Complexity in financial markets

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ESSEC course “ Managing in complexity ”

Chaire ESSEC Edgar Morin de la complexité

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Complexity in financial markets

- Themes of the talk:
  - Feeling complexity in financial markets with SimTrade
    - From simplicity to complexity
  - Complexity / Risk and uncertainty
  - Complexity / Crisis
    - Statistical approach: extreme value theory
    - Historical approach: lessons from history to understand the process of financial crises

Risk and uncertainty

- Franck Knight (1885 - 1972)
- Professor of economics at the University of Chicago
- Cofounder of the Chicago School
- Author of the book « Risk, uncertainty and profit » published in 1921 (a reference)

A business point of view (1)

- « Business as usual »
  - Exemple: a groceryshop at the corner of the street
  - Economic theory says: in a competitive environment, at equilibrium, the firm (managers / shareholders) does not make any profit (no economic profit but accounting profit).
  - The remuneration of the firm is linked to the risk taken by the firm.
  - « Just make money » (usual return)

A business point of view (2)

- « Innovative business »
  - Example : start-up
  - Knight says: the firm (the entrepreneur) can make a profit (economic profit).
  - « Make a fortune » (abnormal return)

Risk and uncertainty (1)

- Risk
  - A probability can be associated to each event.
    - Calculable risk (theoretical model)
      - Example: a perfect dice
    - Estimable risk (data and a statistical model)
      - Example: an imperfect dice that you have launched n times.

Risk and uncertainty (2)

- Uncertainty
  - A probability cannot be associated to events.
    - No theory
    - No data
      - Example: an imperfect dice that you have never launched.

Risk and uncertainty (3)

- Open questions
  - In finance: risk or uncertainty?
  - In ther fields?

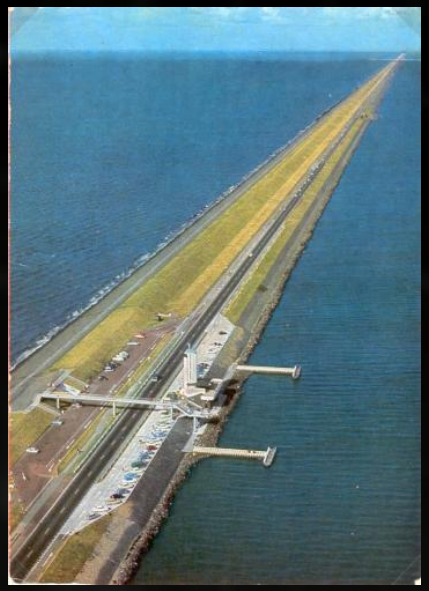
Business, risk and uncertainty

- Knight says:
  - « Business as usual » : risk
  - « Innovative business » : uncertainty
- Impact in terms of financing
  - Risk → Credit
  - Uncertainty → Capital

Extreme events in finance

- A statistical tool: extreme value theory (EVT)
  - Definition of an extreme event (from a statistical point of view)
  - Presentation of results
  - Applications in finance

Uses of extreme value theory



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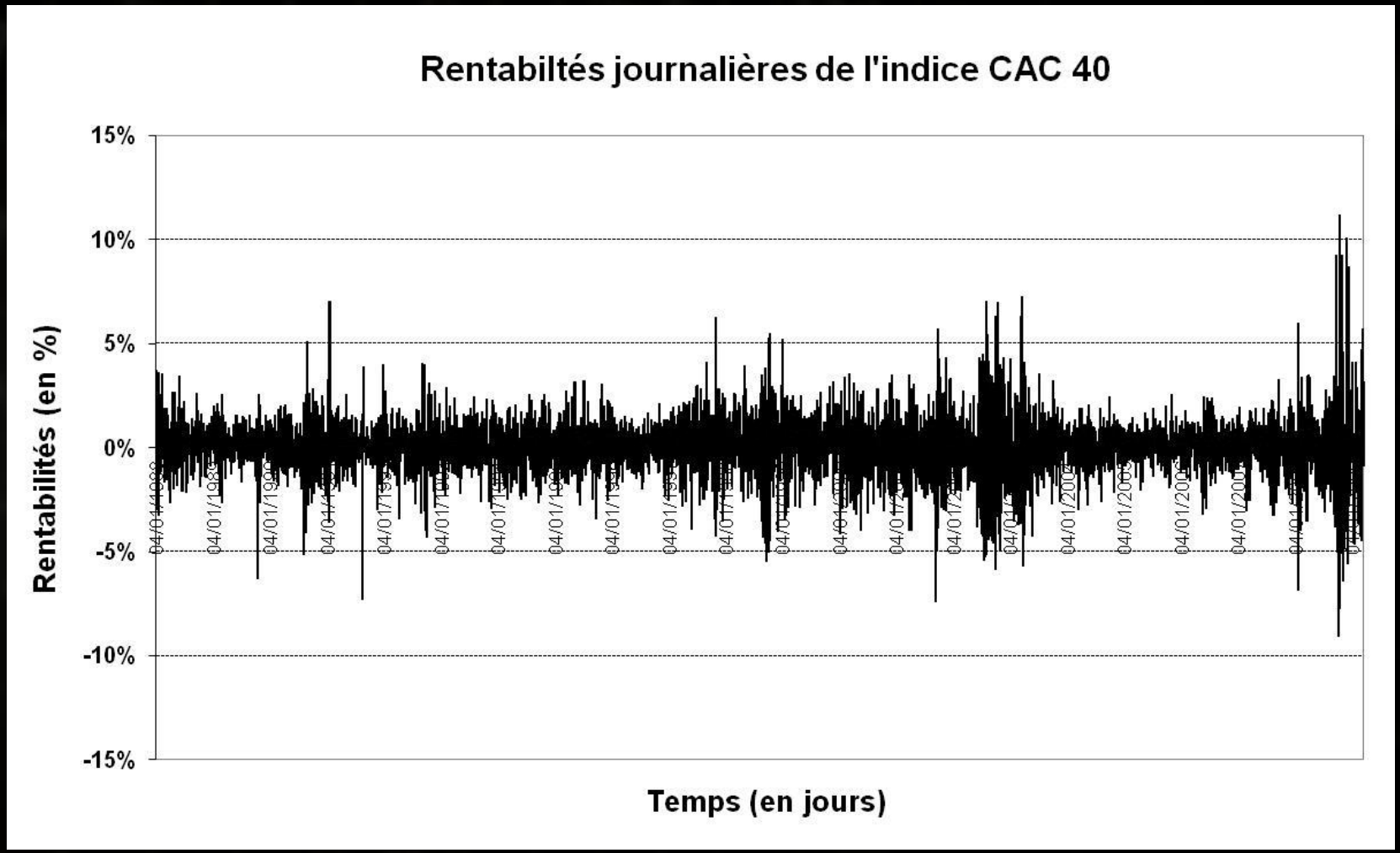
Variable that is studied in finance

