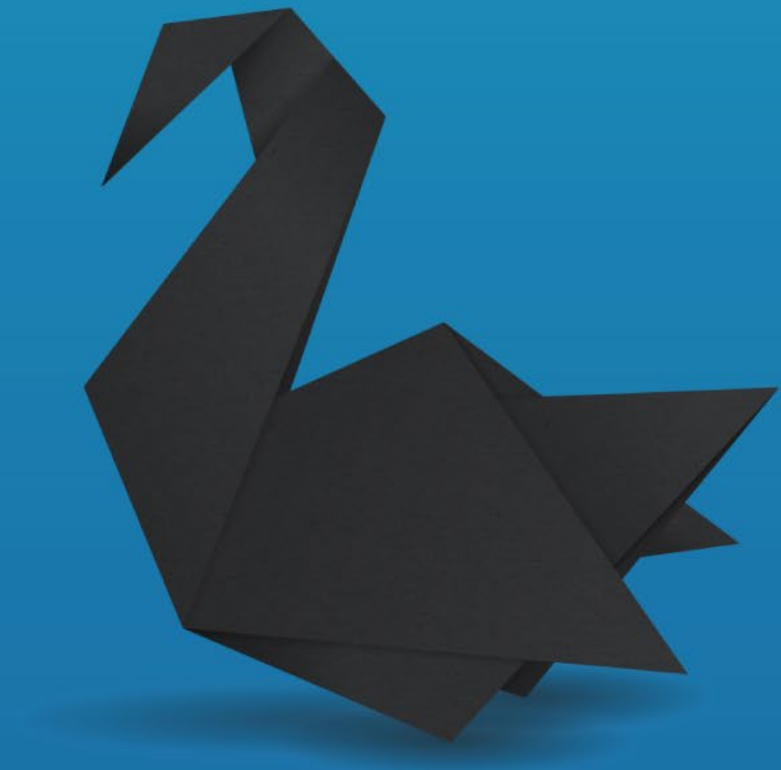
FROM KNOWN UNKNOWNS TO BLACK SWANS

How to Manage Risk in Latin America and the Caribbean

Semiannual Report – Office of the Regional Chief Economist

January 23, 2019



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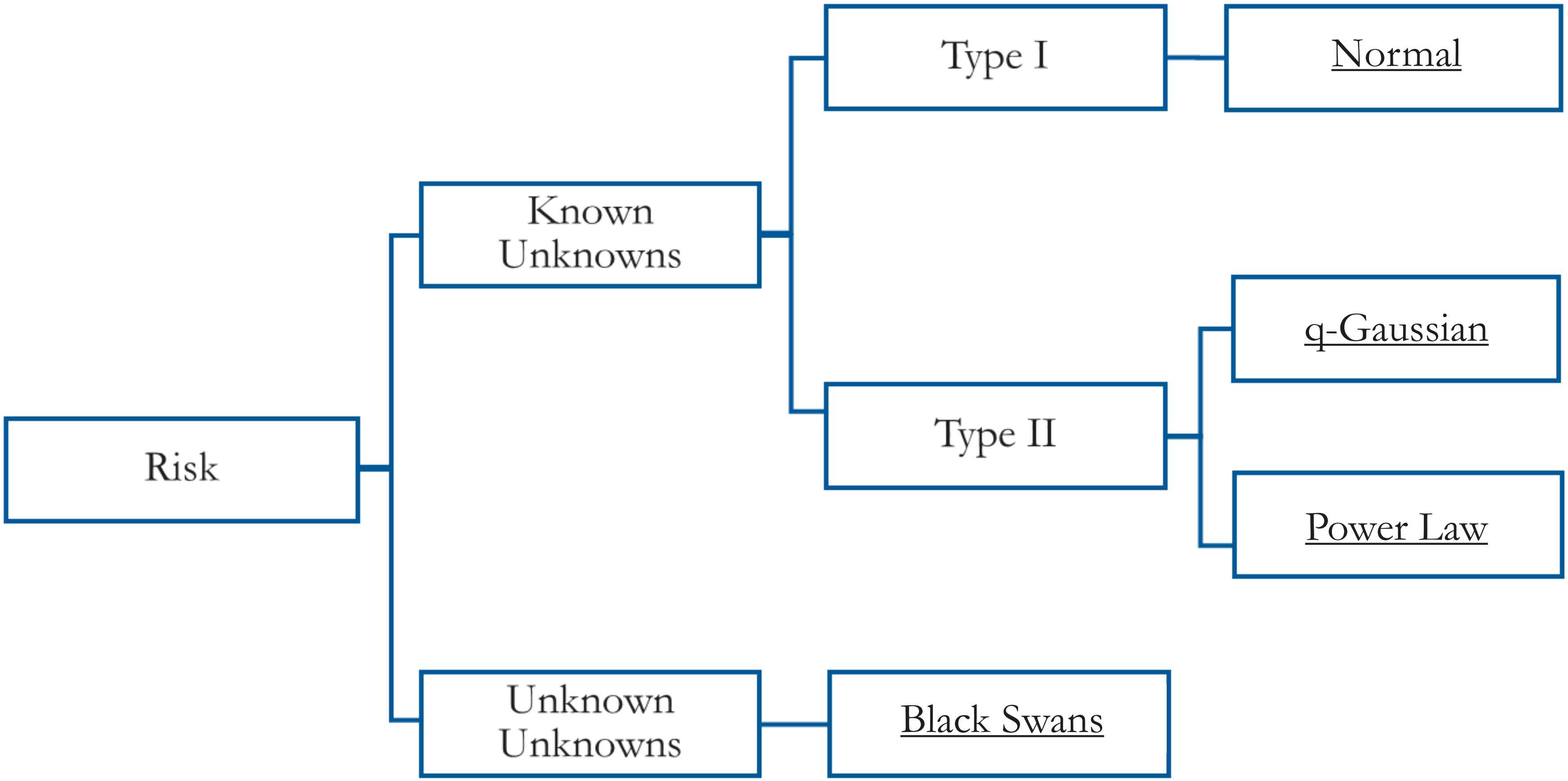
The Foundations of Risk: Roadmap

- Why do we care about what type of risk we face?
- What types of risks do we face?
- The curse of the fat tails
- Not all swans are white…

Why is Knowing the Type of Risk Important for Policy?

