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**ANDREW LO:**

Last time when we met, we saw that the yield curve was somewhere-- the short end was somewhere at the 30 to 40 basis point level. And let's see where it is today. The yield on a three month treasury bill, according to this, is at 71 to 72 basis points. So that's pretty good. That's better than it was last week. There was a point, actually, earlier this morning, that the yield curve was-- the short end was slightly above 1%. But it's now come back down, because of additional trading and demand for these securities.

But that suggests that at least the panic is not as severe as it was last week. Things are getting a bit better. And not surprisingly, the reason they're getting a bit better, is because there's more certainty now that something was going to happen. When we met last, it seemed as if there was a possibility that this wasn't going to happen at all, that there was going to be some breakdown between Democrats and Republicans, and that there was an impasse. Fortunately, that got resolved over the weekend. At least it seems to be. It's going to be voted on as we speak actually. So hopefully, we'll find out by the end of class or end of today whether or not it happens.

If it doesn't happen, what do you think is going to happen to the three month? Yeah, so you could actually look at this as a thermometer. Check the temperature of our economy. It's pretty amazing, isn't it? It tells you that financial markets are very dynamic, and that you actually can learn a lot from market prices. Again, are market prices correct? No, there's no such thing as correct. I want you to get away from that notion of correct. There is a market price that reflects the aggregate sentiment of the economy and the participants on a given day, at a given point in time, with a certain set of market conditions.

And then you have to decide whether or not that set of prices is something that you would like to use in your own calculations. So right now, these are the prices that reflect what's going on in the economy. By the way, at the long end, last time we saw that two weeks ago, the long end of the yield curve was pretty high, because of concerns that there was going to be inflation. And then last week, we saw that it went down. What is it now? Well, if you take a look

at the 30 year, the yield is at 422. That's slightly lower, not by much, but it's slightly lower than what we saw last time. And certainly lower than what it was two weeks ago.

So the concerns about inflation, while they're still there, at least from the data here it looks like they're a little bit less. So are people right today and were wrong last week? Who knows. The point is that this reflects what the current market sentiment is. And so at every point in time, when you look at market prices, what you're getting is a window on current expectations and current information, and you have to make the best of that.

Any other questions? Yup?

**STUDENT:** I just have sort of two questions. One is that, when the three months treasuries are so high, we said it was just a couple basis points, why wouldn't you just short those? Because don't you have a [INAUDIBLE], they can't go above 0. So you have a couple basis points downside, and [INAUDIBLE] basis points upside.

**ANDREW LO:** That's right. You could have shorted them. Andy, do you want to answer?

**ANDY:** I'm not sure I agree that you can short them.

**ANDREW LO:** OK, why not?

**ANDY:** Because going short that means that you want to borrow money at 3 basis points for three months, but you're not the US Government. And no one will allow you to do that.

**ANDREW LO:** Well, it would be hard to borrow the securities and then sell them, right? And unfortunately, you can't manufacture the pieces of paper the way the US Government can. It's kind of hard to do the printing press in just the same way. In fact, I think it may even be illegal.

But you're right that if-- it's such a low level, what you would like to be able to do is you'd like to be able to issue that stuff. And by the way, the US Government did take the opportunity to issue some paper last week to take advantage of this. Because it's a great way to do it, right? You borrow money at virtually zero interest rate because you are the US Government, and all you need to do is print up these wonderful certificates. But I think the issue is exactly right. If you wanted to short it, you've got to be able to borrow it from somebody else and then short, and they have to let you borrow it from them at appropriate premium.

So there's a risk and a price for that. But if you could do it, it was a pretty good trade. On the

other hand, think about what you're saying. What you're saying is that you would like to be able to allow people who want liquidity to have liquidity. You would like to provide them with that kind of a liquidity. If everybody is panicking and wanting liquidity, then that might be a very good strategy because when markets calm down, eventually, you will do quite well. In effect, that's what the US Government is hoping to do with this so-called bailout package, which is what I mentioned last week that bailout is probably not the right term. It's a rescue package undoubtedly. But whether or not it's a bailout or a very savvy investment depends simply on the price-- on the price that you can get it at, and the price that you ultimately sell it for. So that remains to be seen.

Other questions? Yep?

**STUDENT:**

I don't know the details of the [INAUDIBLE], but I'm wondering, this crisis is based on the whole economy is leveraged on some assets that are not really working or are worth less than they were supposed to. And I wonder, at the end, would the people that have credit, but bad credit, suffer? Will they save their homes or not? I don't see-- because the only way I see for this to be corrected is to go to [INAUDIBLE]. There's a lot of people leveraged that cannot pay so how will this get to-- Am I explaining myself?

**ANDREW LO:**

I think so. I think so. I think you're expressing the same kind of concern and confusion that the American public has expressed at the bailout package. Because it doesn't seem like the bailout is really applying to the ultimate root cause of this, which is the home owners. The politicians would say that you're bailing out Wall Street when you should really be bailing out Main Street. Let me hold off on answering that, because it turns out that this Thursday, October 2nd, from 5:30 to 7:00, the Sloan School will be organizing a panel discussion of the bailout, as well as the root causes of some of these issues.

So rather than take up any more class time, let me defer that question to that Thursday panel, and then I'd be happy to talk about it afterwards. But I'd rather make sure that we stay on track with our curriculum and just use this as an illustration. But let me give you the short answer to the question. The short answer is that the idea is that you have to deal with the current crisis right now. So it's sort of like having a patient come into the emergency room and they're bleeding out, and it turns out that the reason they're bleeding out is they've abused drugs and they've done all sorts of bad things to their diet and health. Now, at that time, you probably don't want to give a lecture on good nutrition and the dangers of recreational pharmaceuticals.

You've got to stop the bleeding. And then, over the course of the next few weeks and months, you try to rehabilitate the patient. So what the package is meant to do, first of all, is to stop the bleeding. And then, over time, we're going to have to address exactly the issues that you raised. And that's part of what the proposal was trying to do. That's why it took them time to put it together. It's easy to figure out how to stop the bleeding. Money will stop the bleeding. But the problem is that throwing money, good money, at bad assets is not necessarily the long run solution. You have to figure out what the ultimate causes are dealing with foreclosures, dealing with all of these very complex securities, figuring out how to value them, coming up with proper insurance agreements to be able to create stability across the entire market. And that's what the various aspects of the bailout package are designed to do.