- A random variable :
  - Variation of the value of a market position (trading room)
  - Variation of the value of a portfolio (asset management)
  - Return of a financial product

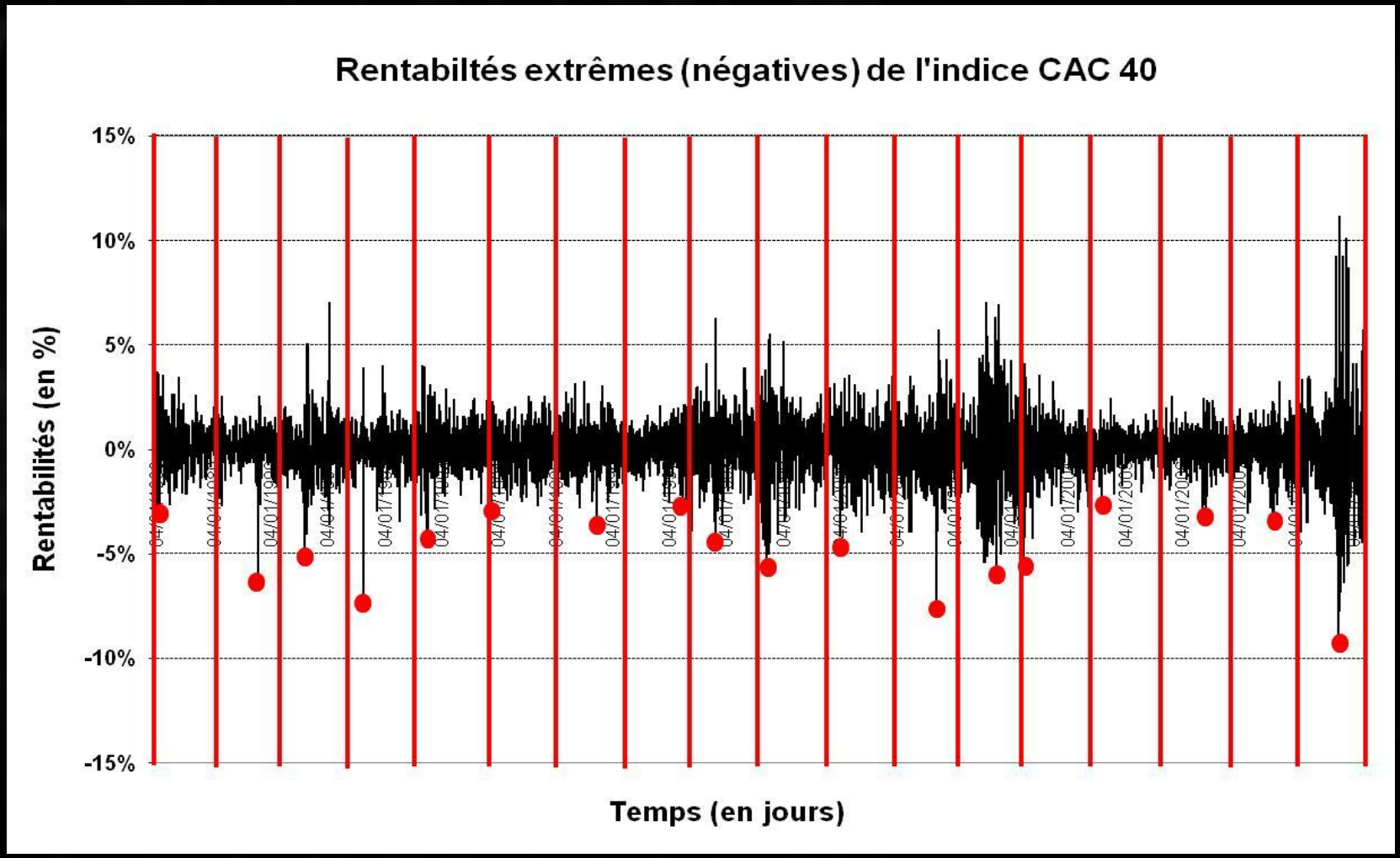
Example: return on the CAC 40 index



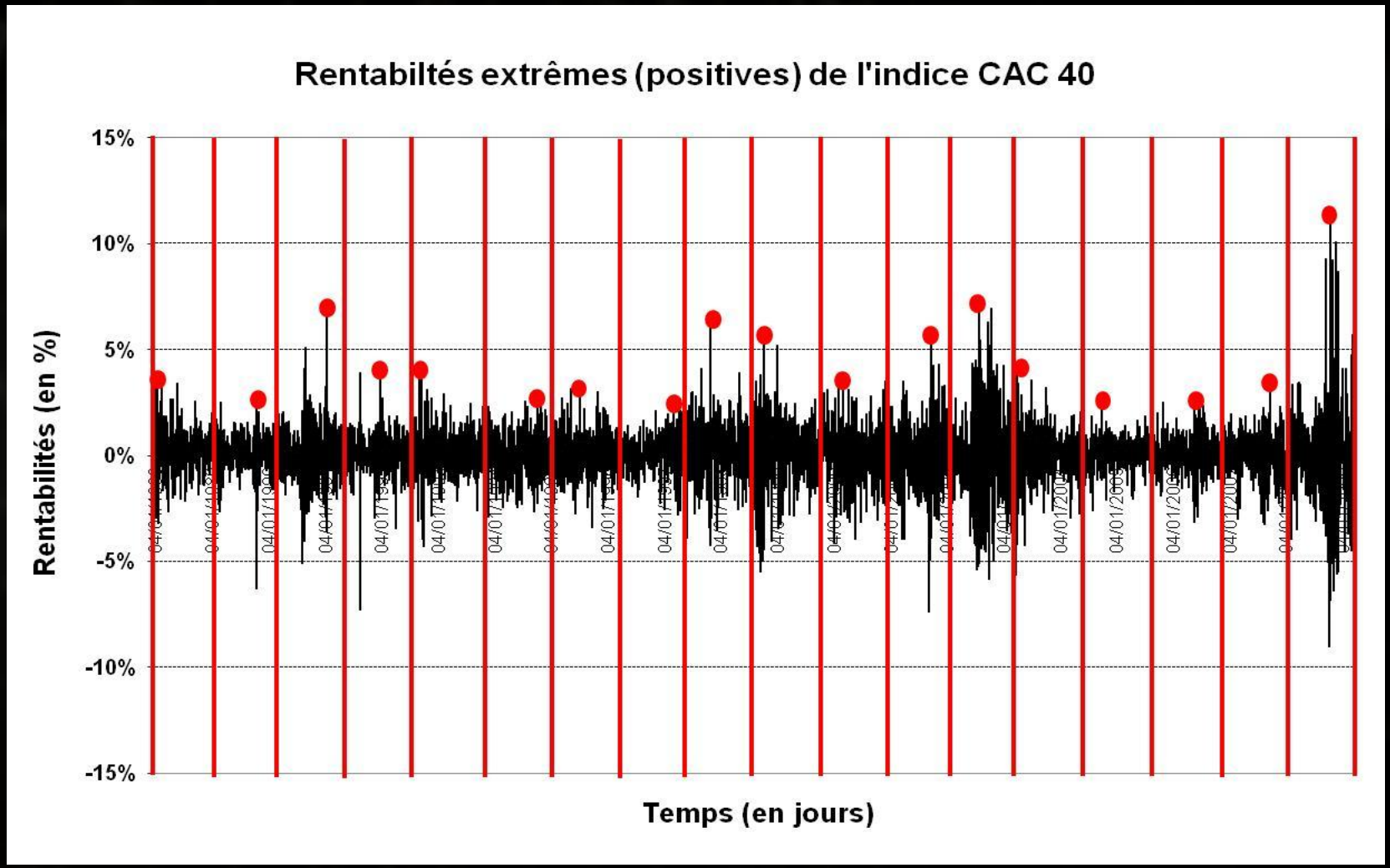
Extreme events

- EVT is interested in extreme observations:
  - The minimum (the lowest observation over a given time-period)
  - The maximum (the largest observation)

Example: minimal return on the CAC 40 index (1)



Example: maximal return on the CAC 40 index (2)



Extreme value theory (1)

