Derivatives, financial engineering
266: Financial Markets and Institutions

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▶ Financial engineering

- Financial engineering is constructing financial instruments that are designed to have particular risk characteristics

  (e.g., the return has a particular covariance structure with other asset returns in the economy)

▶ Create risk?!?

- Create risk?

  You might think 'creating risk' is bad

- FACT: Folks would like, all else equal, to minimize overall portfolio risk
- BUT: optimal portfolio theory says you minimize overall risk by combining assets with the 'right' mixes of risk

  that is assets with returns that have the right covariances

- Folks will pay to acquire 'risky' returns that, when added to their portfolio lowers overall portfolio risk.

  That payment is the equivalent of an insurance premium

▶ Engineering for fun and profit

- It can be extremely profitable to do the following:
- 1. Discover or invent a financial instrument with a particular asset return risk structure (e.g., particular covariances with other returns) that folks in the economy really need for risk management

but a risk structure that existing liquid instruments make it difficult or costly trade

- 2. Facilitate a liquid market in the new instrument

  E.g., by playing the role of market maker.

▶ **Derivatives**

▶ **Derivatives**

- Q: How do I 'create' an instrument the return of which has desired covariance with the return to other assets?
- A: One simple way is to make the contractual payment of the new security literally dependent on the value/return of some other asset(s).

▶ **Example**

- I bet you \$5 that the S&P will end the year below 2,000.
- If the specified event happens, I pay you \$5; if not, you pay me \$5.

  The cash flow that ultimately passes between us depends on or *is derived from* what happens to the S&P 500.

- We write this down on paper and sign it and voilà we have a derivative contract.

▶ **Derivatives and bets**

- Many derivative contracts look simply like ways of making bets on what happens to underlying assets.
- Today I'll say things like 'Suppose you want to bet that GM will default on a bond...'
- Remember, this may either be 'hedging' or 'gambling' depending on whether I own the bond.
- Suppose I own \$1 million dollars of the GM bond and stand to lose \$500,000 in a likely default

  That is I get 50 cents on the dollar in default

- I might like to make a 'bet' that pays me \$500,000 if GM defaults

  Then I am completely hedged against this default risk

- Whether I am 'gambling' or 'hedging' using derivatives depends on what other assets I own.
- If the derivative payoff has a negative covariance with the return of some asset(s) I'm holding, then there is 'hedging' or 'insurance' value to what I'm doing

▶ **Aside:: Gambling/speculating**

- 'Gambling' in the sense I've described is also called 'speculating'

- And 'speculators' are often blamed for nasty stuff that happens in financial markets.
- There is sometimes something to this criticism, but often this has an element of just looking for a scapegoat when bad stuff happens.

▶ **Derivatives: extremely flexible idea**

- The idea of derivative assets is unimaginably flexible
- You could make the payoff contingent on any set of well-defined conditions on any set of asset values returns
- The key, of course, is creating a derivative asset that lots of folks find useful.

▶ **A few derivatives that are heavily traded**

▶ **Credit Default Swaps**

- Joe writes a derivative contract with Betty in which
  - Joe pays Betty \$3 per year for the next 5 years so long as GM does not default on a particular bond
  - If GM defaults, Joe gives Betty the bond and Betty gives Joe \$1,000

    The swap \$1,000 for the bond.
- This sort of contract called a credit default swap (CDS)
- If Joe owns the bond, he is hedging default risk, if not, he is 'speculating.'

▶ **Structure of CDS**

- The 'underlying' asset is the bond; one party is viewed as a protection buyer and one as a protection seller.
- The trigger 'default' is called a 'credit event' and is a formally defined failure of the bond issuer to meet some contractual obligation.

  There is a group the declares whether or not a credit event has happened.
- Protection is bought/sold based on some 'notional' face value amount

  e.g., I buy protection on \$1,000 of face value
- The gross 'notional' amount of value insured in this market is immense.

  recent report at about \$10 trillion (as high as \$60 trillion at time of crisis) go

  http://www.swapsinfo.org/charts/swaps/notional-outstanding
- In particular, the gross notional amount insured is far in excess of the gross value of the underlying.

- Common feature in derivatives markets: 'size' of the market by many measures is immense relative to the market for the underlying.

