FROM KNOWN UNKNOWNS TO BLACK SWANS

How to Manage Risk in Latin America and the Caribbean

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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

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).
Known Unknowns: Type II Risk, q-Gaussian

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

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.
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:

\[
C(P_0, t) = \underbrace{P_0}_{\text{Today's price}} \ast \underbrace{N(d)}_{\text{Probability}} - \underbrace{Ke^{-r(T-t)}}_{\text{PV of strike price}} \ast \underbrace{N(d)}_{\text{Probability}}
\]
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:
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).
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 \( \alpha \) gets smaller, the slope becomes flatter (which implies fatter tails)
Power Law Distributions

As $\alpha$ 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.
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

$$V_t = E\left(\frac{Z_t e^{-r(t,T)}}{\text{Present discounted value of future payment}} \left[1 - \int_t^T m_s[1 - F(D - L_s)]1_{\{L_s < D\}} ds\right] \bigg| \mathcal{F}_t\right)$$

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

![Graph showing the relationship between correlation of disasters and price of Cat Bond](image-url)
• Until 1697, Europeans thought all swans were white ...
• And, then, surprise, surprise ... A black swan was spotted in Australia!!
• 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 Swan Events**

- The Black Death (14th century)
- The Long Depression (1873-1896)
- The Spanish Flu Pandemic (1918-1919)
- World War I (1914-1918)
- The Great Depression (1929-1939)
- First Oil Crisis (1973-1974)
- 9/11 (2001)
- Global Financial Crisis (2008)
- Maracanã 1950: Uruguay beats Brazil

**Ex-Post Policy Aid**

- None (1/3 of European population dies)
- None (U.S. unemployment rises to 14%)
- None (5% of world population dies)
- None (arguably sows the seeds for WWII)
- New Deal
- None (stagflation followed)
- $2.8 trillions on counter-terrorist measures
- $700 billion bail-out plan
- 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

THANK YOU!