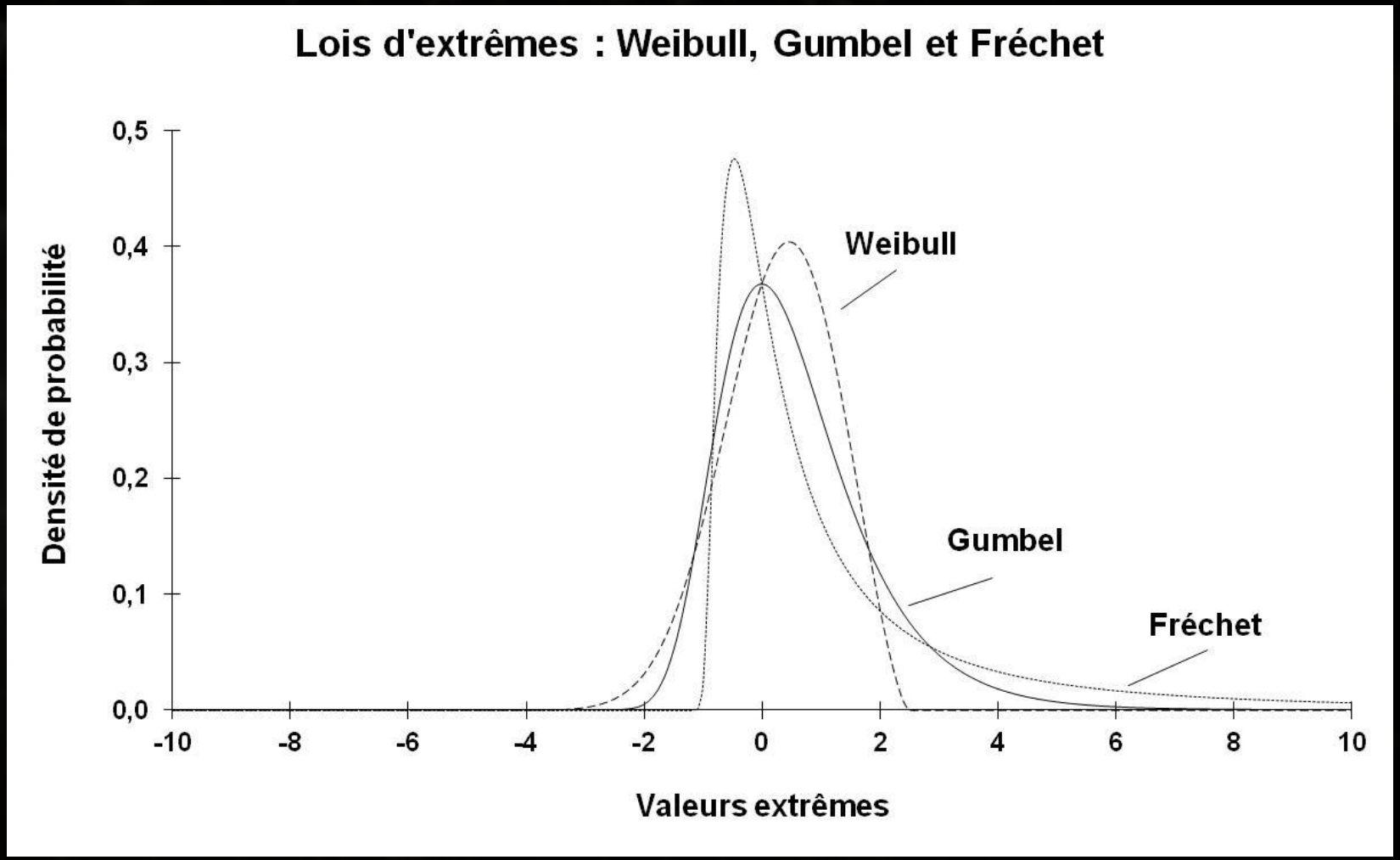
- Statistical theory (1920-1940) which studies the limit distribution (when the number of observations tends to infinity)
- Theoretical result:
  - Existence of an asymptotic distribution