- In a risky world, a country would want to insure/hedge as much as possible
- In an ideal world, you would fully insure against every possible risk, go home, and sleep peacefully!
- In the actual world, the type of risk basically determines a country's ability to insure
- What risks can you insure against?
  - You can fully insure against all Type I risks (normal distribution)
  - You can insure against *some* Type II (fat tails) risks but not all
  - You *cannot* insure against Black Swans

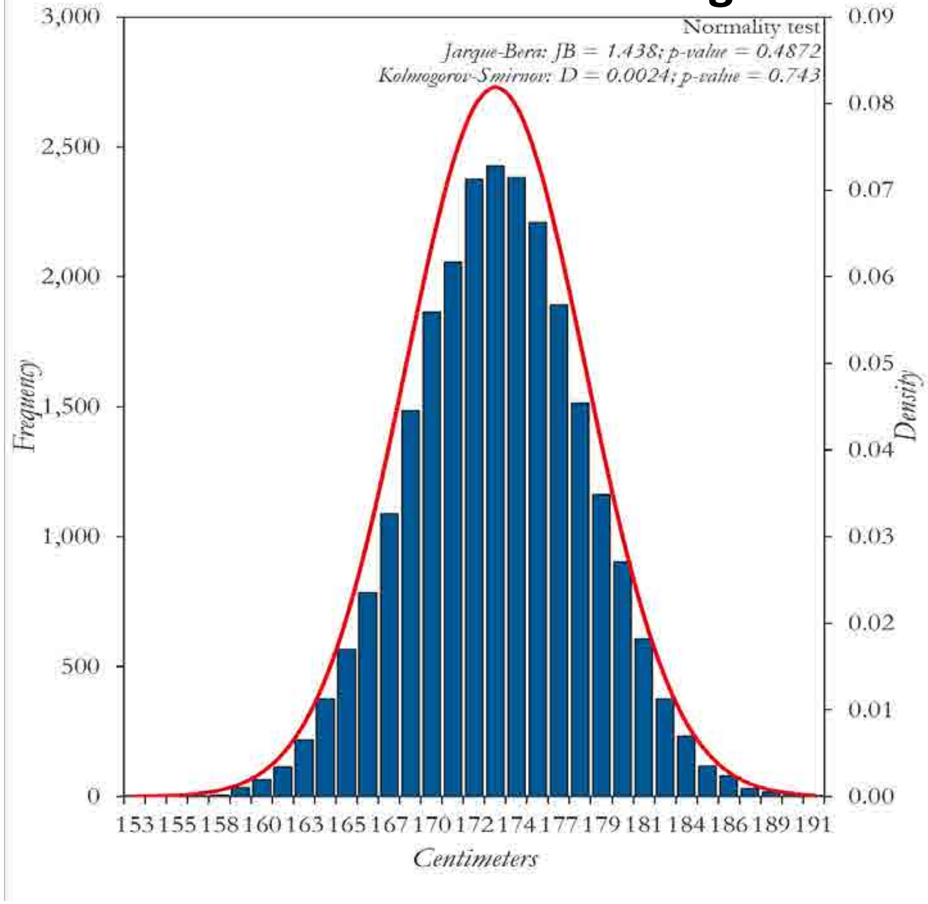
Classification of Risks



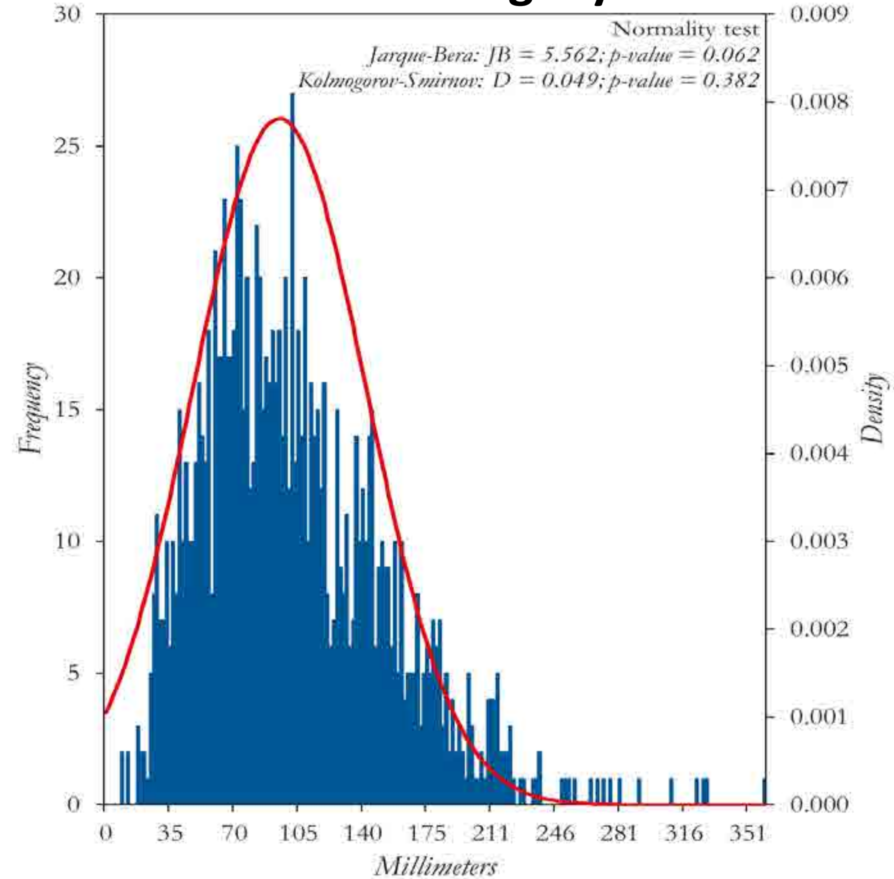
Source: Authors' elaboration.

Known Unknowns: Type I Risk, Normal Distributions

Distribution of Human Height



Rainfall in Uruguay



You can fully insure against Type I risks by, for example, using options (priced à la Black-Scholes).
Big problem: In the actual world, most economic and natural risks are *not* Type I!