So we'll talk about it on Thursday, and I would encourage all of you who are interested to come to that session. We've got a number of economists and accounting faculty and other folks who are going to be there to present. You'll get a notice about that probably later this afternoon.

**STUDENT:** One more thing. On the Wachovia deal, what's going to happen with the bank? Is it going to continue the same?

**ANDREW LO:** Well, obviously that's a work in progress. It looks like most of the units of Wachovia will be sold off to Citigroup, but there are a few units of Wachovia, including AG Edwards, which is a broker dealer, and Evergreen, which is another broker dealer, that will remain separate and will be freestanding. So that will not be acquired by Citigroup. But apart from that, all the other units of Wachovia will be taken on by Citigroup, and that there will be a backstop provided by the FDIC in case the losses exceed more than \$40 billion.

So Citigroup will be able to take that onto its balance sheets. And in exchange for taking on all of these bad debts and other problems, Citigroup gets the retail access to all of the various different channels that Wachovia has set up. So now, Citigroup has the ability to compete head-to-head with Merrill Lynch having been acquired by Bank of America. Whereas before, they wouldn't have been able to do that. So you see, this is what I was saying last time, that with every kind of crisis, with every kind of dislocation, there are opportunities that are created. And so when you have one door closing, three other doors open for opportunities that can be taken advantage of. And by the way, let me mention, this is also true for your careers.

You might be discouraged about financial services. I would argue just the opposite. Right now,

all of you are at an excellent position as first year students, because first of all, you're here in school waiting out the passage of the storm. And when the storm passes, believe me, there are going to be tons of opportunities. In fact, typically the largest growth period for jobs is not at business cycle peaks, but its exactly after these kinds of troughs that occur. So within the next 6 to 12 months, there's going to be tons of career opportunities.

In fact, for those of you who are interested in going to the New York Banking Day, and you really should if you're interested in a career in finance. My guess is if you visit Goldman Sachs, Morgan Stanley, as difficult as a set of circumstances they're in right now, my guess is every single one of these firms will be hiring. And the reason they're going to be hiring is because they want to take advantage of the opportunity to cut costs and to hire younger, more energetic employees to be able to really beef up their future generations of human capital.

So they're going to be making an investment in that. So I think that's a good example of how it's true that you're going to have consolidation. So now, after this, there's going to be three major money center banks, JP Morgan Chase, Bank of America, and Citigroup, which is astonishing because just a few months ago there were quite a few others. So the landscape has changed. But the competitive landscape changing means that opportunities get created along the way.

**STUDENT:**

I was just wondering from your point of view. Why is it better to have the banking industry consolidated into three buckets? In that, wouldn't it have been better to let Wachovia fail and let the regional [INAUDIBLE] pick up the slack instead of now having literally JP, B of A, and CitiGroup dominate the entire landscape and be in a position to monopolize [INAUDIBLE] going forward.

**ANDREW LO:**

Well, so that's an interesting thought, letting Wachovia fail. Obviously, you're not a Wachovia customer. I think that what's happening right now is that there's a great deal of sensitivity, not only on the part of Wall Street, but regulators, to stem the tide of mass financial panic. We talked a bit about that last time. The reason that regulators and the government sprang into action was not because Lehman went under, or AIG went under, or any of these other large organizations.

The reason that finally got them over the edge of moving to do something substantial is because the reserve fund, a retail money market fund, broke the buck. And if that happens on a regular basis beyond the reserve fund, you will have a very, very significant financial market

dislocation. It turns out that Wachovia is part of that retail network. And if you let Wachovia fail, you risk igniting further problems in that retail sector.

Citigroup is perfectly happy to take them over and are able to given their balance sheet-- are able to manage that without any problem. So that seemed like an ideal solution from everybody's perspective. Because if you allow Wachovia to fail, remember, the FDIC is on the hook to pay all the depositors their FDIC deposit insurance up to \$100,000 per name, per account. That could be a very substantial number by letting the bank fail and by having all of its value completely lost. This way, they actually preserve a fair amount of value, because as an ongoing concern, Wachovia has quite a lot of good business.

So it actually is the cost minimizing solution, but at the same time it also preserves the current fragile integrity of financial markets at least until the bailout fund is set. My guess is that in about three or four weeks, if we have banks that end up not being able to make their commitments, they are going to be allowed to fail. Because at that point, those failures won't jeopardize the entire financial system, they'll be dealt with by this bailout organization.

So I think that that's the logic. Yeah, last question, let's move on.

**STUDENT:** Is that the same thought process as freezing Washington Mutual's failure [INAUDIBLE].

**ANDREW LO:** Well, that's right. But the difference there is that Washington Mutual has much bigger exposure to these subprime loans, and so I think in that case, there really wasn't much of a choice. And very much so transferring the business units that are able to be moved over JP Morgan Chase would make a fair bit of sense.

So there's a lot of consolidation going on in this industry, but once again, consolidation, while it seems like it's a big upheaval, and it is for the people that are at these organizations, it's very disruptive, the fact is that these kind of disruptions are part and parcel of how businesses grow and develop and morph over time. In fact, if you went back to the 1960s, and you looked at a Wall Street Journal on microfiche-- I happened to do that just because I was looking for a particular citation at one point-- if you look at the advertisements in the 1960s or even 15 years ago, you look at the advertisements in the Wall Street Journal in those days, there are names of financial institutions that you've never heard of, that were really big institutions back then.

So it's rare that we have institutions that survive for 50, 75, 100 years. It's part and parcel of

how businesses develop. And the key is to focus on the process by which businesses change. So when we start talking about equity evaluation, we're going to see that by looking at income statements and balance sheets together, we can see not only what's a good business and what a bad business, we can also see how businesses evolve over time.

