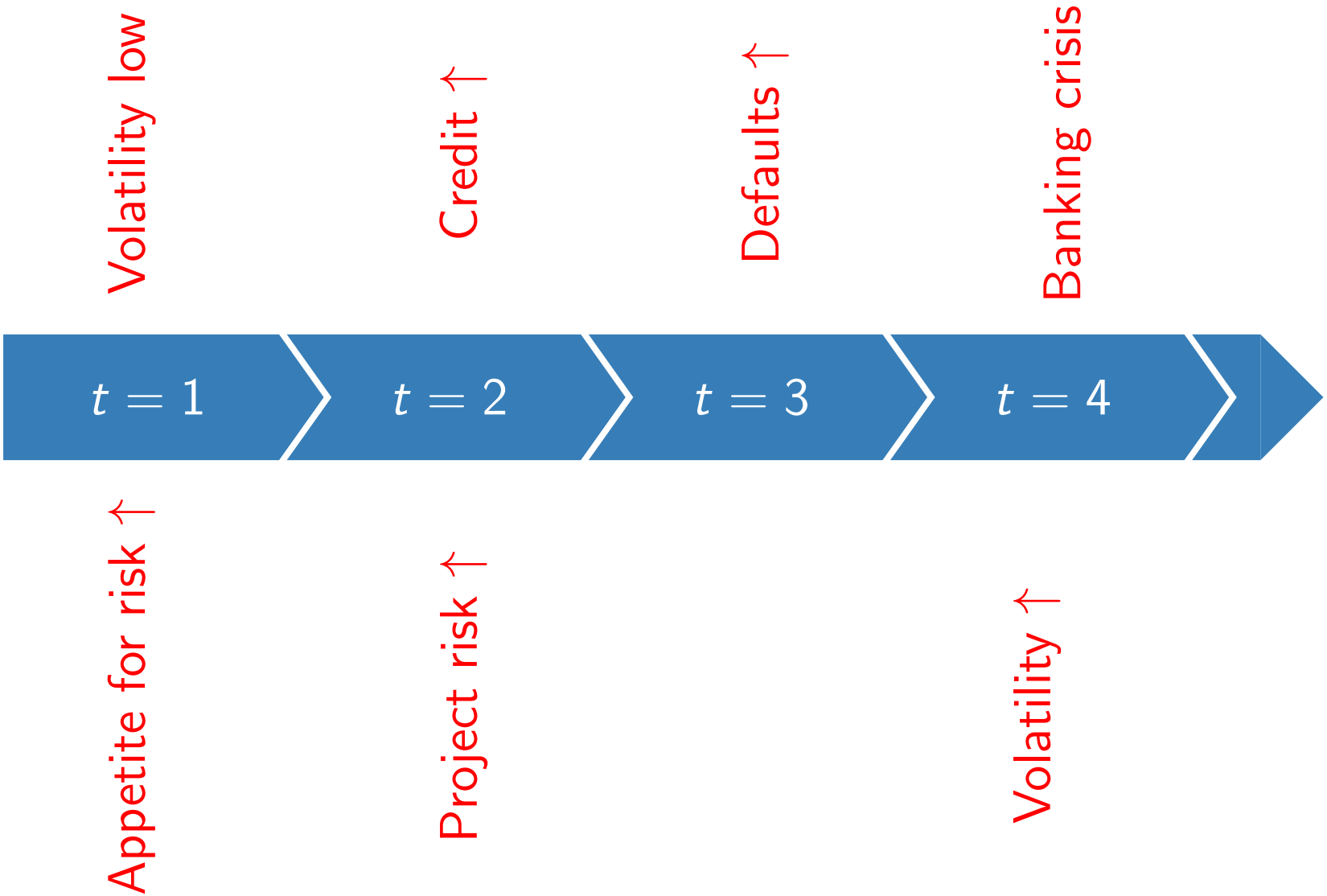
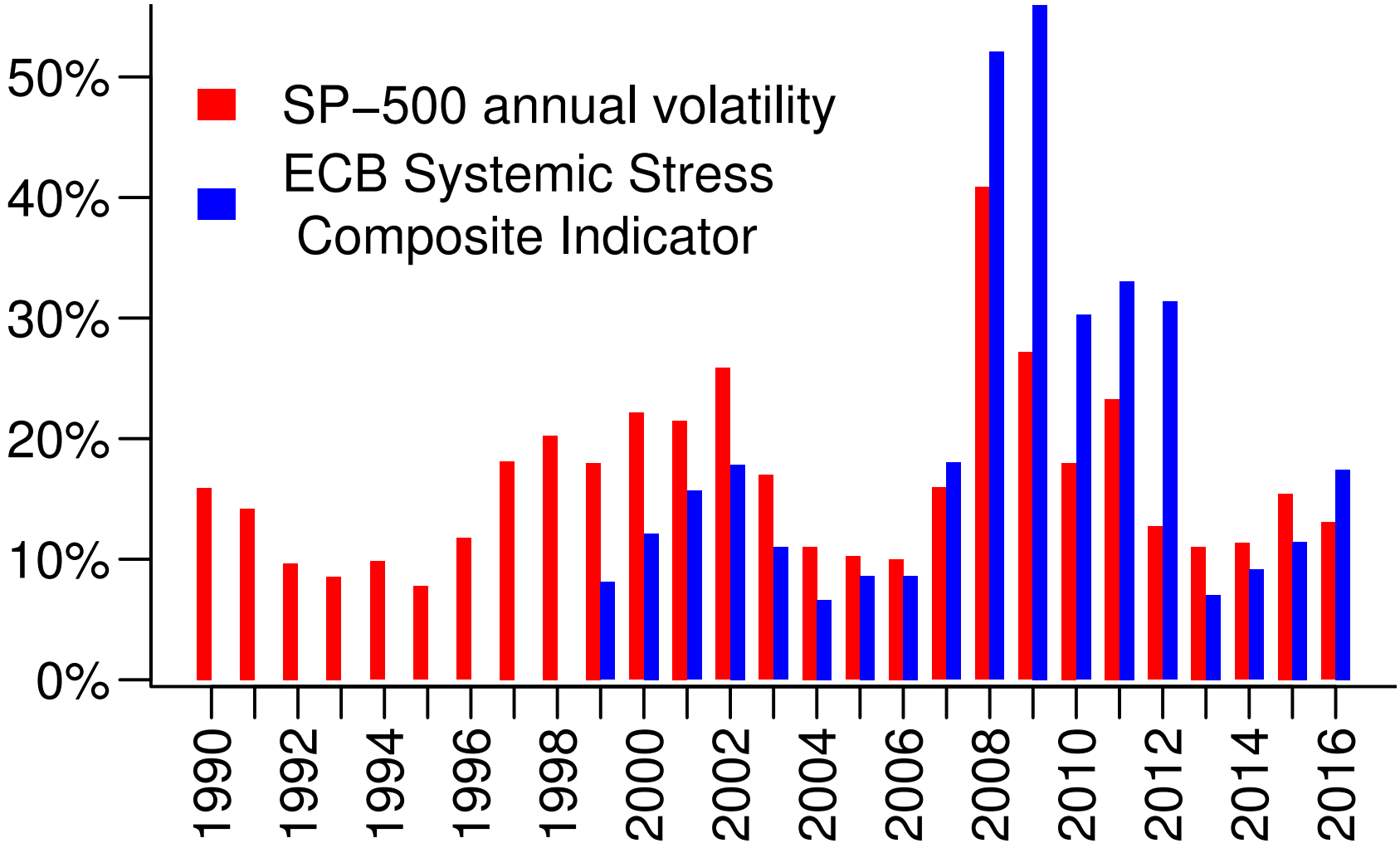