Sources: Height based on Statistics Online Computational Resource (SOCR)-UCLA, based on 25,000 children (up to 18 years old) from Hong Kong.
Rainfall is monthly data for period 1916-2015, based on Climate Change Knowledge Portal (World Bank).

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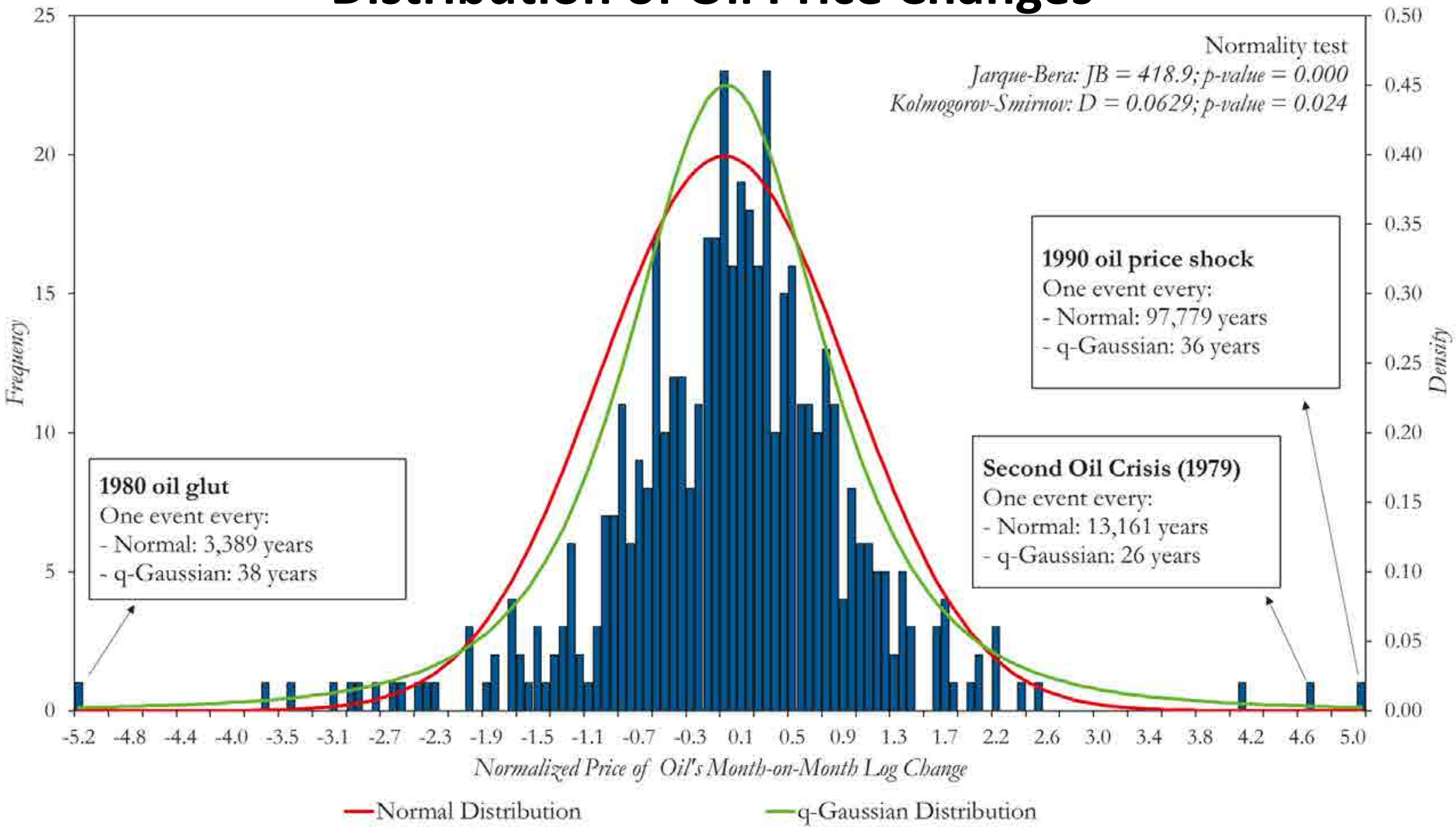
Known Unknowns: Type II Risk, q-Gaussian

