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Financial Derivatives

Welcome to Finance 512.

This brief note spells out what we are going to do this term, how we are going to do it, and why.

First I will define our subject and our goals for the term. Then I'll offer some perspective on the role of derivatives, and why they matter. I'll describe the basic methodology we are going to use throughout the course, and put derivatives pricing in the broader context of all theories of pricing.

I'll end by giving you an overview of some of the most important current developments in the world of derivatives.

Outline:

I. Where this course fits in.
II. What do derivatives do?
III. What do models do?
IV. Cases – An Example.
V. Derivatives today.
VI. Summary.

I. Goals.

- This course aims to provide you with an in-depth survey of **derivatives products, markets,** and **applications.**

- You know already that the key to really understanding derivatives is to learn the <u>models</u> that allow us to price them and hedge them.
  - ▶ Derivatives are the basic building blocks of financial engineering.
  - ▶ Models embody the fundamental principles.

- Our emphasis will be on seeing how the principles work in the *real world.*
  - ▶ We will of course have to ground our analysis in modelling.
  - ▶ We will also make extensive use of the modelling you are learning in your other courses.
  - ▶ Here, we will specifically aim to understand how to make those models useful by taking into account the actual details of the situations in which we want to use them.

- A cold, hard truth about financial engineering:

  All the models are wrong!

- All models are built on *assumptions* which are always abstractions from reality.

- Our ability to capture *all* the complexities of actual markets is always going to be limited by the need to make the models simple enough to be useful.

- This does not mean the models are a waste of time.
  Far from it!
  - They can be spectacularly good at identifying value and risks – which is what we ask of them.

- The point is that, whenever we use a model, we have to ask *whether we are taking it too far.*

- <u>We</u> have to know what *the model does NOT know about.*

- More precisely, we have to know how sensitive each model is to each of its assumptions, and then make sure we do not rely on it in situations when a very important assumption fails to hold.

- Thus, while, the primary task of the course is to teach you how to use the models....

- The secondary task is to teach you how *not* to use them!

- I want all of you to be able to be able to be able to be *intelligent users* of both the products and the models.
  - To some extent, this means being skeptical of both.
  - "Financial engineering" sounds like an objective and scientific discipline.
  - But we should not delude ourselves – or others – about its limitations.

II. What Do Derivatives Do ?

- Derivatives (or *contingent claims*) are financial contracts whose value is derived from that of some other primary security (or securities) whose prices are taken as given.

- Some people's reaction to derivatives is that they are unnecessary, wasteful, and perhaps inherently dangerous.

- In fact, *many economists agree.*
  - ▶ Particularly since the 2007-2009 crisis, the social value of financial engineering has been harshly questioned.
  - ▶ To understand why derivatives matter, we need to understand the nature of this criticism.
  - ▶ Take a closer look at what a "derivative" really is.

- A **pure** derivative is a security whose value is completely determined by the underlying assets.

- In that case, there is a *pricing function* – which our theory will tell us how to find – that describes the relation between the derivative and the underlying asset(s):

$$P(t,\ S_t;\ \begin{array}{l}\text{contract}\\ \text{description}\\ \text{[fixed]}\end{array};\ \begin{array}{l}\text{anything else}\\ \text{we know at}\\ \text{time } t\end{array})$$