▶ Futures and forward contracts

▶ Futures and forwards

- Two versions of the same basic trade that differ in terms of regulatory features and the particulars of the contracts and markets
- The basic trade: one party agrees to sell a given item to another party for a fixed price at a fixed date in the future
- Example: Donald agrees to buy 1 metric ton of hard red winter (HRW) wheat from Invanka on July 15, 2017 for $430

  see HRW wheat futures prices at go

  http://www.cmegroup.com/trading/agricultural/grain-and-oilseed/kc-wheat.html

- Futures/forward contracts have been traded in agricultural commodities forever.
- Flour mills need to buy wheat when it matures; farmers will need to sell wheat.
- Both can reduce uncertainty by agreeing on a trade well in advance of when the wheatr is harvested.
- 'Forward contract' is the name given to the deal if it is an 'over the counter' agreement between two parties.

  Think of it as a private arrangement between two 'counterparties' who can write the particulars of the deal any way they like

- Futures contracts are fully standardized, traded on an exchanges, and subject to various rules //www.cmegroup.com/trading/agricultural/grain-and-oilseed/kc-wheat.html

▶ Further details

- Many futures settle in cash, not with delivery of the underlying (e.g., a ton of Wheat).

▶ Settle in cash

- Ivanka is selling Donald a ton of wheat for $430 on July 15.
- Come July 15, suppose the spot price of wheat is $440.
- Ivanka simply gives Donald $10 (and Donald never pays the $430).

  Now if Donald want the wheat, he can buy it on the spot market with his original $430 plus the $10 from Ivanka.

▶ **In practice**

- In practice, some futures settle with delivery of the underlying, but many settle in cash.

▶ **More differnces: futures and forwards**

- Both futures and forwards are about some future action.
- Thus the counterparties face 'counter-party' risk: the risk that the counterparty will be unable to deliver.
- Forward contracts are private agreements between private parties and both parties have to be aware of this risk.
- Futures are traded on organized exchanges and the exchange steps in as counterparty to both sides of the deal.
- Ivanka sell a ton of wheat to the exchange; the exchange then sells a ton of wheat to Donald.
- To be clear: Both Donald and Ivanka have a contractual relation with the exchange; they have no contractual relation with each other.
- The exchange is what is known as a 'central counterparty'
- From a counterparty standpoint, Donald and Ivanka only need to worry about the exchange going under.
- The exchange then specializes in managing counterparty risk of the traders out there in the world

  (the Donald's and Ivanka's)

▶ **Margining**

- We covered margin calls in equity trading.
- To lower the risk they face, futures exchanges require the parties to post collateral through margining requirements.

  See the text for particulars

▶ **Interest rate swaps.**

▶ **Interest rate swap contract**

- I promise to pay you the interest on a 10-year fixed rate $1 million loan
- You promise to pay me the interest on a 10-year floating rate loan of the same size
- We swap the two payments streams.

▶ **Interest rate swaps: motivation**

- Joe makes a 10-year, fixed rate loan

  But this led to duration mismatch for Joe, and Joe wants to reduce the duration of his assets.

- Sally made a 10-year floating rate loan.

  But has longer-term liabilities and wants to increase duration of her assets

▶ **Alternative 1: Trade loans**

- Joe and Sally could trade loans
- This would reduce both Joe and Sally's interest rate risk.
- But these loans have credit risk as well, and Joe and Sally may understand the credit risk of one deal much better than the other.
- They really only want to trade the interest rate risk.

▶ **Alt. 2: Interest rate swap**

- Pick a 'notional' underlying loan value, e.g., $1,000
- Joe agrees to pay Sally the fixed rate interest payments on a $1,000 loan for 10-years.
- In return, Sally agrees to pay Joe the floating rate interest payments on a $1,000 loan for 10-years.
- Note: the interest rates may not exactly correspond to the rates on the underlying loans
- But they will be similar and have similar interest rate risk characteristics

  So they will have the effect of offsetting the interest rate risk in the loans the two are holding.

▶ **Because interest rate risk is a big deal**

- Because interest rate risk is a big deal, interest rate swap markets are immense.

▶ **Options**

▶ **Options contracts**

- Two varieties: call and put
- The buyer of a 'call option' gets the right (but not the obligation) to purchase the 'underlying' from the option seller at fixed price known as the 'strike price' up until a specified date called expiration.