  - Three parameters :
    - Mean μ
    - Standard deviation σ
    - Tail index τ

$$G_Y(y) = \exp\left(-\left(1-\tau\cdot\frac{y-\mu}{\sigma}\right)^{\frac{1}{\tau}}\right)$$

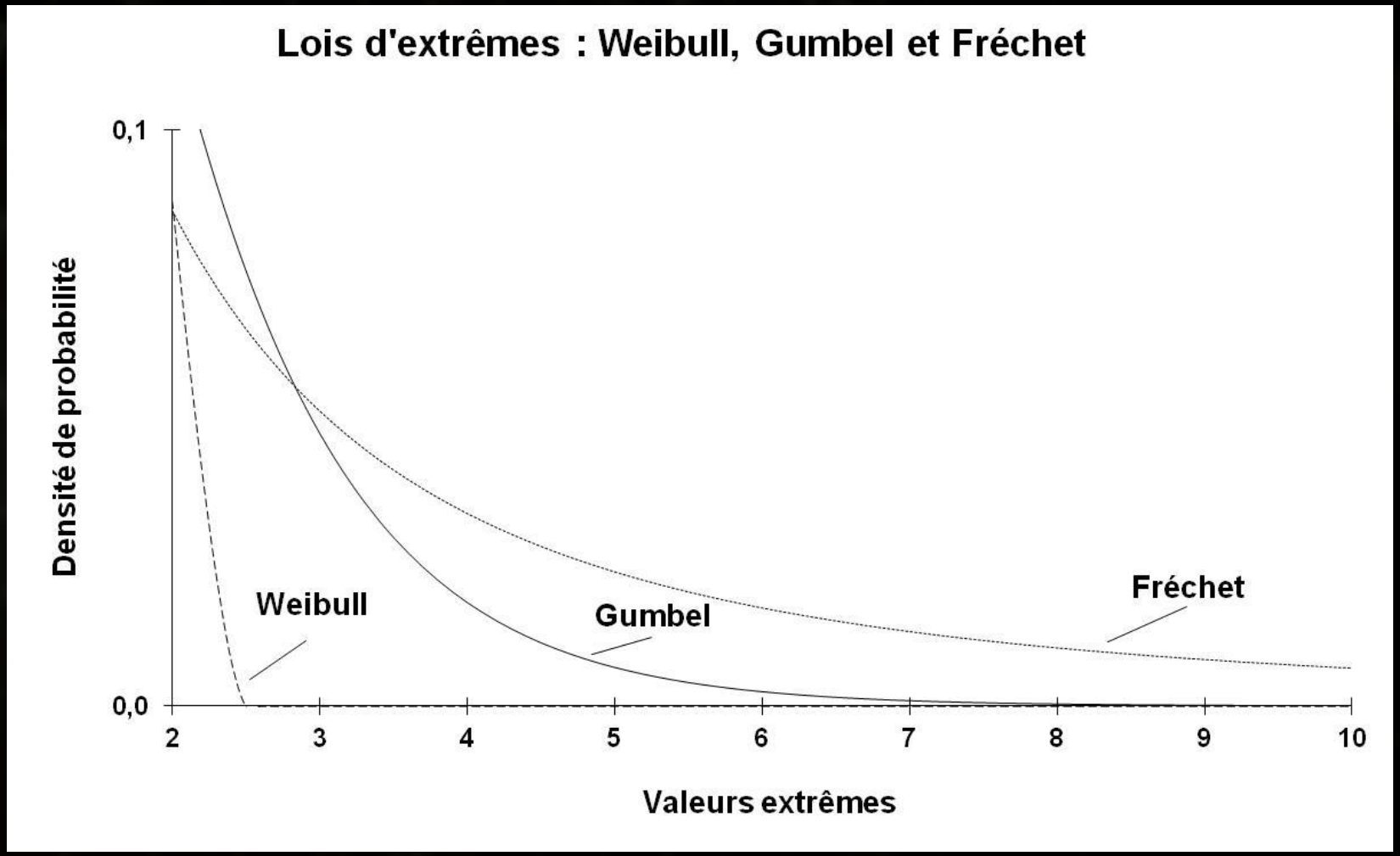
Extreme value theory (2)