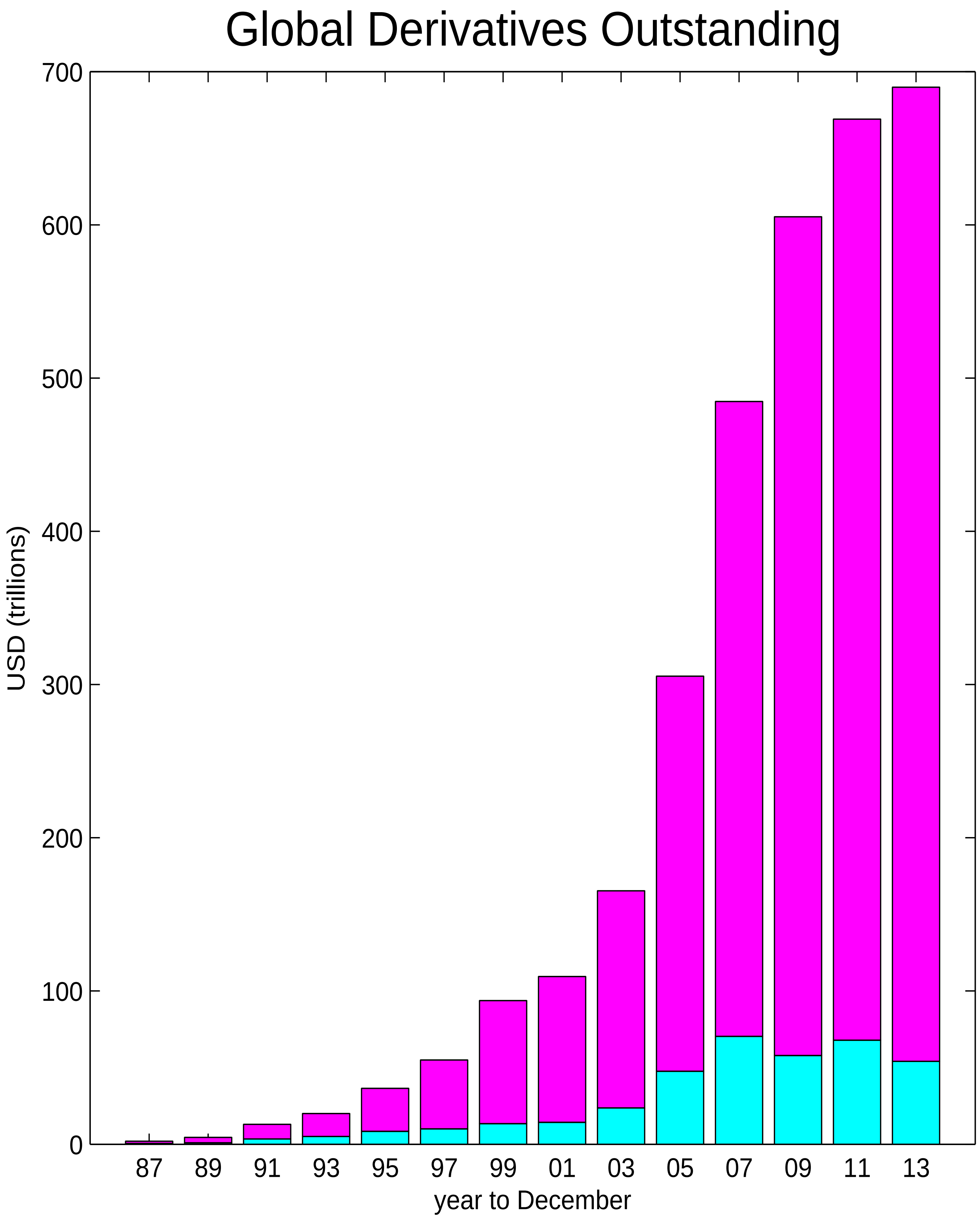
Q: If S determines P, doesn't P determine S?

- You can see the point: why do we need both?

- By definition, these *pure* derivatives are redundant.
  - ⋆ They are merely agreements to re-allocate cash-flows.
    They don't create any value.
  - ⋆ For every buyer there is a seller (zero-sum game).
    So the economy as a whole is not changed by them.

- Moreover, if they don't do anything new and they are costly and complex, then maybe they really are dangerous and wasteful.
  - ▶ Just a high-tech excuse for gambling?
  - ▶ Or worse: a means for fooling people and avoiding oversight.

- And yet if they don't do anything useful....


Global Derivatives Outstanding
700
600
500
400
300
200
100
0
USD (trillions)
87
89
91
93
95
97
99
01
03
05
07
09
11
13
year to December

- So why *do* derivatives matter?
- Textbook answer: Because they permit transfer of risk (like insurance).
- But insurance hedges you against untraded risks, like someone running into your car.
  - But mostly derivatives only transfer risks of things that were already tradeable.
  - So this can only be part of the answer.
- More generally, they just make risk transfer (and speculation, and investment, and financing) *cheaper*.
  - Lower transactions costs.
  - Minimize taxes.
  - Avoid regulatory constraints.
  - Simplify credit problems.
  - Lump many transactions together.
- In other words, they get around market imperfections.

- *Examples:*
  - Portfolio manager wants to follow policy of lower risk in falling markets.
    - Problem: constant rebalancing is expensive in time and commissions.
    - Solution: buy long-term put option on portfolio.
  - Fixed-income fund wants to hedge against deflation risk.
    - Problem: limited liquidity in government issued inflation linked bonds.
    - Solution: zero-coupon inflation swap.
  - Investor wants to lower exposure to a winning stock position.
    - Problem: high short-term capital gains tax.
    - Solution: take off-setting short position in single-stock futures.
  - American fund wants to invest in Taiwanese stocks.
    - Problem: government limits foreign holdings, requires costly on-shore presence.
    - Solution: local depository institution swaps cash-flows from equity portfolio for fixed payment.