  (note that I'm leaving out a detail here you'll see below when we come to European vs. American options)

- The buyer of a 'put option' gets the right (but not the obligation) to sell the 'underlying' to the option seller at the 'strike price' up until the expiration date.

▶ **Options: Expiration date**

- Options always come with an expiration date

  At that point, the rights conveyed by the option contract expire

- Two versions: called American and European
- American option: party owning the option can exercise that option at any time before expiration.
- European option: The right only exists at the time of expiration

  Wait until the final date, then decide whether or not to exercise.

▶ **Intuition about options valuation**

▶ **Valuing an option.**

- Suppose I own a European call option for 1 bbl. of oil with a strike price of \$60 per bbl. that expires in 12 months.
- In a year, what will the value of this option be if the spot price is \$55?

  Zero. The 'option' to buy oil for \$60 isn't so attractive if the spot price is \$55.

- And if the spot price is \$75 at expiration?

  The value of my right to buy at \$60 is worth \$15 (that is, 75-60)

- Anybody can buy oil for \$75, but I can buy it for \$60.

  Thus, my option saves me \$15

- Value is zero at expiration if spot price, $P_{oil} \leq \$60$
- Value is $\$P_{oil} - 60$ if $P_{oil} > 60$.

▶ **How about the value before expiration?**

- We will need a statistical model for the price of the underlying at expiration

▶ **Example**

- Our model for the oil price in 12 months is:

outcome	probability	price \$
1	0.30	30
2	0.50	50
3	0.20	95

▶ **Add a column for the payoff in each outcome**

outcome	probability	oil price $	option payoff $
1	0.30	30	0
2	0.50	50	0
3	0.20	95	35

▶ **The payoff**

- In the first two outcomes, we just let the option expire.

▶ **Thus, expected payoff**

- The expected payoff in one month is:

$$0.30 \times 0 + 0.50 \times 0 + 0.2 \times 35 = \$7$$

,

- The price of the option should be the present value of the expected payoff
- Thus, calling the option asset Z:

$$P_{Z,t} = \frac{7}{(1 + i_{Z,t})}$$

where as always, $i_{Z,t}$ is the appropriate annualized discount rate for this particular risky flow

▶ **Black-Scholes formula**

- The famous 'Black-Scholes formula' can be used to compute the value of a European option under the assumptions of a particular statistical model for the price of the underlying.
- Merton and Scholes got the Nobel prize for this; Black had died.

▶ **Hedging with options**

- One primary reason option markets exist is to hedge the risk of price changes

▶ **Example: hedging with options**

- Suppose I am an airline and buy lots of petroleum products
- I think that oil prices will probably stay at their recent low levels (compared with the price of the last few years)
- But I am afraid that there is some chance that the Middle East will slip into turmoil, driving prices very high.

e.g., $150 per bbl.

- I buy a call option for a bunch of oil with a strike price, of say, $100
- If prices fall or rise a bit, the option is worthless

  and I never exercise my option.
- But I have insured myself against the risk that oil prices rise above $100

  The price of the option looks like an insurance premium

▶ **Terminology note:**

- Options that are not profitable to exercise at present are called 'out of the money'

  options that would be profitable to exercise are 'in the money'
- I buy a call option that is deeply out of the money in order to insure against some very large (but low probability) event.

▶ **Call option value**

- If the strike price is higher relative to the current spot price, the option is more or less valuable?

  less valuable; you would pay less for the right to buy at higher price
- If the spot price is more variable, the value of an option at any given strike price is higher or lower

  Higher. The more variable is the spot price, the more likely that it will surpass any given strike price.
- You should be able to do this reasoning and the analogous reasoning for put options.
- Book gives a number of nice examples of hedging with all sorts of derivatives. You should get a feel for this.

▶ **E.g.,**

- You should be able to answer questions of the form: I currently face a risk of a major loss if [specified event] happens. How could I use [specified contract] to hedge this risk?
- In general terms, the answer is always that you buy and or sell a contract the payoff of which covaries negatively with the risk in question.

▶ **Derivatives regulation**

▶ **A regulatory note**

- Gambling is generally illegal or heavily regulated.
- And insurance markets are always heavily regulated.