And it's that evolution that we hope to try to bring across to you in this course. I want to show you how it is that you can understand the dynamics of changes in business conditions, because that really is, I think, the key to a lot of what you can use in your own careers. I know there are more questions. But let me hold off on those and start on the lecture today and then we can cover those a little bit later on after we've made some progress.

So this is a continuation of last lecture where we were talking about convexity and duration as two measures of the riskiness of a bond portfolio. And I concluded last lecture by talking about the fact that if you think about a bond as a function of the underlying yield, then you can use an approximation result that says that the bond price, as a function of yield, is approximately going to be given by a linear function of its duration and a quadratic function of its convexity. So we have an approximation that says that the price of the bond at a yield  $y$  prime, is going to be equal to the price of the bond at a yield  $y$  multiplied by this linear quadratic expression.

And really, the purpose of this is just to give you a way of thinking about how changes in the fluctuations of a bond portfolio, as well as the curvature of that bond portfolio, will affect its value and therefore its riskiness. These are just two measures that will allow you to capture the risk of a bond portfolio. So I have a numerical example here that you can take a look at and work out, and you can see how good that approximation is. This is an approximate result that the price at a yield of 8% is going to be given as a function of the price of the bond and a yield of 6% multiplied by this linear quadratic expression.

And the actual result of the bond price, now that we have high speed digital computers that can calculate all of this at a moment's notice, you can see the difference. It differs basically by about a penny. A penny it's not a big deal. But when you're dealing with billions of dollars actually, a penny is a pretty significant amount. So what you want to do is to make sure that you use the right formula to calculate it. I wouldn't argue that you should use convexity and duration to do any kind of bond pricing analysis, but for a quick and dirty method for getting intuition about how risky a bond portfolio is, the two questions you ought to ask somebody is, what's the duration and what's the convexity.

And what those two numbers, you can develop a kind of intuition for how the bond price is going to move in response to underlying changes in the yield curve. And right now, we see that the yields are changing pretty rapidly. The Treasury yield curve, at least at the short end, is bouncing around depending on what happens every day in Washington. And so if you have that sense of short term yields changing, by looking at convexity and duration you can get a sense of how sensitive your portfolio might be to those kinds of exposures.

The last topic I'm going to take on is now corporate bonds. Up until this point, the only thing that we focused on has been default free securities, namely government securities, because governments can always print money and therefore they can always make good on the claim that they will pay you a face value of \$1,000 in 27 years. There's no risk that they can't run those printing presses. What I want to turn to now is risky debt, and in particular I want to point out that risky debt is fundamentally different in the sense that there is a chance that you don't get paid back. So one of the most significant concerns of pricing corporate bonds is default risk. And the market has created its own mechanism for trying to get a sense of what the default risk really is.

Namely, credit ratings. These are ratings put out by a variety of services. The services that are most popular are Moody's, S&P, and Fitch. And these services do analyzes on various companies, and then they issue reports, and ultimately ratings, on those companies. They'll say this company is rated AAA, AAA being the highest category. And I've listed the different ratings categories for the three different agencies here so you can get a sense of how they compare. Typically, these ratings are grouped into two categories, investment grade and non-investment grade.

And really, the difference is just the nature of the default risk or the speculativeness of the default probability. Bonds that are below investment grade have a higher default rate, and bonds that are supposedly investment grade are ones that are appropriate for prudent and conservative investments.

**STUDENT:** Do you mind maximizing the slide? It's a little hard to read back here.

**ANDREW LO:** Oh, sorry about that. Thank you. Yeah, that's better. So investment grade for Moody's is AAA, high quality is AA, upper medium quality is A, and then medium grade is BAA, and then anything below BAA is considered non-investment grade. Now, the one thing you have to keep in mind about fixed income securities is that apart from some of the more esoteric strategies



that we talked about last time like fixed income arbitrage, this idea of taking a bunch of bonds and figuring out which ones are mispriced and trading them, apart from those strategies, most people invest in bonds not because they want exciting returns.

If you want exciting returns, you put your money in the stock market or real state or private equity or other kinds of exciting ventures. Bonds are supposed to be boring. You put your money in, and five years later you get your money out with a little extra. That's what bonds are supposed to do. And it wasn't until the 1970s, when the era of junk bonds came on the scene, 70s and 80s, with Michael Milken and Drexel, Burnham, Lambert, that you really had a very different face of fixed income markets.

By and large, fixed income markets dwarf equity markets. But the reason that they're so large is because most people use them as a kind of a safe haven. And as you get riskier and riskier, it starts to look less like bonds and more like equity. In fact, if you think about the bankruptcy process, if you've got a risky corporate bond, you're the bond holder, and the company declares bankruptcy, they can't pay your interest payments that are due to you, when they declare bankruptcy, then at least from a theoretical perspective, you the bondholder now become equity holders.

You own the assets. Because they can't pay you, so they're obligated to give you control of their company. So as bonds become more risky, they start to look more and more not like debt, but like equity. That is, the returns are random and you don't know what you're going to get. It's sort of a surprise every day. It's the gift that keeps on giving. But for the most part, investors that are invested in bonds aren't looking for that. We're looking for safe returns.

And they're looking for the highest yield that is a safe return. So investment grade is the category that typically pension funds, endowments, and other relatively conservative institutions look to. Within that category, they would like to get as much yield as possible. So which of these different grades do you think offers the highest yield? Why is that? Yes, you're right. Why is that? What's the logic for that?

**STUDENT:**

[INAUDIBLE]

Exactly. Given that it's lower rated, that means it's got a higher probability of default, you've got to pay investors a little bit of extra for them to bear that risk. Simple as that. So the reason that there are multiple categories, even in investment grade, is that there are different levels of risk aversion that investors want to take on. Some investors are highly risk averse, and for the

very, very risk averse investors, they're going to take on AAA. And for those that are a little bit more adventurous, they'll take on lower grade. And for those hedge funds, who are looking for lots of risk and lots of return, they're the ones that are dealing in the non-investment grade issues.