- ▶ Bank needs to hedge housing market exposure while continuing to originate loans.
  - ∗ Problem: No way to short sell property.
  - ∗ Solution: Credit default swap on asset-backed index.

- ▶ Governments want banks to have more capital when their assets deteriorate.
  - ∗ Problem: That's precisely when problems of transparency make it expensive to issue new equity.
  - ∗ Solution: Contingent-capital (CoCo); bonds that automatically convert to equity when loan write-offs rise.

- **Conclusion:** derivatives only matter because markets aren't perfect.

  Financial engineering is the process of using derivative securities to improve opportunities to receive efficient risk/return trade-offs. – Robert Merton (1994).

- Thus, we will *always* need to analyze the role of *frictions* in real markets to understand how derivatives are useful.

III. Models.

- How do derivatives models work? How can we look at a particular security and figure out what it *should* be worth?

- **How do any valuation models work?**

- I want to call you attention to a key distinction between two approaches to valuation.

  Economic theory: Deduce it's "fundamental value" from some theory of investor attitude towards risk & reward.

  - ▶ Equivalent to specifying "correct" discount factors that should be applied to a given cash-flow stream.
  - ▶ e.g. via the CAPM

  Pricing by analogy: look for other products a lot like it, and use their price.

  - ▶ Just like selling a car.

- We could call these two approaches *absolute pricing* versus *relative pricing*.
  - ▶ Each of them has difficulties, as the box below describes.

	Absolute Valuation	*Relative Valuation*
IDEA:	Utility function determines discount rates to apply to uncertain future cash flow.	Market prices of existing similar assets should be close to yours.
PROBLEMS:	What is the utility function? Computation may be hard. Market may not agree with answer.	How much is the dissimalar part worth? What if market is wrong? Why should it hold? What if it doesn't?

- For pure derivatives, we are able to use relative pricing AND overcome its main weaknesses.
  - This is very convenient!
  - It means we can often solve our problems without needing to understand the deeper economic forces that determine the prices of the primary assets.
  - We also do not need to know if they are priced "correctly" in any sense.
- The really big idea is that the universe of things that we can price *relative to* includes more than just other assets that are already out there.
- It ALSO includes
  - *portfolios;*
  - *trading strategies.*
- Often we can find candidates that
  - are very similar;
  - have precise values.
- So those values "ought" to be the value of our security.
- **Why?** Well, you already know the answer.

- **The No-Arbitrage Principle.**

(A) An **arbitrage** is any trading strategy requiring no cash input that has some probability of making profits, with no risk of loss.

  ▶ A portfolio with a zero price and a strictly positive payoff, or

  ▶ One with a negative price and a non-negative payoff.

(B) **In an efficiently functioning financial market arbitrage opportunities cannot exist** (for very long).

(C) This law implies that:

  Two securities (*or portfolios, or strategies*) that have the same payoff **must** have the same price.

(D) If they don't, we create an arbitrage by buying the cheap one and selling the expensive one.

  ▶ Unlike other physical assets, financial assets can be sold ("short") by someone who does not already own them.

  ▶ This is the KEY TRICK that makes relative pricing work.

    * We will be spending a lot of time examining how this works in practice in different markets and what happens when it *doesn't* work.

- Notice that the no-arbitrage principle does NOT *assume* that markets are perfectly efficient, and that arbitrages never exist.
  - That would be unrealistic and not the basis for a sound theory.
  - Instead, it just identifies a particular property that markets must have – once they have reached equilibrium.
  - So the prices that we will find are those that must prevail *when there are no arbitrage opportunities*.

- Our job in pricing a pure derivative boils down to finding a replicating portfolio (or strategy) for it.

- Then we invoke the Principle: if their prices aren't equal, risk-free profits are possible.

- Not just "possible" either. We show how to **make** them.

- However, we will also see that there are many financial engineering problems that require us to leave behind the comfortable world of "pure" derivatives.
  - Then we will need to put on our economists hats and go back and think about deeper theory.
  - But, as you will see, we will still be guided by the logic on no-arbitrage valuation.

- **Our basic approach:**
  Over the course of the term we will discuss the most important derivative products, and, for each, answer:
  1. What is it? Why does it exist? What problems can it solve?
  2. How do we price it?
  3. How do we hedge it?
  4. What assumptions does the model need?
  5. How does the market actually work?