- Many derivatives deals are arguably one or the other.
- Many types of derivative contracts would be illegal in the U.S. if not explicit exempted both from gambling laws and from regulation as insurance

▶ **Case study: regulation in CDS**

▶ **Insurance regulation**

- Q:How does regulation help insurance markets function effectively?
- A:You as a consumer can be pretty sure your insurance will payoff when it is supposed to

  (i.e., you don't have to check that your insurance company is really prudently planning for possible payoffs)
- Most consumers simply wouldn't have time to monitor their insurance company
- Without some simplifying/confidence enhancing regulation, we would tend closer to the 'neither an insurance buyer nor seller be' world.

▶ **But CDS,. . .**

- But at the outset, CDS was essentially an unregulated insurance market.

  Remember before the crisis, a notional value of $60 trillion was insured.
- What could possibly go wrong?

▶ **Simplified version of CDS in the crisis**

- A buys CDS insurance from B.
- B buys insurance against having to pay A also using CDS
- And so forth.
- If anyone in the protection chain fails, then some or all of the protection buyers are actually not protected.
- Q: if folks understood this, how much faith should they have had in their 'protection'
- A: Very little.

  There is a reason you don't buy your home insurance from an unregulated insurer.
- As it happened, AIG was the main net protection provider in the market.
- And AIG had vastly underestimated the risks of payoff, so it had not set aside money to make payoffs.
- This became clear the day after the Lehman Bros. collapse and AIG was bailed out

- The Lehman-AIG event really kicked off the critical phase of the crisis.

▶ A detail: margins and collateral

- It is not that a bunch of credit events happened and AIG was called on to payoff on the protection.

  ultimately few of the underlying assets suffered credit events.

- But some of the over-the-counter contracts had conditions saying that as the risk of payoff of the insurance rose, the protection provider had to post collateral

  the collateral is essentially a demonstration that the protection provider would in fact be in a position to pay if needed.

- It was the collateral calls that AIG wasn't prepared for and that brought it down.

▶ Dodd-Frank/post crisis regulation

- I've said that one effect of Dodd-Frank was to make banks hold more high-quality capital.

  And that on the whole that's a good thing.

- And that much of the rest of Dodd Frank is a bunch of complicated regulations the merits of which are not at all clear

  reasonable folks disagree on whehter good or bad.

- One part of Dodd-Frank was to require that lots of derivatives be exchange traded with central counterparties, good data, etc.
- I believe that, on net, has been a good thing.
- Nonetheless there are many details about this we can debate
- For example, one of the earliest articles on our list of news concerns this topic.

  Who's sucking up all the world's safest bonds go

  https://www.wsj.com/articles/whos-sucking-up-all-the-worlds-safest-bonds-1487251552

▶ Derivatives regulation in general

- Derivative contracts are generally regulated by the CFTC: commodity futures trading commission.

▶ CFTC self-described mission

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The mission of the CFTC is to protect market participants and the public from fraud, manipulation, abusive practices and systemic risk related to derivatives – both futures and swaps – and to foster transparent, open, competitive and financially sound markets.. . .

- –

  The CFTC's predecessors in the Department of Agriculture date back to the 1920s. . .

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  Over time, the markets regulated by the Commission have grown to include contracts on energy and metals commodities, such as crude oil, heating oil, gasoline, copper, gold and silver, and contracts on financial products, such as interest rates, stock indexes and foreign currency.

- –

  The agency now also has regulatory oversight of the over $400 trillion swaps market, which is about a dozen times the size of the futures market.

- –

  The futures and swaps markets are essential to our economy and the way that businesses and investors manage risk. Farmers, ranchers, producers, commercial companies, municipalities, pension funds and others use these markets to lock in a price or a rate and focus on what they do best – innovating, producing goods and services for the economy, and creating jobs. The CFTC works to ensure these hedgers and other market participants can use these markets with confidence.

- cite

  http://www.cftc.gov/About/MissionResponsibilities/index.htm

▶ Financial Engineering: modern view

- Find some risk exposure that lots of folks would like to buy exposure to or sell exposure to
- Create a standardized contract delivering a payment stream with the properly engineered stream of risky payments
- Reap the benefit of creating a liquid market in this stream
- The idea of being able to freely re-package risk so that it can be sold to those most capable of/willing to bear it makes immense sense.
- Establishing market institutions and regulations so that this all works dependably is a work in progress.