Those are the ones where you have relatively large returns, 15% or 20% returns, you didn't think you can get a return of 15% to 20% for bonds, but you can if there is a 5% or 10% chance that you won't get anything. So when you do get paid, you get paid well, but you don't always get paid. So that's the categories that are developed by the various different ratings institutions. And once you get a rating, that allows you to approach investors and say, OK, this is what I'm looking to get for my corporate bond, and what I'm hoping to get is commensurate with the risks that we're bearing.

Here's a little history of the yields on Moody's BAA bonds minus the US 10 year treasury yield. So this spread tells you what the difference is between a very safe asset and a BAA asset, which in this category, is just above non-investment grade. So it's the lowest grade that you can get and still be passing. This is sort of like the 65 or something of junior high school and high school. So that spread between BAA and US treasuries is an indication of the risk premium implicit in the default potential of a BAA bond.

And look at how it's changed. In the 1930s, this spread was about 7 and 1/2 percentage points. That's a big spread by today's standards. Now of course, by today's standards, literally today, things are different, and we may be getting up there soon. But let's take a look at where we were at least where the data ended, which is back in 2005. At the end of this dataset, the credit spread was maybe 1 and 1/2 to 2%. That's at a near historic low. Now, you can see that there are a little bit of a blip every once in a while. December, 1987, this is after the stock market crash of October 87. You see a big blip going up. And September of 1998 after LTCM, that goes up. And then of course credit spreads widen over here.

September 11 happened, 2001, over here. And so credit spreads got as high as something like 3- 3 1/2% percent, and now, prior to what's happened over the last several weeks, credit spreads were at a close to all time low. What does it mean when credit spreads are really low? What does that tell you? What does it say? Yeah.

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** Right. That's one interpretation, that the market is perceiving the default risk as not as significant as it used to be. Another way of interpreting that is that the investment population is less concerned about the default risk than back in the 1930s. Not surprisingly. Something did happen in the 1930s that was kind of significant. What was that? The crash of 29, and then the depression that led from that crash.

So that tells you that at least at the end of 2005, beginning in 2006, people were less risk averse, at least on paper what this shows. What else does it tell you about the probability of credit?

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** Exactly. Lots of money. Another way of interpreting this is that there's lots of money out there. Lots of money willing to be lent out to all sorts of risky ventures without much in the way of expectation that they should get paid a much larger premium. So those two interpretations are likely to be both true. That is, the population of investors did seem less risk averse, and there is empirical evidence to support that. But on top of that, it also suggests that there's tons of money out there being lent to various different projects, and because there's so much money, there's such an increase in supply of funds, the extra premium that is commanded by those funds could not be that great, simply because of the competition to supply funds to these various risky ventures.

So if you wanted to do a startup, the time to have done it was in 2006, because you would have gotten great deals since there was so much capital out there. Now that's changed. But part of the reason it's changed, part of the reason that we're in the current financial difficulties that we're in, is because there was too much money chasing too few genuinely good opportunities. And so we're seeing now the after effects of some of those poorer investments in those opportunities.

So this kind of credit spread picture can give you a sense of the dynamics of money flows within the economy, and definitely worth keeping track of. Now, there are a number of things that are in that spread, in that premium. Obviously, there's an expected default loss, but there's also tax effects. There's also some other kind of systematic risk premium that has to do with aggregate risk exposure. And a variety of other academic studies have been done to decompose that spread into different components. Graphically, you can see that if you look at - if you take a look at the composition of that premium, you can show that part of it is due to

default, part of it is due to the riskiness of the particular investment, and then the other part is simply the default free. That's the part that we've studied up until today.

So the other two parts, the other extra risk premium, is really decomposed into a default risk premium, but also a market risk premium. That is, just general riskiness and price fluctuation. People don't like that kind of risk, and they're going to have to be compensated for that risk irrespective of default. Just the fact that prices move around will require you to reward investors for holding these kind of instruments. And in the slides, I give you some citations for studies on how you might go about decomposing those kind of risk premiums. So you can take a look at that on your own.

But the last topic that I want to turn to, in just a few minutes today, before we move on to the pricing of equity securities. The last topic I want to turn to is directly related to the problem of subprime mortgages. I promised you that I would touch upon this. I'm not going to go through it in detail, because this is the kind of material that we will go through in other sessions on the current financial crisis. But I want to at least tell you about one aspect of bond markets that's been really important over the last 10 years. And that is, securitization.

Now, when you want to issue a risky bond, as a corporation or even as an individual, you have to deal with a counterparty, a bank typically. Banks were the traditional means of borrowing and lending for most of the 20th century, and up until the last 10 years. But about 10 years ago, an innovation was really created. Actually, it wasn't created 10 years ago but it really took off 10 years ago, where instead of borrowing from financial institutions like banks, you were able to tap into the borrowing power of financial markets. This is what's often called disintermediation.

Banks are considered intermediaries. They serve as a conduit between us, the retail investor, and financial markets or other counter-parties. They stand in the middle. They take money from us, put it in deposits, they take those deposits, lend it out to corporations, and they take money from corporations, and bring it into their bank, and lend it to us in the form of mortgage payments-- mortgages, so that we can buy our house.

About 10 years ago, intermediation started to unwind because of innovations in securitization. The idea being that we are going to instead of dealing directly with banks, tap into the power of financial markets in borrowing and lending. And so I want to give you an example of how that works. Something that I went over in the Pro Seminar. But for those of you who didn't

attend, I want to show it to you because it's such an important idea. And this is an idea that is best done through a very simple numerical example.

So in about 10 or 15 minutes, I'm going to illustrate to all of you the nature of problems in the subprime mortgage market. That's all it'll take. To get to the bottom of it could take years. But at least to understand what's going on, I'm going to do this very simple example. Suppose that I have a bond, which is a risky bond. It's an IOU that pays \$1,000 if it pays off at all. So the face value of this bond is \$1,000. But this is a risky bond in the sense that it pays off \$1,000 with a certain probability, and it pays off nothing with another probability, let's say 90 10.