- According to the tail index value:
  - $\tau < 0$
    - Weibull distribution
    - No tail
  - $\tau = 0$
    - Gumbel distribution
    - Thin tail
  - $\tau > 0$
    - Fréchet distribution
    - Fat tail

Extreme value distributions



Extreme value distributions: zoom on the tails



Extremes in finance (1)

- Empirical results: application of extreme value theory

Reference : Longin F. (1996) The asymptotic distribution of extreme stock market returns *Journal of Business*, N°63, pp 383-408.

Extremes in finance (2)

- Empirical results: a Fréchet distribution with a tail index between 0.1 and 0.4.
  - Similar results for individual stocks, stock indexes, interest rates, bond returns, foreign exchange rates, commodities, etc.
  - Similar results across time-periods
  - Similar results with different frequencies (daily, weekly, monthly)

Extremes in finance (3)

- A Fréchet distribution for extremes: stylized fact about financial asset prices
- Other stylized facts:
  - Bell curve for the distribution of returns
  - Week auto-correlation of returns
  - Week auto-correlation of squared returns (persistance of volatility)
  - Fat-tailed distributions

Knight and extremes in finance: a paradox (1)

- On the one hand:
  - Extreme events in finance (booms and crashes) are associated with periods of innovation.
    - Technical innovations during the internet bubble
    - Financial innovations during the subprime crisis
  - Extreme events in finance are associated with periods of great uncertainty.
  - Extreme events in finance are not well understood (« outliers »).

Knight and extremes: a paradox(2)

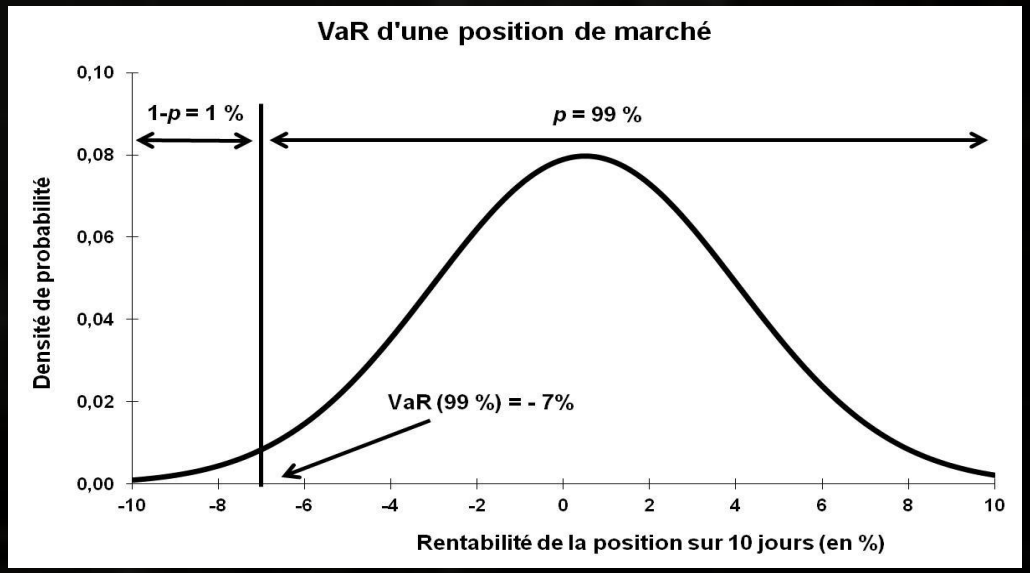
- On the other hand:
  - By application of extreme value theory, we know very well the statistical distribution of extreme returns even if we do not know precisely the statistical distribution of returns.
- Let’s go back to Knight:
  - Difference between risk and uncertainty
  - Paradox
    - Extreme events : precise risk
    - Normal events : uncertainty / risk

Applications of EVT in finance

- Risk management
  - VaR and stress testing of a market position
  - Setting of deposit in derivatives markets
- Portfolio management
  - Calibration of management methods for capital guaranteed products
- Financial modelling
  - Choice of the process for returns

Value at risk and stress testing (1)

- Value at risk (VaR) :
  - Loss of a market position over a given time-period *T* for a given probability level *p* donnée
  - Example: 10 day 99% VaR



Value at risk and stress testing (2)

- Computation of VaR in practice
  - Choice of method: variance-covariance (normal distribution), historical, Monte Carlo
- VaR corresponds to ordinary market conditions
  - Waiting-time period (average time that we have to wait) for 10 day 99% VaR: 4 years

Value at risk and stress testing (3)

- 4 years: quite short!
- Necessity to have a model to complete VaR model : stress testing (useful for internal management / regulatoy requests to validate intenal models)
- Stress testing corresponds to extraordinary market conditions
  - Waiting-time period: 20 years, 50 years (in finance) 200 years in insurance

Value at risk and stress testing (4)

- Models used to compute VaR (mainly based on the thin-tailed normal distribution) cannot be used for stress testing.
- Utility of extreme value theory to model distribution tails properly

Ad !