Empirical approach

- We construct a comprehensive database on historical volatilities from primary sources (1800 to 2010, 60 countries
- Realized volatility
- Decomposed with HP filter into low and high volatilities (deviations from trend)

- Strong and significant support for volatility cycle
- Low volatility increases the probability of banking crises 5 to 10 years in future
- Low volatility significantly increases risk-taking (credit-to-GDP)
- High volatility *correlated* with crisis but *not causal*


50%
40%
30%
20%
10%
0%
SP–500 annual volatility
ECB Systemic Stress
Composite Indicator
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

Politics

- Bill Clinton 1992 "it's the economy stupid"
- Reality 2017 "it's the politics stupid"
- Politics drives markets
- The measurements of risk should take political uncertainty into account
- But it is uncertainty not risk
- So we end up measuring the measurable, ignoring the non-measurable
- Why VIX is record low
- In the era of Brexit, Trump, South China Sea, Ukraine, Qatar,...

The dilemma of political risk

VoxEU.org (2016) Jon Danielsson and Robert Macrae

- Can a nonpolitical entity legitimately implement macroprudential policies that affect democratic outcomes?
- Recall Bank of England and Brexit
- Does the mandate given by the political leadership to the regulator extend to the behavior of the political leadership?
- If the macropru authorities are not able to incorporate political risk in their analytic frameworks, how effective can they be?
- And how legitimate?

Technology and modeling

- Fintch — financial technology
- Regtech — regulation technology
- In conjunction with
  - big data (or just very large databases)
  - ML — machine learning
  - AI — artificial intelligence
- Will have increasing impact on models
- How will it work?

Fintch and parallel banking

- Risk modeling frameworks — bank fragility analysis
- Only apply partially to the new forms of financial intermediation
- Broadly they increase ability and efficiency of the financial system
- The challenge is to find the new fragilities
- That is, how to model Fintch and parallel banking
- Macro and micro prudential model implications

Regtech

- For example map the rulebook on to a formal logic engine
  - analyze coherence
  - API to regulated institutions
  - better analysis of disclosed data
- KYC — know your customer
- Blockchain type methods
- Will have significant impact on both macro and micro prudential modeling

AI

- Infinite data — finite human capital
- Infinitely complex system
- Two levels
  1. deep data structure — mapping
  2. high-level interaction with policy objectives
- Still very far from either
- And the second is conceptually impossible

The new modelling approaches and their impact on risk management

- An old joke
- A policeman finds a drunk man at night crawling under a streetlight
- Policeman asks "what are you doing?"
- Drunk responds "looking for my keys"
- Policeman asks "why there?"
- Drunk responds "Because that is where the light is"

The new modelling approaches and their impact on risk management

1. Existing risk measurement methodologies are highly inaccurate — even when we know the true data generating process
   - with 4 years of data, VaR $\in [74, 151]$, true=100
2. The lead-lag time between decisions and outcomes is many years
   - decisions in 2003 led to crisis in 2008
   - high volatility correlates with crisis, does not predict crises
   - low volatility predicts crises
3. Risk is endogenous
   - can only measure perceived risk not actual risk
4. Difficult or impossible to incorporate political uncertainty in risk measurements