So the simple expected value of this is \$900. And so you might think that that should be a proxy for the market price. And in fact, that would be a pretty good approximation. Now, right there is an interesting insight into the pricing of risky bonds. Because if we have a security that has \$1,000 face value, but it's got a probability of default, and you compute the current value as \$900, then that gives you an implicit yield for the bond.

What yield is it? It's whatever number, one point something multiply by 900 gives you \$1,000. So the very fact that it defaults, now allows us to compute a yield without reference to the time value of money. The time value of money can add an additional piece into this calculation. I decide to ignore it just for simplicity. But suppose the interest rate was 5%, the risk free interest rate was 5%, then what I might do is to say, OK, \$900 is what I expect to get out of the bond. I'm going to take that \$900 and discount it back a year by 1.05, and that will give me a number such that when I compute the yield on that number relative to \$1,000, it will have the total yield of this bond. 5% of which is the risk free part, and the other part is the default part.

But I want to keep the example simple. So let's just assume that the risk free rate of interest is zero 0. So I've got my bond that pays off \$1,000 next period with probability 90%. So the expected value is 0.9 times 1,000 plus 0.10 times nothing. \$900 for this bond. Now let's suppose that I have not just one of these bonds, but I have two of them. And they're absolutely identical in every respect. They're just two of the same bonds. For each of the bonds, you might think that it's not that easy to find a buyer. And you're right, because a 10% default rate is pretty risky.

In a minute, I'll show you how risky when we look at the default rates, historical default rates, of bonds with various different credit ratings. But right now, with a 10% rating, this bond would be rated below BAA. It would be below investment grade. So you're not going to get a lot of

people that want to buy one. In fact, we can auction it off in this class right now to figure out what the price is. My guess is that I may not even get \$900 for that in this class, given your current mood and liquidity issues. But I'm going to show you some magic that will make this incredibly interesting to a large number of investors, including all of you.

I'm going to take these two bonds and put them together in a portfolio. Now, what exactly does that mean? So far I've said nothing. I've drawn a circle around the bonds. By portfolio, I mean that I'm going to create an entity, a corporation, whose sole purpose it is to buy these two bonds. And therefore, the fortunes of the corporation are tied not to the performance of any one or two bonds, but to the performance of the collective portfolio of bonds. So that's what I mean when I say, form a portfolio. I mean, consider a single entity that will hold both of these bonds.

And let's assume, for the sake of argument, that the default of these two bonds is uncorrelated. In fact, I'm going to assume that these are two separate coin flips, and they're different coins, they have the same probability of coming up heads 90%, 10% tails, but they're different coins. They have nothing to do with each other. So they're independent. Whether or not one bond fails has nothing to do with the other bond. When I put this into a portfolio, how does the portfolio behave looking at it as a single entity?

There are three possible outcomes. Actually, there are four, but only three of them are really distinct. Both bonds will pay off, or both bonds will default, or one bond pays off and the other defaults. Those are the only three outcomes that are possible. And the payoffs and probabilities, assuming that they are separate and independent coin tosses, is given in that table. \$2000 if they both pay off. And the probability of that is 81%,  $0.9 \times 0.9$ . And I'm multiplying, because I'm assuming they're independent.

The probability that they both don't pay off, in which case my portfolio is worth nothing, is 1%,  $10\% \times 10\%$ . And then whatever's left over is in the middle. That is, there's a chance that one of them pays off but the other one doesn't, and then the portfolio is worth \$1,000, and there's an 18% chance of that. So here's the stroke of genius. The stroke of genius is to say, I've got these two securities that are not particularly popular on their own. What I'm going to do is to stick them in a portfolio, and then I'm going to issue two new pieces of paper, each with \$1,000 face value. So they're just like the old pieces of paper, but there's one difference. They have different priority. Meaning there is a senior piece of paper and there is a junior piece of paper. The senior piece of paper gets paid first, and the junior paper only gets paid if and

when the senior paper gets paid.

So I'm going to issue two pieces of paper. The blue is the senior and the red is the junior. The senior paper I'm going to call the senior tranche. Tranche, I believe is the French word for trench, which seems much more appropriate today than it did before. We're digging our own trenches here. The senior paper is going to have first dibs on that portfolio. And the junior paper will only get paid after the senior paper gets paid. And so let's see what happens with that.

Remember, they're both \$1,000 face values. So on paper, I've done nothing in terms of creating or destroying the total claims on the asset pool. The portfolio has claims at \$2000 of face value, and my new securities has claims on \$2000 at face value. But all I've done is to change the order, the priority, of the payout. Here's the table. I have three values for my portfolio, \$2000, \$1,000, and nothing. Now let's see what happens to each of those two claims, the senior claim and the junior claim, of my new securities that I've issued

The senior claim gets paid \$1,000 if both bonds in my portfolio pay off. But the senior claim also gets paid \$1,000 if only one of those bonds pays off. So two out of the three outcomes are good news for the senior debt. And in the third case, where both of them don't pay off, then the senior paper is out of luck. Now, the junior paper is exactly the reverse. The junior paper only will get paid if both bonds pay off, because in that case, the senior guy gets paid and then there's money left for the junior guy. In the latter two cases, if only one bond fails or both bonds fail, then the junior claim gets paid nothing.

So what I've done is to take two identical bonds, and I've created two non-identical claims, such that one is a lot safer than the other. How much safer? Well, the bond that is senior has a 1% chance of default, 1%, because both bonds have to fail before the senior guy doesn't get paid. 1%, what was it before? It was 10% for both bonds. But because I stuck it in a portfolio, and I changed the priority of payouts, the senior claim now looks a lot safer. But that's not a free lunch, because the junior claim is a heck of a lot riskier. The junior claim now loses money 19% of the time.

It used to be the case that one of these bonds had a 10% default rate, but the junior claim has a 19% default rate, 18% plus 1% from those two outcomes. As long as investors know the structure, nobody's getting a good deal or a bad deal. There's no cheating going on. We explain this to investors, so you all see these probabilities. And now, let's calculate what the

expected values are for the payouts.