- Conference
  - *Academics and practiotionners*
  - *Theory and practice*
  - *Visit the conference website: http://extreme-events-finance.net*

Beyond numbers... stories

- Historical approach
  - Work by historians on financial crises (Zola, Aftalion, Galbraith)
  - Formalizsation by Kindleberger « *Manias, Panics, and Crashes: A History of Financial Crises* »
    - Anatomy of bubbles anf financial crises

Anatomy of a financial crisis

- Kindleberger (Minsky) distinguishes five stages:
  - Change
  - Boom
  - Euphoria
  - Crisis
  - Revulsion

Anatomy of a financial crisis (1)

- Stage 1 : Change / shock / *Displacement*
  - Apparition of a new element (technological innovation, regulatory change, political event)
  - Crisis of 2007: political will to make American people own their home, period of low interest rates, financial innovation (structured products in the credit market)

Anatomy of a financial crisis (2)

- Stage 2: Boom
  - The phenomon is rather limited to professionnals.
  - Invcrease in prices
  - Importance of crédit
    - At the economic level (firms)
    - At the financial level (investors)

Anatomy of a financial crisis (3)

- Stage 3 : Euphoria
  - The general public (individual investors) is affected by the phenomon.
  - Sharp increase in prices (exponential)
  - Difficulty to liquidate positions
  - Positive contributions from the media

Anatomy of a financial crisis (4)

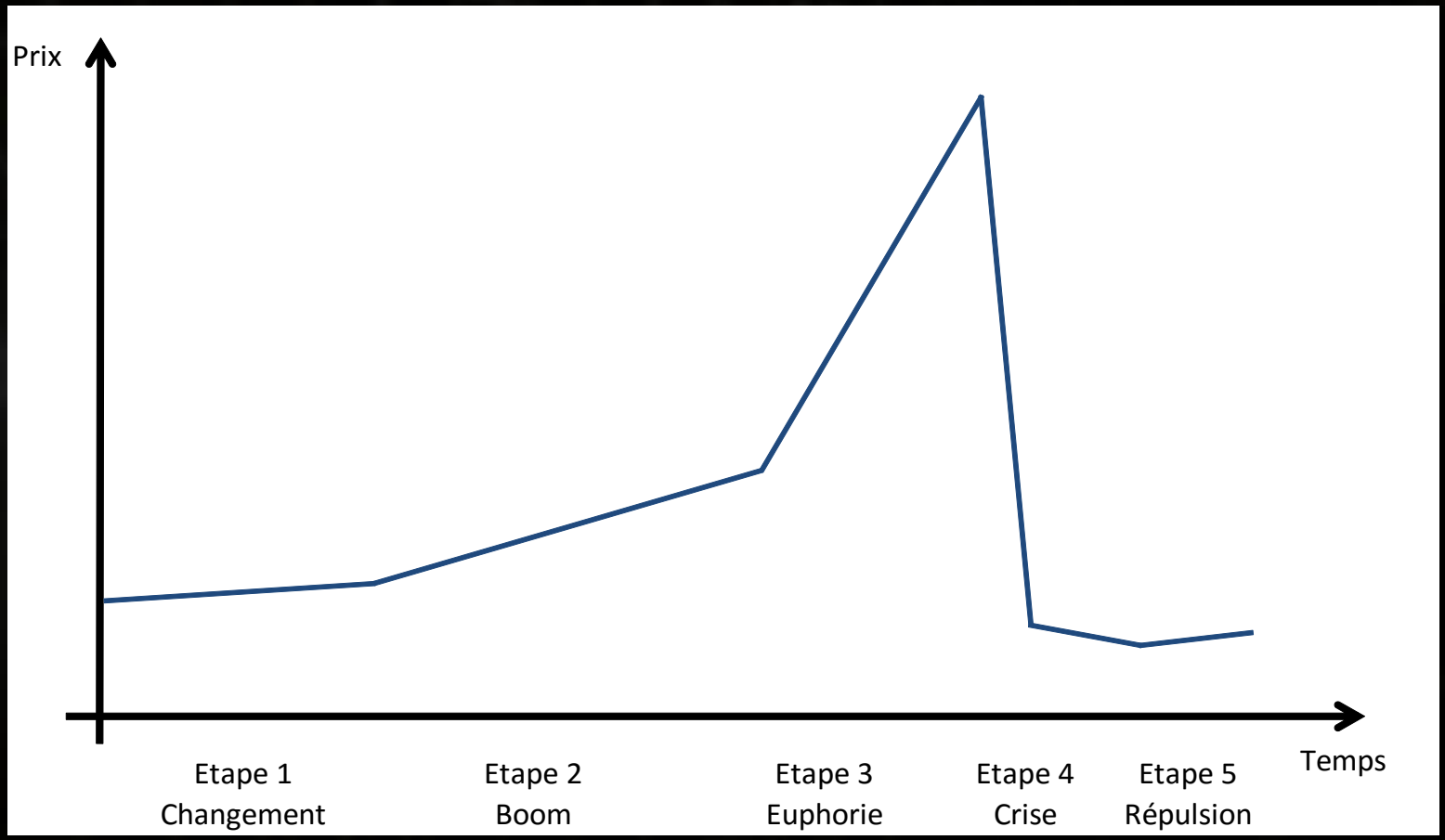
- Stage 4 : Crisis
  - Sell by professionnals and informed traders
  - Triggering event
  - Panics sales by speculatos and individuals
  - Lack of liquidity