Distribution of Oil Price Changes

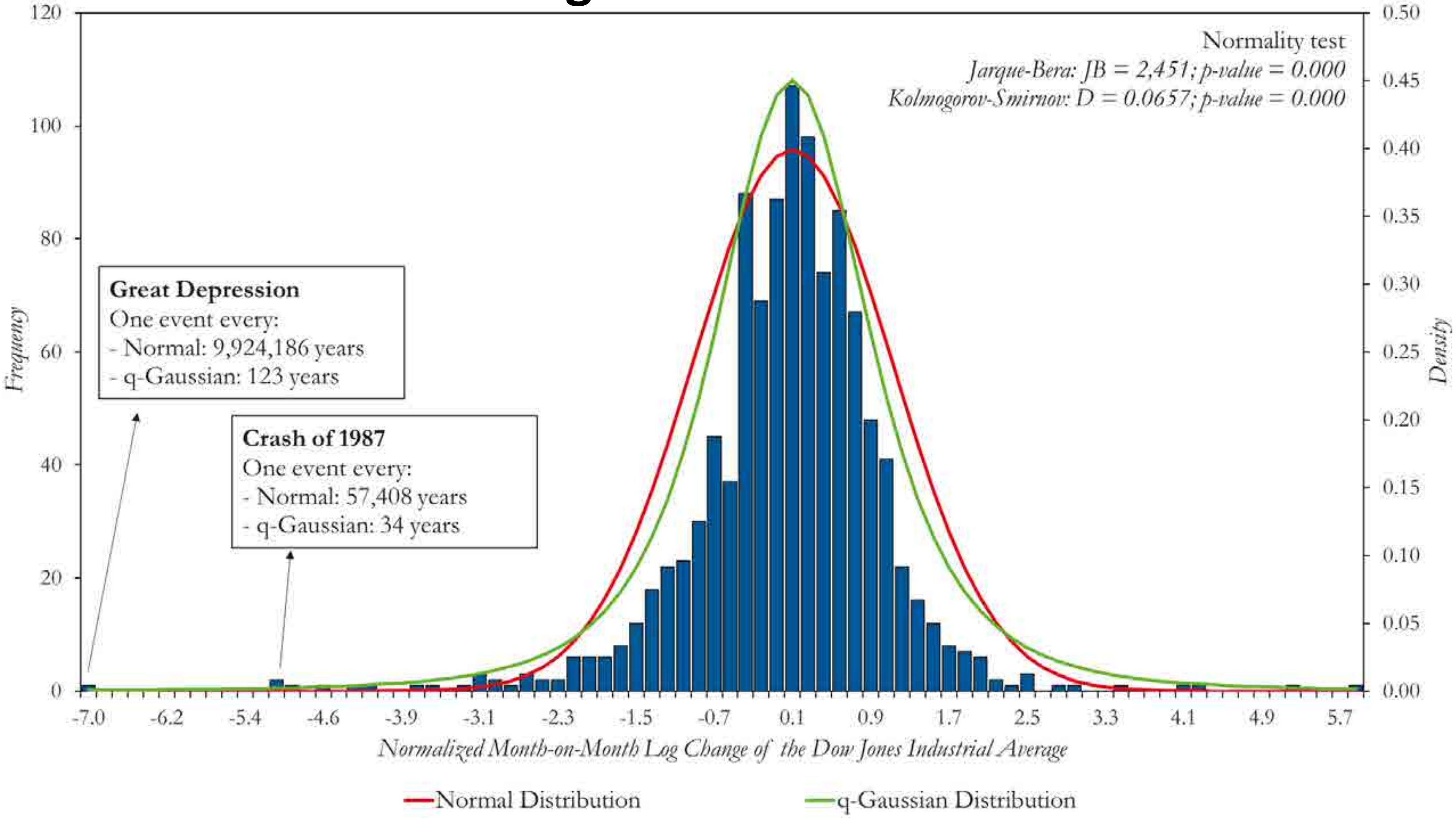


q-Gaussian distributions begin to grow "fat tails." As long as they are not too "fat," risk can be priced (with a "premium" over Black-Scholes) and you can insure. Changes in stock prices and many commodities follow q-Gaussians.

Source: Authors' computations based on World Bank Commodity Prices Data (Pinksheets).

Known Unknowns: Type II Risk, q-Gaussian

Distribution of Changes in Dow Jones Industrial Index



q-Gaussian distributions can be mistakenly taken for normal distributions due to their bell-shape form. But because of fatter tails, we can clearly reject normality.

Note: Dow Jones series from January 1928 to May 2018. Source: Authors' computations based on Bloomberg.

Pricing Options in a General Equilibrium Framework (I)

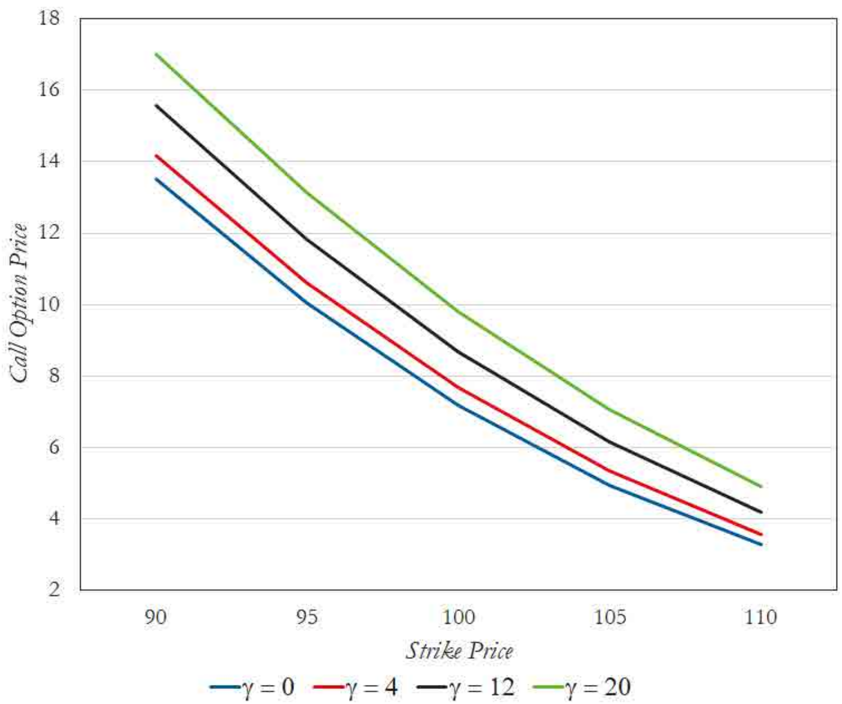
- If we assume risk neutrality and a normal distribution for the stochastic endowment in the second period, we are able to replicate the Black-Scholes pricing solution for an “option” or claim to future consumption endowment:

$$C(P_0, t) = \overbrace{\underbrace{P_0}_{Today's\ price} * \underbrace{N(d)}_{Probability}}^{GROSS\ RETURN} - \overbrace{\underbrace{Ke^{-r(T-t)}}_{PV\ of\ strike\ price} * \underbrace{N(d)}_{Probability}}^{COST}$$