The expected values-- before I do that, let me comment on default rates. So a 1% default rate seems like a small number. And a 19% default rate seems like a large number. Well, let's take a look at the empirical evidence given debt ratings. These are historical default rates for bonds from 1920 to 1999. So I've got almost an 80 year record of bonds that have been issued by corporations and that have been stamped by Moody's with their ratings. And the different bars correspond to how long the bonds have been issued and are outstanding. Because obviously, the longer the bond is out there, the more likely it is that it will default.

So you have to separate them by the years out in the market. If you take a look at a five year period, that's the bars all the way to the extreme left of each rating category, you see that for a five year periods, the default rate of AAA securities is well, well below 1%. It's measured in basis points, that probability. If you wait 20 years for AAA bonds, the default rate goes up to maybe 2% or 3%. So that means that when AAA bonds are issued and you wait for 20 years to see what happens to them, it's a very, very small group that ends up defaulting, if they have a AAA rating.

On average, AAA bonds default maybe 1% of the time or less. On the other hand, if you take a look at below investment grade-- so BAA is just at the borderline of investment grade. And if you take a look at the default rates here, lots higher. But by lots higher, we're talking about 5% to 10%, 5% to 10%. So based upon these categorizations, we can now rate our own bonds, what I just decided to issue with these securities, right?

The senior tranche is rated AAA, and what would you rate the junior tranche? BA maybe. BAA at the best, but probably more like BA. So the senior tranche looks pretty good, and the junior tranche looks pretty bad, but you know what their ratings are, and therefore, go ahead and price them accordingly. So let's do that. If you price them accordingly, what happens is that the senior tranche gets priced at \$990, and the junior tranche gets priced at 810, 990 and 810.

Now, this is very different from what the price was before. The price for both bonds was 900, right? The expected value of the payout. And the expected value of each bond is 900. When you add them up, you get 1,800. Here, when you add up these two bonds, you also get 1,800. So I have neither created nor destroyed value. All I've done is to reallocate that value. I've given the senior bondholders lower default risk and therefore higher likelihood of getting their money back, therefore a lower yield is necessary in order to sell that bond.



On the other hand, that extra benefit that we've given to the senior claimants comes from the junior claimants, and therefore, they get a lower price, or they have to be given a higher yield, to entice them to bear that kind of risk. Now, why is this such a stroke of genius? It's because what we've done is take two identical securities that nobody was particularly excited about, and we've created, by this securitization process, we've created two other securities that actually a number of communities are very excited about. For example, the pension funds, endowments, foundations, all of the very conservative investors that want a very boring bond portfolio. No excitement, no headline risk. They just want their money back with a reasonable rate of return. They've got it with the senior tranche.

And by the way, if they're even nervous about this very, very safe structure, let's insure it. Let's get a large, stable insurance company, oh I don't know, maybe AIG, and let's get them to insure that these won't default. Because if they do, AIG will pay an extra premium on top of that. So then they're called super senior securities, super senior tranche securities, because they've got guarantees on top of the securitization features.

Pension funds love this. They bought this in large, large quantities. Now, what about the so-called toxic waste that the junior tranche? Well, we know it's toxic waste. We've priced it as if it were toxic waste. And so those investors that are looking for 15% or 20% returns, that are not looking for boring, safe assets, they will go for the junior tranche. Namely, the hedge funds. And as many of you know, hedge funds have grown by leaps and bounds. Over just the last 10 years, they've increased their assets under management by a factor of 10 to 20.

And that money is looking for a home. And boring, safe investments that earn 6%, 7%, 8%, that's not for hedge funds. They are looking for 15, 20, 30 40%, and they get that with that junior tranche. That's why the market, over the last 10 years, has exploded. It's twofold. It's because money has come in from pension funds for the senior debt. Money has come in from the hedge funds for that junior debt. And together, they brought much, much more money into this business than ever before. And the question is, how do you take that money and push it out to people.

Well, it turns out that because housing markets are going up, that was a perfect way to get these this money out to investors. Yes?

**STUDENT:**

This model is based on the probability of the Moody's. I have a question. Is there any way investors can estimate this probability by themselves instead of relying on Standard and Poor's

or Moody's?

**ANDREW LO:** It's very difficult for investors to estimate the probabilities themselves, because they don't have access to the same data that Moody's and S&P and Fitch do. Typically when you estimate the probabilities, you need data in terms of the underlying portfolio and the riskiness. As a typical investor, certainly as a pension fund investor, you would not be given access. And even if you were given access, you don't have the staff that can actually analyze this.

**STUDENT:** So if Moody's or Standard and Poor's made a mistake, then every pension fund or other investors will made the same mistake.

**ANDREW LO:** The mistakes can carry over. That's right. There is no way for pension funds, endowments and foundations, or retail investors, to do their own kind of due diligence. They're relying on those managers of the pension funds to do that. And by the way, it wasn't just pension funds that did this. There was some mutual funds that did this too. And not only mutual funds, but there were also some money market funds that did this.

Now, money market funds you say, why would money market funds get invested in this? Well remember, money market funds are supposed to be putting money into short term, fixed income instruments. Well, these could be short term, and these are fixed income instruments. And if you add some insurance on top of that, they're even safer, on paper anyway, than many of the other traditional instruments. So you can see now how a wonderful idea, and this really is wonderful because it dramatically increased the risk bearing capacity of the economy.

And by the way, it made a lot of people better off. So right now, we're in the midst of a financial crisis and we're focusing on the negatives. But let's not be too quick to forget that these kinds of securitization processes brought in huge amounts of money that ultimately went to homeowners to be able to buy homes that they otherwise couldn't have afforded, and maybe you would argue they shouldn't have afforded, but there are still many, many homeowners out there that have subprime loans that are paying their mortgage payments, that are perfectly happy living in their atoms, and otherwise couldn't have afforded it without it.

And Moreover, there are a whole host of individuals that made tons of money because of the real state boom and because they were able to leverage using these kinds of funds.