Anatomy of a financial crisis (5)

- Stage 5 : Revulsion
  - Negative contributions from the media (fraud stories)
  - Search for culprits
  - Lender of last resort

Anatomy of a financial crisis

- Price process



Conclusion

- Crises : rare, extreme, extraordinary particular events
- Message : **regularity in the phenomenon**
  - Approach by statisticians: these events obey to a well-known distrbibution : the Fréchet distribution (robust result)
  - Approach by historians: we always observe the same pattern for these events

A third approach: simulations

- Developp a new approach based on simulations for a deep undestanding of the phenomena (bubbles and crashes)

  - Available on www.simtrade.fr
  - Concept of simulation

A few citations by Edgar Morin

- « Toute connaissance (et conscience) qui ne peut concevoir l'individualité, la subjectivité, qui ne peut inclure l'observateur dans son observation, est infirme pour penser tous problèmes, surtout les problèmes éthiques. »
- « La connaissance est une navigation dans un océan d'incertitudes à travers des archipels de certitudes. »
- « Rétrospectivement, tout semble logique mais quand on le vit au fur et à mesure, tout arrive de façon imprévue. »

SimTrade

What is SimTrade?

What are the objectives of SimTrade?

What is the originalit y of SimTrade?

SimTrade: 3 key points

- SimTrade: pedagogical tool in finance
- Objective of SimTrade: pedagogical
  - To understand financial markets
  - To learn to act in financial markets
- Originality of SimTrade
  - Complete simulation: markets and firms
  - Advantage: impact of SimTrader on the market

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SimTrade: a story in 3 words

- Learn
  - Courses
- Learn by trading
  - Simulations
- Compete
  - Competitions

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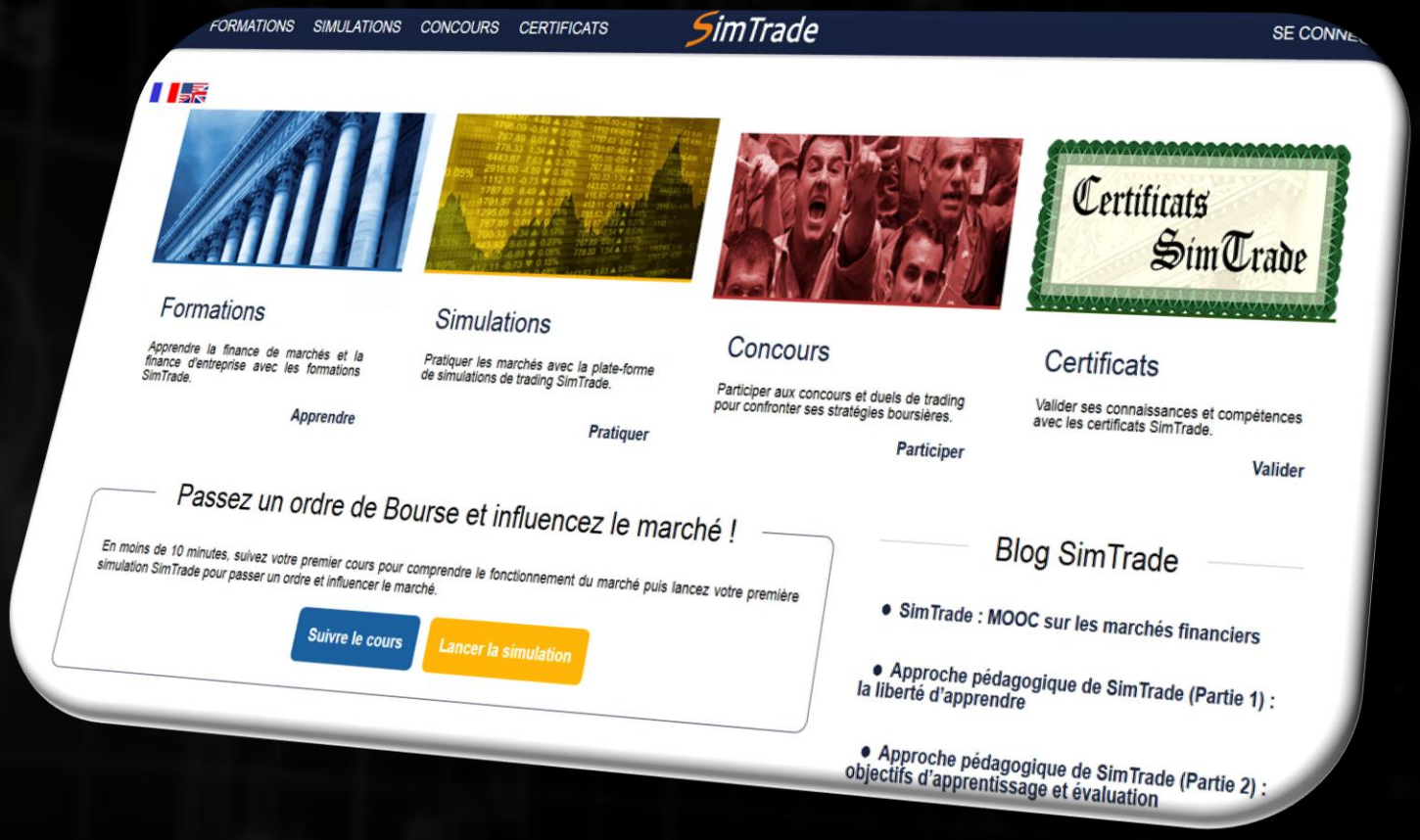
SimTrade demo



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Complexity of financial markets (1)

- Modeling of the market

  Market: place where buyers and sellers meet (traders/ investors in financial markets)

  Modeling of traders :

  → Motivation / objective: liquidity, information, etc.