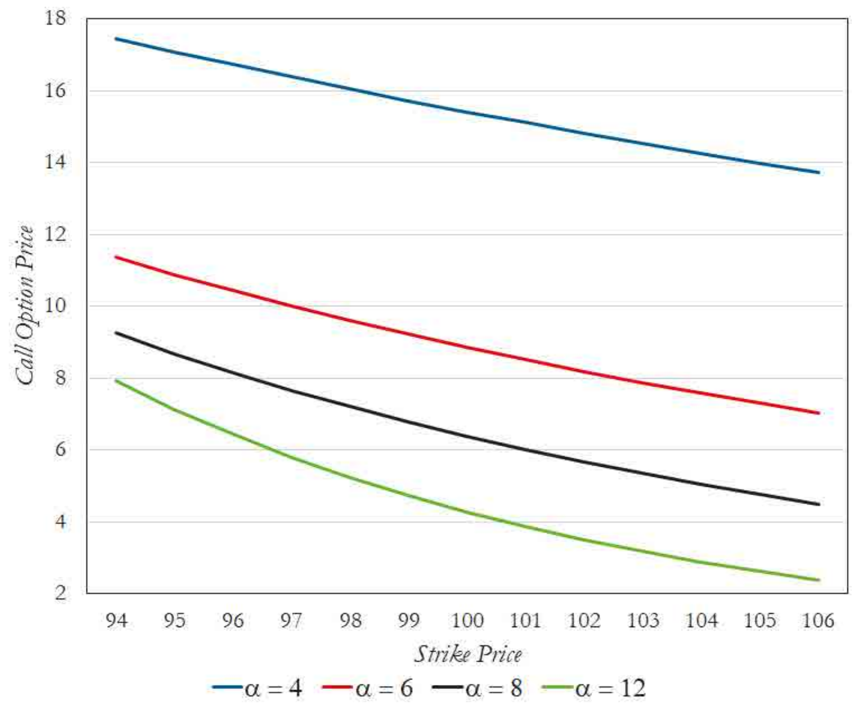
Pricing Options in a General Equilibrium Framework (II)

- Relaxing the assumption of risk neutrality or assuming distributions with fatter tails than a normal distribution results in a premium relative to the standard Black-Scholes pricing

For different levels of risk aversion



For different tails



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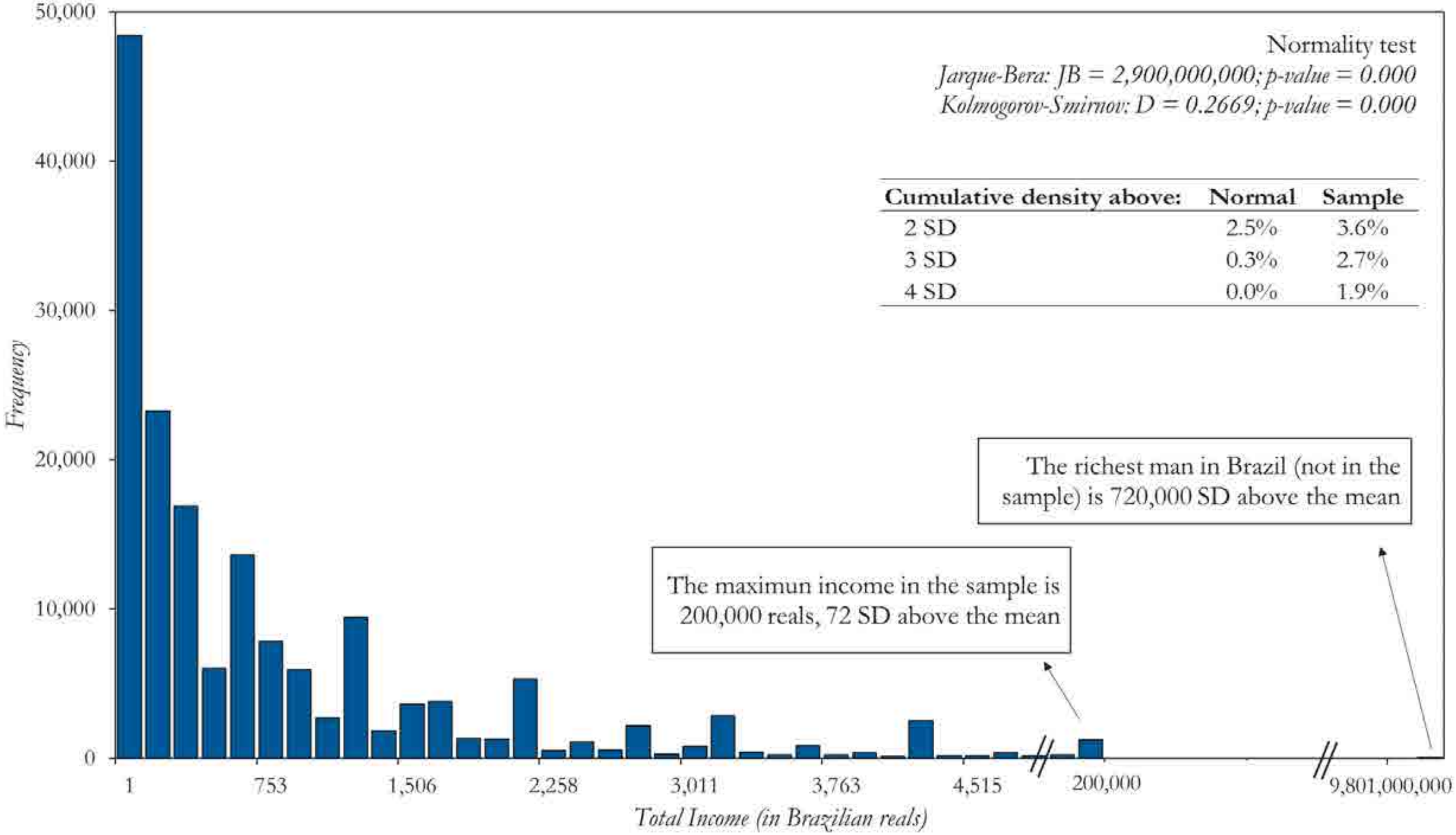
Known Unknowns: Type II Risk, Power Law Distributions