**STUDENT:** In this example, the ones who [INAUDIBLE] are us. Is that like Lehman Brothers? Are those the companies--

**ANDREW LO:** That's right. So an example would be some of the investment banks, as well as some of the commercial banks. Now, in a minute, I'm going to tell you what went wrong with all of this. So far, the story is great. This is really an innovation in financial engineering, because by securitization, by repackaging, we've done nothing dishonest. We've told people exactly what we're doing. We've given them transparency. And we've given the safer asset to the community that wants safer assets. And we've given the very exciting assets to those who want the exciting assets.

Now, where does this go wrong? Question before we do that.

**STUDENT:** The assumption that you made in this is that they are not correlated? Isn't there more likeliness of correlation between the two?

**ANDREW LO:** So that there's always somebody that's ready to spoil the party for the rest of us. You're absolutely right. That's where the story gets interesting. I've assumed that these two bonds are uncorrelated. What if that assumption is wrong? In fact, what happens if not only are they uncorrelated, but what happens if the bonds are perfectly correlated? Let's work that out. That's a numerical example that's not hard to do.

If the bonds are perfectly correlated, that means they default at the same time and they pay off at the same time, then instead of three outcomes, we only have two outcomes. Either we get paid \$2,000 in the portfolio, or we get paid nothing in the portfolio. Now, what happens to the senior and junior tranches? Well, now, the senior tranche, the tranche that was AAA, the tranche that had less than 1% probability of default, the tranche that was supposed to be so safe that all sorts of very conservative institutions could take it on, that tranche has now increased in riskiness by a factor of 10.

The probability of default has gone from 1% to 10%. And the junior tranche, the tranche that was supposed to be toxic waste, and that had a 90% default rate, now it looks incredibly good, because it's gone up in terms of its quality. It's gone down in terms of its default probability from 19% to 10%. So if you look at the pricing, now the pricing of these two things, of course, is \$900. If they're perfectly correlated, then securitization does nothing. All you've done is to take two pieces of paper and slice them up into two identical pieces of paper. That's what happens if they're perfectly correlated.

So now, why would they become perfectly correlated? Well, this has to do with what happened

in the housing market. When the housing market turned down, as it did shortly after June of 2006, that created a huge dislocation in these credit markets, because what was uncorrelated all of a sudden became highly correlated. It's as if an insurance company that was insuring property and casualty across the country, all of a sudden experienced earthquakes in every one of the 50 states all at once. An insurance company cannot withstand that kind of an event, unless of course it's prepared for it.

And earthquake insurers prepare for it by insuring not just earthquakes but hurricanes, fires, and other natural disasters, which rarely come all at the same time and all in the same place. We weren't prepared for this. The people that sold these securities, that held them, weren't prepared. In fact, I skipped over a quote at the very beginning of this section. This is a quote that appeared in *The Economist* magazine, anonymously, and it was the Chief Risk Officer of a major financial institution. And the risk manager wrote in the first part of the article, "Like most banks, we owned a portfolio of different tranches of collateralized debt obligations" that's what the securitized set of obligations are called, "which are packages of asset-backed securities. Our business and risk strategy was to buy pools of assets, mainly bonds, warehouse them on our own balance sheet" meaning put them in a portfolio in our company, "and structure them into CDOs and finally distribute them to end investors." Issue the pieces of paper to the different investors.

"We were most eager to sell the non-investment grade tranches," the toxic waste, "and our risk approvals were conditional on reducing these to zero." So they were very, very careful to get rid of all that toxic waste. "We will allow positions however of the top rated AAA and super-M senior (even better than AAA) tranches to be held on our own balance-sheets as the default was deemed to be well protected by all the lower tranches, which would have to absorb any prior losses."

"in May of 2005 we held AAA tranches, expecting them to rise in value, and sold non-investment grade tranches, expecting them to go down." They were long the seniors, short the juniors. That's a strategy. "From a risk-management point of view, this was perfect: have a long position in the low risk asset, and have a short one in the higher-risk asset. But the reverse happened of what we had expected: AAA tranches went down in price and non-investment grade tranches went up, resulting in losses as we mark the positions to market."

And then the risk manager, this Chief Risk Officer of a major financial institution, said the following. "This was entirely counter-intuitive. Explanations of why this had happened were

confusing and focused on complicated cross-correlations between tranches. In essence it turned out that there had been a short squeeze in non-investment grade tranches, driving up prices and generally selling of all the more senior [INAUDIBLE] even the very best ones." He still doesn't get it. The numerical example that I just showed you explains what happened.

What happened is the correlations, that were assumed to be zero, turned out not to be zero. And when things change, when the correlations change, that changes the risk. And when you change the risk, it changes the valuation because the markets are not stupid. People realize, wow, I assumed they were uncorrelated, but now these things are very correlated. I better recalculate my model and see what it tells me. And it tells me that AAA is not AAA any longer. And it tells me that the BA is actually now BAA.

So what he experienced is what every major financial institution dealing with this stuff experienced over the last couple of years. It's that kind of a double whammy, because of the default rates changing in a way that was never expected given the historical behavior of the US housing market. Yeah, Beta.

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** It was typically through the banks. So the banks actually arrange with the insurance companies to insure those assets. And then they would sell it to the end investor. The end investor wasn't the one engaging in these. Although, under certain circumstances, certain pension funds were so risk averse that they ultimately ended up buying extra insurance in the form of credit default swaps on these kinds of contracts with other counter-parties. So in many cases, some of the insurance companies actually did have relationships with the end investors, as well as with the investment banks. Yeah, Maria.

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** They do. They do downgrade these. Absolutely. And in fact, not only do they downgrade the bonds, but they also downgrade the equity of the companies that are issuing the bonds. So for example, AIG was downgraded because there was concern of whether or not it could meet its obligations. And because of that downgrade, that triggered a bunch of other transactions.

**STUDENT:** And the other question is, are they independent, and are they really objective when they are--

**ANDREW LO:** Well, so those are two separate questions. Are they independent and are they objective? Yes, they are independent, strictly speaking, in the sense that S&P and Moody's and Fitch are not owned by any of the companies that are being rated, number one. Are they objective? That's a different question because remember that S&P, Moody's and Fitch are businesses, and businesses generally try to make money. And in order to make money, you have to get revenues. And in order to get revenues, you have to have lots of customers.