  → Strategies

  → Orders (caracteristics)

  →Trading plateform (infrastructure de marché)

  → Transactions (price and volume)

Complexity of financial markets (2)

- Tool to simulate random numbers
  - Monte Carlo method
  - Series of numbers U_n between 0 and m
  - First nomber : U_1 (seed of simulation)
    - Example : $U_1 = 10$
  - Generation of next random numbers :
    - $U_{n+1} = a \times U_n + b \ (m)$
    - Example : $a = 23$, $b = 3$ et $m = 100$
  - See the Excel file

Complexity of financial markets (3)

- Use of random numbers
  - Simulation of the behavior of simulated traders
    - Active or inactive ?
      - If active : buy or sell? (direction of the order)
        - Other caracteristics of the ordrer:
          - Type
          - Quantity or amount
          - Date of validation

Complexity of financial markets (4)

- Randomness of the simulation
  - Simulations which can be repoduced identically at every launch: randomness will come from the SimTrader (impact on the market)
  - Simulations which cannot be repoduced identically at every launch: randomness will come from the seed
  - Simulations which cannot be repoduced identically at every launch: randomness will come from the events (news flow)

Illustration of complexity in financial markets

Change in the seed of the simulation algo

Seed = 122

Seed = 123

Seed = 124

Work by Edgar Morin

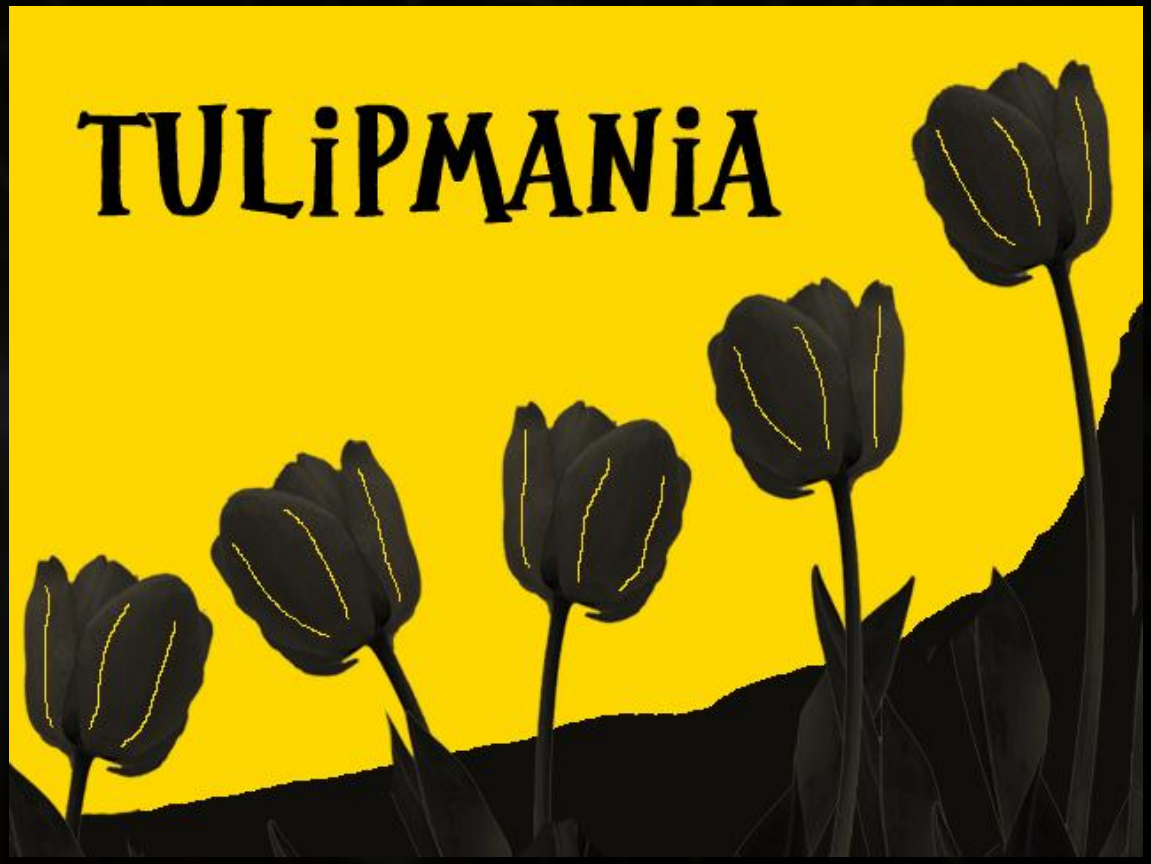
- La pensée complexe
  - « Pense-bête » : never forget that the world is complex

Continuation of my work (1)

- SimTrade :
  - Research side (experimental ecocomics / experimental finance) :
    - Use of simulations by SimTraders
    - To understand the behavior of investors
    - To explain stylized facts in financial markets

Continuation of my work (2)

- Simulation Tulipmania



Conclusion (1)

- Diffrent approaches
  - Mathematical model
    - Statistical methods to model risk
    - Model of risk / Risk model (uncertitude)
    - Paradox in times of crisis
  - History
    - Histrory seems to repeat itself
  - Simulation
    - Complexity and risk
    - Interactions between agents (role of expectations)

Conclusion (2)

Citation of Alan Greenspan (Fed)

“I guess I should warn you,
if I turn out to be particularly clear,
you've probably misunderstood what I've said.”

« Si vous m’avez compris,
c’est sans doute que je me suis mal expliqué. »