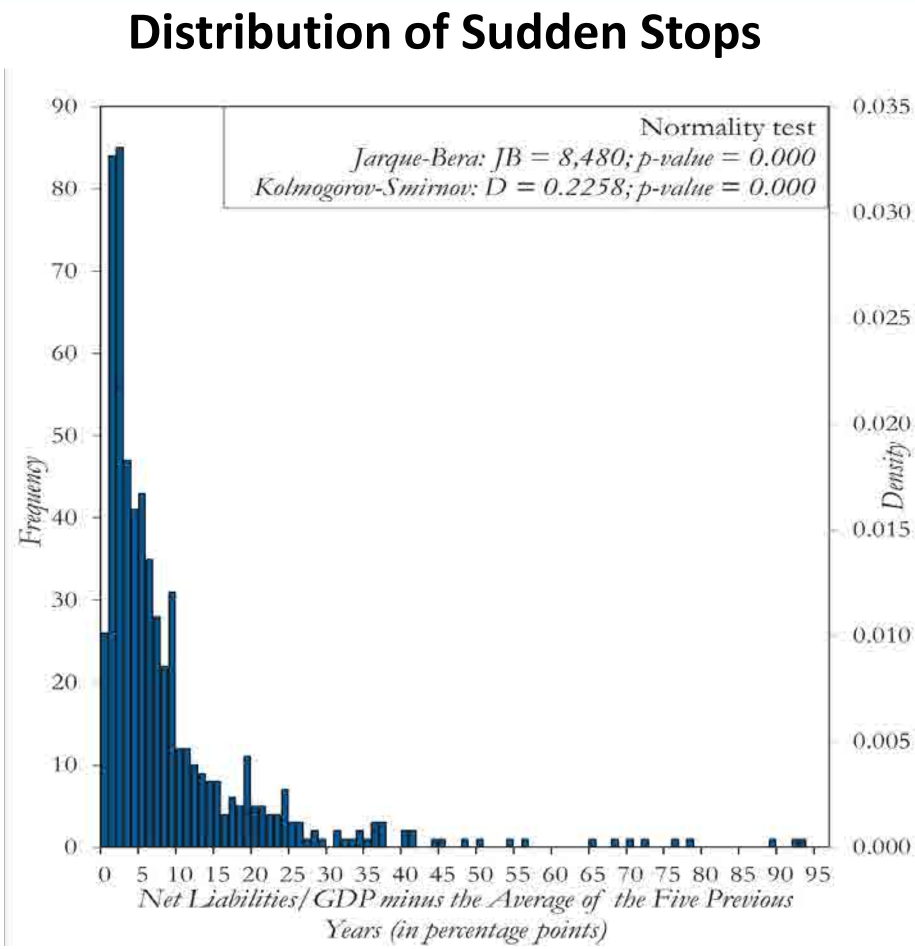
Distribution of Income in Brazil

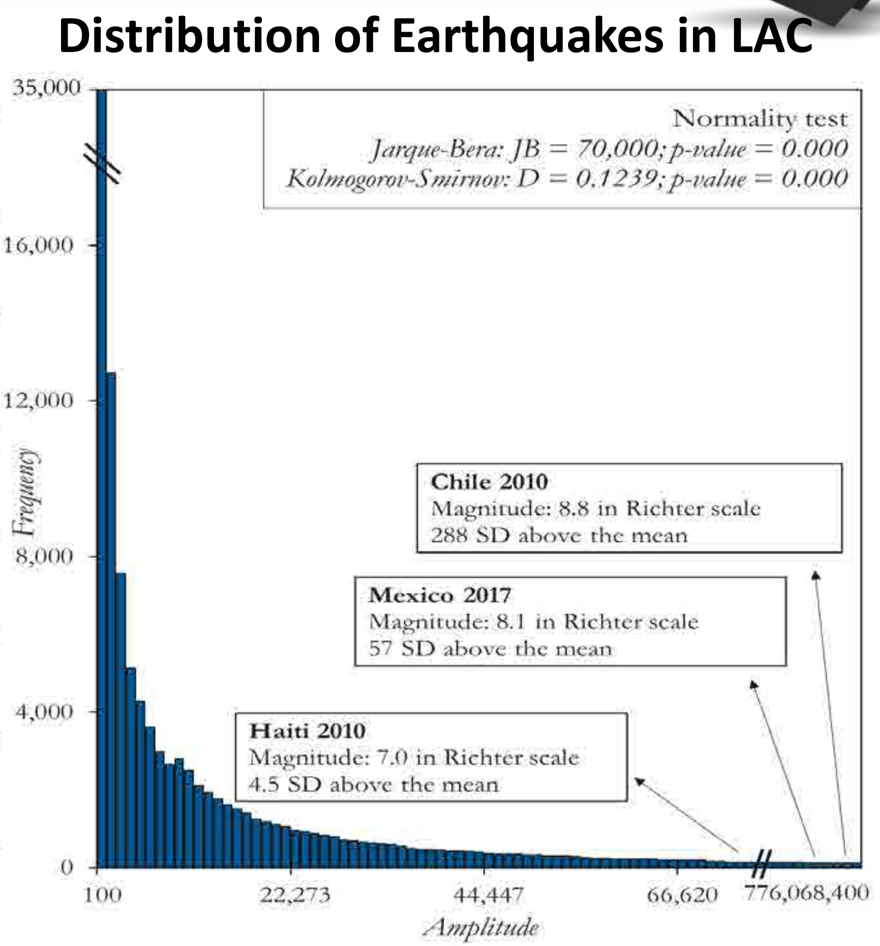


Textbook example of a power distribution. Richest man would be 720,000 standard deviations above the mean!

Source: Authors' computations based on data from SEDLAC (CEDLAS and World Bank).

Known Unknowns: Type II Risk, Power Law Distributions





Power distributions have a lot of mass close to zero and long, fat tails. Hard to price because the occurrence of a single "fat tail" event could bankrupt the insurer. Many economic/natural risks follow power distributions.

Sources: Authors' computations based on data from BoP-IMF, NCEI, NOAA, and WDI.