- We will *always* pay especially close attention to the assumptions.

- And here we must note an important **paradox.**

- I told you earlier that derivatives are really only important because they help resolve market imperfections.

- *Yet,* our approach to derivatives starts
  ... by assuming perfect markets !
  * No transactions costs.
  * Unlimited trade at market prices.
  * No taxes.
  * Perfect institutions.
  * No borrowing/lending restrictions.
  * Enforcable contracts.

- **Why ? ? ?**

(A) To build a complicated theory, start with a simple one.

(B) Focus attention *on* the assumptions. Theory will allow us to ask how much each one matters. Often the answer is a lot. By learning this, we learn when *not* to use the theory.

(C) Some markets *are* nearly perfect ... *for some players.* As long as there is competition among them, the market will then appear perfect to all players.

(D) Markets are coming closer to "perfection" over time.

- Through out the course I will remind you about this "paradox" that I am pointing out.

- For financial engineering to be truly useful, we (the practitioners) have to dance on a fine line:
  - We need to grasp the market imperfections that lead to derivatives coming in to existence in the first place.
  - We need to ignore as many real-world details as we can, in order to have models that we can actually solve and put to work.

IV. About Case Studies

- When we examine a particular type of derivative, we will complement our "textbook" treatment of it by considering a real-world situation.

- **Example: – The London Whale, 2012**

  ▶ As you are probably are aware, in 2011-2012 the largest and perhaps most sophisticated U.S. bank – JP Morgan Chase – lost billions of dollars in a series of complex transactions.

  ▶ Here the derivatives in question were "return swaps" tied to baskets of "credit default swaps."

    * Sort of like futures on the S & P 500 index....
    * ...except the underlying things in the index are not stocks.
    * Rather, they are *themselves* another type of derivative.

  ▶ We will see lots of examples of derivatives built on top of other derivatives!

    * Most journalist, politicians, and commentators on this episode have no idea how the *first* level of derivatives work, let alone the *second* !

- There are many, many questions one could ask about this episode. Here are some.

  (A) What was JPM trying to do? Did their idea make sense?

  (B) Did they make mistakes or did they just have bad luck?

  (C) Were they misled by bad models? What roles did models play?

  (D) Did they do anything wrong – morally, socially, legally?

  (E) Could people with better models have made money trading against them?

- In thinking about these questions, we cannot even start to answer them until we understand the underlying product and how to model it.

- But, as I think you can also see, the model is just one piece of the puzzle.
  - Your job will be to get into the details and see the whole picture.

V. Derivatives Today

- Let me close today's talk by giving you an overview of some of the important developments that are shaping derivatives markets today.

- As you all know, the landscape of financial engineering was (and is still being) strongly affected by the financial crisis of 2007-2009.
  - ▶ Today financial engineering is widely distrusted in society as a whole.
  - ▶ The major economies are all trying to re-design the landscape in which derivatives are employed to limit the damage that they can do when they are NOT fully understood and their overall risks can NOT be easily measured.
  - ▶ In July 2010 the U.S. passed the **Dodd-Frank** bill which set in motion a detailed rule-writing process that is still being carried out.
    - ∗ Parallel legislation is being implemented in the E.U. under the so-called European Market Infrastructure Regulation.
  - ▶ Globally, bank usage of derivatives is also being reshaped via the capital rules of the Basel Committee on Bank Supervision.

- This evolution means starkly different things for **OTC** markets and **exchange traded** markets.

- The pressure is for OTC markets to become more like exchange traded ones.

- All of the products that caused the financial crisis were traded OTC.

- Nearly all OTC markets experienced disruptions during the crisis.

- Exchange traded markets all functioned fairly normally and were not the source of any kind of systemic problems.

• The key distinction between the two market types is the difference between **bilateral** and **central** clearing and settlement.

  - "Clearing" is the process of enacting a transaction: exchanging money when it is due; and verifying the legal obligations of each party.

  - In bilateral OTC markets, every trade must be processed by every pair of counterparties.

  - In centrally cleared markets, all settlement of obligations is done through a third party, the "central counterparty" (CCP).

    * For example, all stock trades in the U.S. are cleared by the Depository Trust and Clearing Corporation (DTCC) and all listed options are cleared by the Options Clearing Corporation (OCC).