And so the question is, did they ultimately end up giving ratings out too easily that they shouldn't have because they wanted to get more business? I don't know the answer to that, but there is going to be a lot of people, particularly lawyers, asking those questions in the coming months. So the rating agencies have definitely been under fire by a number of different organizations. I don't know where that's going to come out and I don't know the details of how they actually conducted the ratings, but there is definitely an issue because what is AAA should not default more than 1% or 2% over the life of the particular loan. And clearly, with these securities, they've defaulted at a much higher rate.

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** Yes. That's right. They only relied on three companies. And actually, it's very difficult to start a rating agency now, because the regulatory authorities require certain kinds of standards to be met that are virtually impossible for a startup to be able to do. So you're right, that investors relied on this, and they ultimately were badly misled. But the argument that S&P, Moody's and Fitch would make is that, we were doing the best we could, we looked at historical default rates of mortgages, and we made very conservative assumptions.

In fact, if you assume that they were zero correlation, but instead you tried to be conservative and you said OK, the correlation maybe is not zero, but let's make it, oh I don't know, 25%. Even though historically, the correlation is maybe much, much less than that. If you just used an artificial number like 25% or 30%, you would still not have had the kind of dislocation that we saw over the last couple of years, because the correlation actually has gone much, much higher than that, particularly for the subprime mortgages, as you know, because the housing market's turned down.

And a lot of this was triggered by this decline in housing, which has been a very, very sharp decline. And over the last 30 years, the housing market in the United States has really never gone down by more than 1% or 2% in a year. Never mind going down 10% over the last 12

months. That's a really big shock to the system. Yeah?

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** Well, in fact they have done that in the sense that they've actually chopped up these kinds of security into five different tranches. And they've done it, they've spread it out very, very broadly. That's how the US housing market was able to grow as quickly as it has over the last 10 years. It's because they brought in huge amounts of money, unprecedented amounts of money, through this mechanism. And all of the investors invested based upon these ratings, as well as their sense of how secure these markets were. And in each case, there is going to be dislocation, other than perhaps in the middle tranche where it hits exactly right and you don't get any kind of dislocation.

But that's not the biggest tranche. The biggest tranche was by far the most senior one, because that's the one that has the largest amounts of money waiting to be invested.

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** Oh yes, absolutely. Yes, absolutely. Hedge fund managers have profited greatly from this, because they bought the toxic waste that nobody else wanted and then the value has gone up dramatically because of these kind of increases in default rates. Because they were priced to be much worse than they ultimately ended up being. So it's absolutely the case that the money has not disappeared into thin air. It's gone from the senior to the junior. It's a wealth transfer in a way. Sorry, Ken.

**STUDENT:** Just a comment on why Moody's maybe rated these things the way they did. At least in my experience, what would happen was the structuring teams would meet with people who were going to rate these securities and explain to them, hey, this is what we did, this is why it makes sense, and essentially convince them. True earlier why the

**ANDREW LO:** Oh sure. There's a lot of research that goes on. In other words, Moody's, S&P and Fitch doesn't just decide based upon how they feel that day whether it should get AAA or not. They do a fair amount of research, and they go through the details of the portfolio, they look at the seniority of the claims, they look at the legal documents, they look at the historical record, they go back and go back 30, 40, 50 years and take a look at the data. So that's why I said, they actually have a case for making the ratings as they did. How they could have gone so far

wrong is a question that we're going to debate for the next several years.

And ultimately, I think we're going to learn that we need to make our models more sophisticated. We need to have parameters that are time varying. We need to have a different approach to how we do quantitative analysis for these kinds of markets. But that is an open question that I think will have to be examined in much more depth.

**STUDENT:** [INAUDIBLE]

**ANDREW LO:** Oh, in the current situation can somebody make money? Absolutely. Absolutely. This is why I was saying at the very start of this crisis that times of crisis are also times of opportunity. You can absolutely make money, because these securities now are priced all over the place. Some way to high, some way to low. And if you understand these models better than the next person, you will make money. One of the largest payouts that has occurred in hedge fund history occurred last year to a hedge fund manager in New York named John Paulson.

I think he was paid-- it's in the Wall Street Journal so you can look it up-- I think he was paid something like \$3 or \$4 billion. Was it \$4 billion? That was his take home pay last year. That was on his W-2. That was not wealth, that was income. And he did it by betting on certain movements in these markets, including these kinds of securities. So there's a lot of money to be made. There's a lot of opportunity out there. But it requires an edge. So you really have to spend some time trying to understand these securities. And what we've done today, this relatively simple analysis, is an analysis that apparently eluded this Chief Risk Officer.

Because they're focusing at a very, very detailed level on models that are probably not as relevant for the macroscopic picture. Yeah?

**STUDENT:** If no one is able to determine the right price for these things, how is the government going to use the \$700 billion to buy these things?

**ANDREW LO:** Well, that's a great question. That's one of the reasons why there's so much debate. It's because the view is that if the very best minds on Wall Street couldn't get this right, what makes us think that the Treasury can get it right, which is a little scary. I agree. There are a couple of things that are being done to address that. One is that as part of the proposal, they plan to set up an advisory board of people that are in the industry, seasoned veterans that are engaged in these transactions, to help the government price these things. That's one.



The second approach is that they plan to engage in equity ownership as a possible outcome for this. So in other words, it's a bailout if you buy for \$100 what is really worth 60. But it's not nearly as much of a bailout if you buy for 50 what's 60. And it could actually be quite profitable if not only do buy for 50 what's worth 60, but you also get to own 80% of the company in the process, which is kind of like the deal that AIG has struck, and not that different from some of the discussions that Warren Buffett has had with Goldman Sachs.

So the idea behind the current proposal is that there will be additional protections to allow the government to benefit from the upside of these securities, and to be able to get the expertise needed to price them. And there are other protections that would require industry to pay up for additional insurance on these portfolios, and ultimately to allow legislation to recoup some of the losses, if at the end of 5 or 10 years the government ends up losing money on these kind of transactions.

Let me stop here, and we'll see you on Wednesday. We'll talk about common stock.