The Simple Arithmetic of Power Law Distributions

- Probability distribution function:

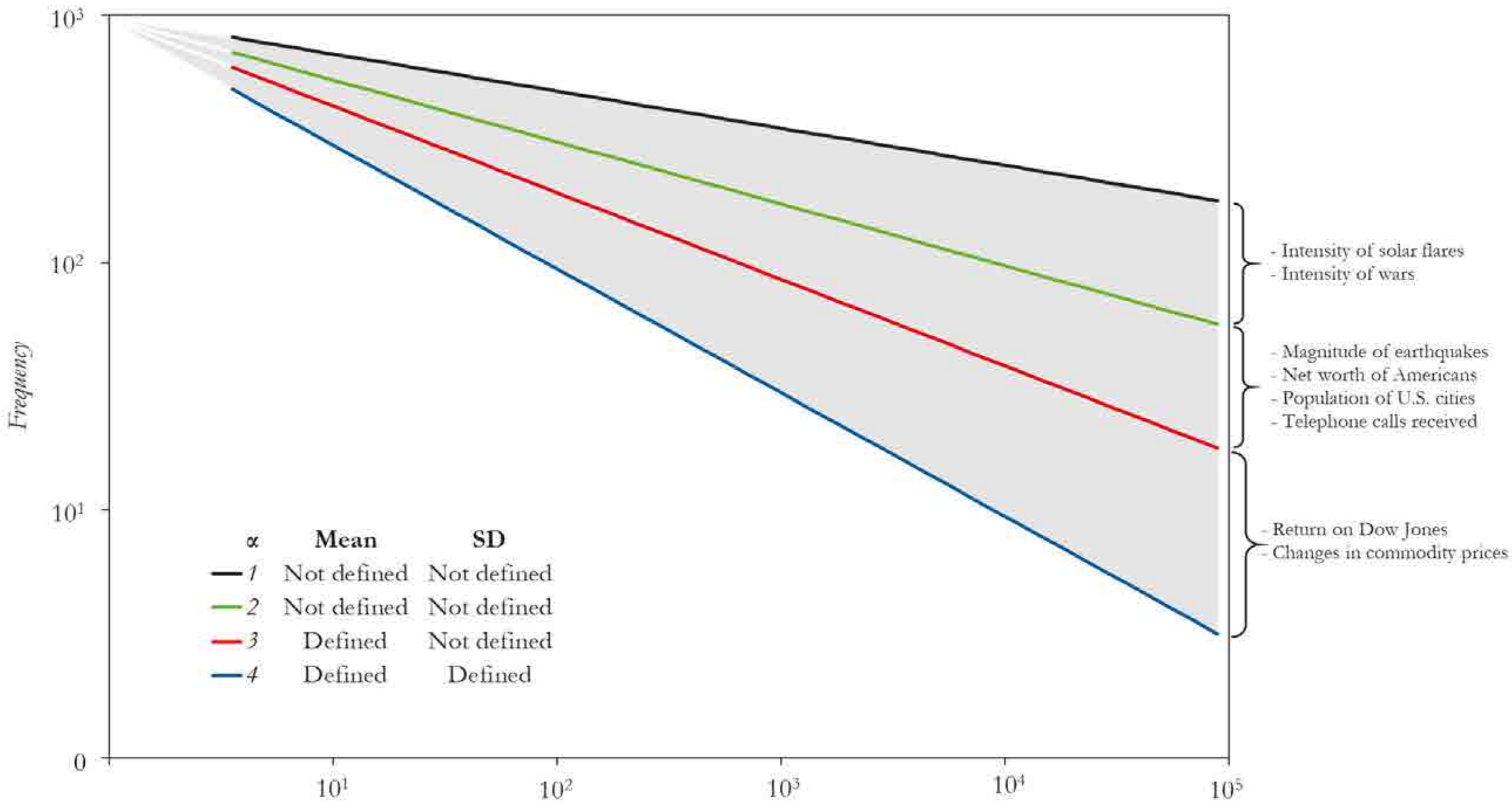
$$f(x) = \frac{c}{x^{\alpha}} .$$

- Take logs and rewrite as:

$$F(x) = \log(c) - \alpha \log(x) ,$$

- where $F(x) \equiv \log[f(x)]$. As α gets smaller, the slope becomes flatter (which implies fatter tails)

Power Law Distributions



As α decreases and the line becomes flatter, we "lose" moments of the distribution and underlying risk becomes impossible to price. But for "steeper" power-law distributions, we can sometimes price.

Source: Authors' elaboration.

Pricing Catastrophe Bonds (I)

- The key difficulty in pricing a catastrophe bond is that the underlying process of the cat bond is driven by two distributions:
    i. the probability of an event occurring
    ii. the intensity of such event
- Jointly, these distributions determine the probability of the bond being either paid in full to investors or being liquidated to help the insured
- A popular arbitrage-free solution involves a compound doubly-stochastic Poisson distribution to measure the probability of occurrence of the natural disaster

Pricing Catastrophe Bonds (II)

- If we assume that the bond can be liquidated only if the accumulated losses L at time t are larger than some threshold D, then a zero-coupon cat bond paying a certain amount Z at maturity time T will have a value for investors of

$$V_t = \mathbf{E}\left(\underbrace{Z_t e^{-r(t,T)}}_{Present\ discounted\ value\ of\ future\ payment} \underbrace{\left[1 - \int_t^T m_s [1 - F(D - L_s)] \mathbf{1}_{\{L_s < D\}}\, ds \right]}_{Probability\ of\ not\ liquidating\ the\ bond} \middle| \mathcal{F}_t \right)$$

where r is the risk-free interest rate and $F(.)$ is the probability function of the strength of the natural disaster

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Pricing Cat Bonds

- Increasing the time to maturity or decreasing the threshold level (thus increasing the probability that the cumulative loss surpasses the threshold) will decrease the value of the bond

- Fat tails in the distribution of the strength of the event may generate losses big enough to exceed the threshold

- Thus, fatter tails will be associated with higher premiums and thus a lower present discounted value of the bond

    - If the tails are fat enough, the premiums could be so high that the market would disappear