- It is much easier to monitor centrally cleared markets, and there is much less credit risk.
- For some of the most widely used derivatives – some types of swaps – central clearing is (or soon will be) required.
  - Mandatory clearing in the U.S. was phased in during 2013 and 2014 and will be phased in in Europe in 2015.
  - The range of covered products is expected to expand to most OTC options and commodity derivatives.
  - Some institutions and contracts will remain exempt, for example in the case of commodities producers using forward contracts to hedge physical production.
  - But, for most firms and most contracts, central clearing will become the rule rather than the exception.
- It is still very much an open questions *who* will be the CCPs for which products.
  - There are several competitors in each market.
  - Each one will have different rules and margining mechanisms.
- Whoever wins, though, the move to central clearing will have important implication for valuation models – as we will see in more detail in later weeks.
  - The good news is that, when central clearing is a reality, some modelling issues will be much easier to deal with.

- In the absence of such clearing, an enormous amount of effort since the crisis has been devoted to trying to adequately capture counterparty risk and funding risks within derivatives models that traditionally ignored them.
- We will investigate this as well.

- Another feature of exchange-traded markets that is coming to the OTC world is more public price discovery.
  - Under Dodd-Frank, dealers are supposed to be discouraged from providing prices directly to clients via private, bilateral negotiations.
  - Instead, prices are supposed to be communicated through "swap execution facilities" (SEFs) that are suppose to operate like public exchanges in the sense that orders submitted to them can be seen and traded upon by anyone.
- As with CCPs, there are now many different players competing to become the platform that traders actually use.
- SEFs in the U.S. began trading for the first time in October, 2013. More and more products are supposed to migrate to all-SEF trading over 2014-2016.
- The transition to SEFs will not necessarily affect pricing models, but it could have big consequences for liquidity.
  - We will analyze SEFs more in a couple of weeks.

- On the subject of liquidity, the biggest question mark is the impact of the "Volcker Rule".
  - ▶ This is supposed to stop banks from proprietary trading, i.e., taking derivatives positions specifically to bet on future price moves – instead of to simply intermediate trades.
  - ▶ But it is sometimes hard to tell proprietary trading from providing liquidity to customers.
    - ∗ Banks may be reluctant to make prices for customers who want to unload large positions if they will have to justify having a big exposure on their books for an extended period.
  - ▶ If liquidity in derivatives markets is thinner, however, there will be more opportunities for hedge funds and other specialized firms to make money by filling the void left by banks.

- While OTC markets are evolving to look more like exchange traded one, the exchanges themselves are also evolving away from their traditional form.
  - Like stock markets, listed markets for derivatives are coming to be increasingly dominated by algorithmic trade.
  - There is much less reliance on traditional "market makers" because anyone can "supply liquidity" via *electronic limit order books*.
  - A prominent example is the S&P 500 **e-mini** futures contract traded on the CME.
    - Millions of orders from "the public" arrive and are cancelled *every second*.
      - Interestingly, this market continued to function normally throughout the financial crisis.
      - Even in the "flash-crash" in 2010, there was still enough liquidity to execute reasonably large trades.
- What all this means is that there is now a demand for derivatives pricing and risk-control functions to be performed faster than ever.
- In addition, the whole subject of *execution strategy* – i.e. quantifying the price impact of different policies – is now an issue in derivatives valuation.

- High-frequency trading in the U.S. is under regulatory scrutiny and may eventually be curbed, for example by a small transaction or order cancellation tax.

- There is a certain irony that the conditions necessary for HFT to flourish – low trading costs, transparency, and open access – are precisely those that regulators are trying to bring to OTC markets.

- An open question is whether we will soon see algorithmic trading of swaps and other OTC products.

- So, to summarize, most of the action in derivatives markets today is about developing the *infrastructure*.
  - ▶ Today's financial engineering has a lot in common with civil engineering.

- This does not mean that modelling is any less important.

- Indeed, the financial crisis exposed numerous ways in which the modelling capabilities of the last decade were totally inadequate.

- Moreover, building more solid infrastructure will require more reliable models for many products.
  - ▶ Without believable models for OTC products, there is no way for CCPs to reliably manage their risk.

- There is a lot of work to be done!

VI. Summary

- This course is about exposing you to real derivatives markets and how they work.
  - ▶ If a market exists for a particular instrument, it <u>must be</u> that it is doing something economically useful for some one.
  - ▶ We want to understand the financial engineering problem that each product is designed to solve.

- Derivatives modelling can be really beautiful and cool.
- But when we also ask it to be *realistic* life gets hard!
  - ▶ The right response is not to throw the models away!
  - ▶ Instead it is to see what the model cannot see.
    - ∗ Use the model as the starting point.
    - ∗ Understand how its assumptions limit its conclusions.
- Those are our goals for the term.