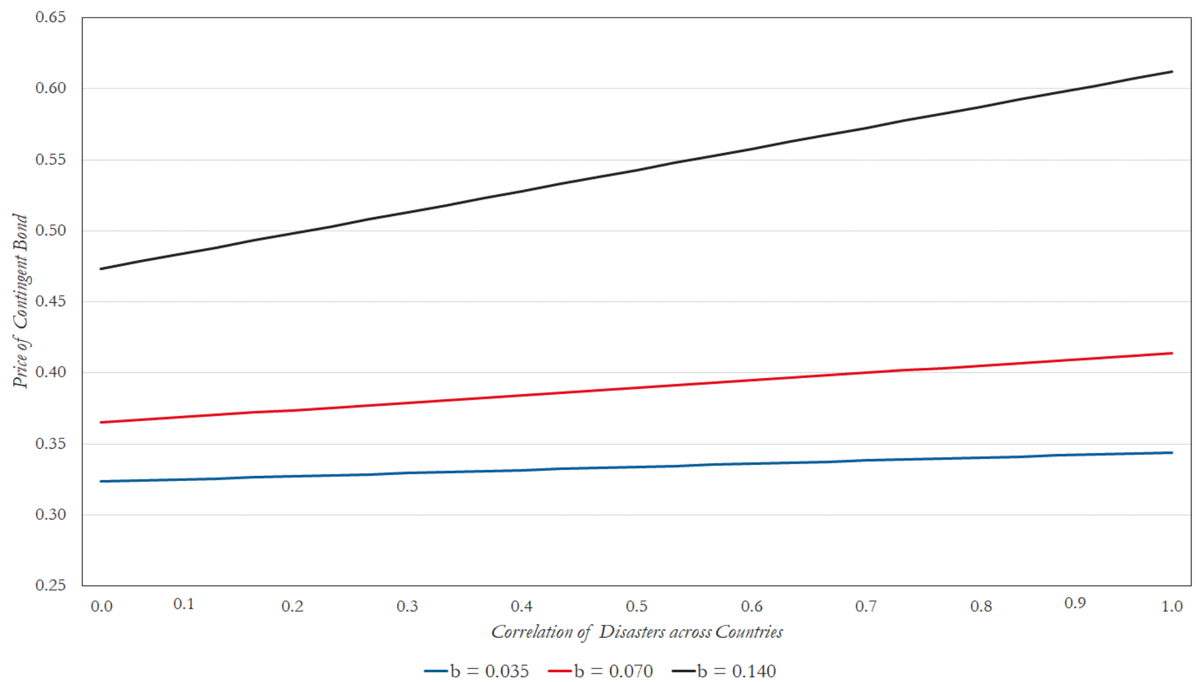
Insuring Against Natural Disasters

- An important absence from the previous pricing tools is the role of time and the cross-country correlations of the events
- We can use a simple two-country, two-period model to highlight the key role of the cross-country correlation in the pricing of insurance
- Assumptions of our model:
  - Deterministic income in period 1
  - Stochastic income in period 2 (the only source of uncertainty are disaster-type shocks)
  - Symmetry across countries
- Our model predicts full risk sharing in all states of nature
- Insurance pricing will be a function of the correlation of events across countries

Insuring Against Natural Disasters

- The price of insurance increases as the correlation tends to one
- The correlation elasticity of the insurance price seems to be closely associated to the size of the disaster shock (b)
    - The larger the shock, the more important is the correlation

Price of Cat Bond, correlation of disasters across countries and size of the natural disaster



Unknown Unknowns: Black Swans (I)

- Until 1697, Europeans thought all swans were white …

Unknown Unknowns: Black Swans (II)

- And, then, surprise, surprise … A black swan was spotted in Australia!!

Unknown Unknowns: Black Swans (III)

- A “black swan” is an event that is:
  - Unpredictable
  - Typically “large”

- You cannot insure against a “black swan” because, by definition, they are unpredictable (and hence have not known distribution)

- All you can do is to provide ex-post aid

- Big public policy implication: You cannot insure against everything!

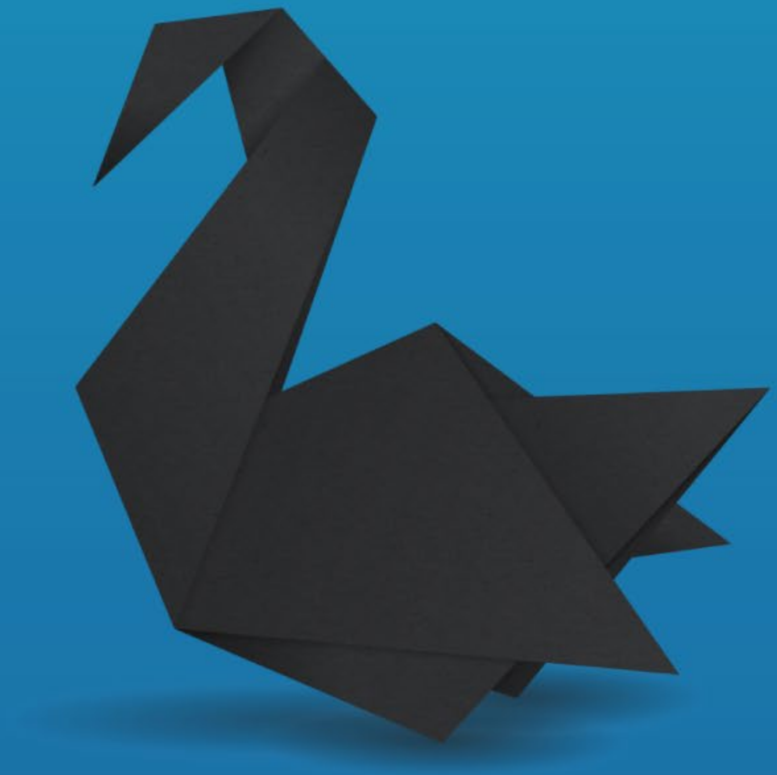
Black Swans in Practice

Black Swan Events	Ex-Post Policy Aid
The Black Death (14th century)	None (1/3 of European population dies)
The Long Depression (1873-1896)	None (U.S. unemployment rises to 14%)
The Spanish Flu Pandemic (1918-1919)	None (5% of world population dies)
World War I (1914-1918)	None (arguably sows the seeds for WWII)
The Great Depression (1929-1939)	New Deal
First Oil Crisis (1973-1974)	None (stagflation followed)
9/11 (2001)	$2.8 trillions on counter-terrorist measures
Global Financial Crisis (2008)	$700 billion bail-out plan
Maracanã 1950: Uruguay beats Brazil	None

Policy Lessons on Foundations of Risk

- Knowing the type of risk is critical
- Type I risks (normal distribution) or close to normal are easy to insure against (and hence should)
- Type II is insurable as long as tails are not too fat (and we can now sell earthquake bonds)
- Key policy implication: The fatter are the tails, the less market insurance will be available, and hence the more important precautionary/ex-post aid becomes

Full report in Spanish and English available at:
http://hdl.handle.net/10986/30478



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