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**ANDREW LO:** Any questions from last lecture? Where we left off last time was the adaptive markets hypothesis. The fact that markets are not always in everywhere efficient, but rather they satisfy the following six properties that I listed at the end of last lecture.

Individuals act in their own self-interest, but they make mistakes. However, they learn and adapt, and competition drives that adaptation and innovation. Natural selection, essentially, is the mechanism that shapes the survival of the heuristics. And in the end, the only thing that matters is survival. Now I illustrated how heuristics develop by giving you an example of the problem of getting dressed in the morning. And I pointed out that each of us have our own heuristics that have been developed over many, many years of selection of various different sorts.

So when you take this all together and you put them into a framework that tries to focus on understanding market dynamics, you get a number of implications that are actually quite different from that of efficient markets. Let me tell you what they are. I'll give you some examples.

One of the implications is that the risk-reward trade-off the relationship between risk and expected rate of return, like the CAPM's security market line. That's not stable over time or over circumstances, because individual preferences are not stable over time or over circumstances. I'll give you an example of that. Anybody know somebody who has lived through the Great Depression, OK, so grandparents or great-grandparents? My guess is that if you talk to them, or if you even observe their habits, they're actually quite different from your parents and yourselves in terms of how frugal they are, how careful they are with money, with resources, even something as simple as turning off the lights.

A friend of mine is a customer a very wealthy family. They own a private business. And so their family's net worth today is probably in the order of \$300 million, which, even in today's economy is worth a lot. Actually, it's worth more than what it used to be worth now.

And so this family, the patriarch, the matriarch is their grandmother, who lived through the Great Depression. And she lives in Lower Manhattan in a relatively small, nondescript apartment, despite the fact that the family, you know, my friend's parents, live in a beautiful

penthouse apartment on Park Avenue. And they keep asking the grandmother to move in with them.

And she refuses. She just thinks it's a waste. It's embarrassing. And when she comes to visit them, she'll take the bus. She refuses to take taxis just from Lower Manhattan to Midtown.

And so, you know, my friend, you know, pleads with her. You know, Nana, why are you doing this? You know, we have more money than we'll ever be able to use.

You can afford to take a taxi. Let us send a car for you. Why do you do this? It's dangerous for you to take the subway or the bus. And she's like 95 years old.

And she says to him, listen, Sonny. You don't remember the days that I do, when I had to stand in line and wait for my dinner, not knowing whether or not I was going to get me by the time I got to that end of that line. So don't you tell me that we have more money than will ever be able to spend.

I'm sure you've heard that. Those of you who know people who lived through the depression, you've heard that. These individuals were indelibly altered by their experiences. They're not the same person before, as after, living through such difficult times.

And you're not going to change them. So my friend has stopped trying. And so he just does what he can in order to make her life easier, but realizing that she simply can't enjoy the same kinds of things that he does, because she lived through such traumatic times.

So if you understand that, if you acknowledge that there are people that are indelibly altered by tough times, then, in the same way, people can be indelibly altered by really good times as well. As I said last time, you learn nothing from your successes, right? Because you succeeded, what's there to learn? Do more of the same. But that affects the way you think as well.

And so what we think of as this beautiful mathematical relationship, this risk-reward trade-off, the CAPM, the CAPM works if all of the assumptions that I specified are true. But those assumptions are predicated on people acting rationally. If people don't act rationally for whatever reason, if they're emotionally traumatized, if the balance between emotion and logical deliberation has been permanently altered, then the theory is not going to work. So you have to understand that when you're looking at markets, you're looking at the complexities of the interactions among various different people with different balances of logical deliberation

and emotional response.

So one of the things that says is that risk premia, the expected return on risky assets as a whole, is not a universal constant like, you know, gravity. It changes over time and over circumstances.

It was going to be quite different if we had continuing prosperity over the next five years as to where we're likely to be headed now. It's just different. We have a different path that we're going to follow. And so as things change, market dynamics will change with them. Yeah, Zeke.

**AUDIENCE:** So last time, we had talked about when you give somebody [INAUDIBLE] that [INAUDIBLE] and so on. And you said that lasts for a couple of hours.

**ANDREW LO:** Yes.

**AUDIENCE:** So with combined with what you're saying today, are you connecting the two and suggesting that such huge events actually change our biology permanently for years? Or do you think that there's a different reason behind that sort of learning?

**ANDREW LO:** I'm saying that it can change not so much our biology, but rather, it can change our decision-making abilities for years to come, in the same way that you know your grandmother or great-grandmother was indelibly affected by living through the Great Depression, or through the Holocaust, or through some extraordinary emotional trauma, in the same way we will be affected by these sets of circumstances for years to come. Right? That's it. Ingrid.

**AUDIENCE:** I was really impressed about two weeks ago that I heard the different networks, the channel lists trying to convince people not to getting them to buy Christmas presents, and people are going to complain because they could not not buy gifts to their kids. And where I come from, if you don't have money, you don't have money [INAUDIBLE]. So it was really surprising to see how that consumption mindset was so, so strong here.

**ANDREW LO:** That's right. And you know, that's a very unusual mindset for the United States, because we are the land of consumers, right? I mean, consumption is what drives this economy, for better or for worse. You know, that is what has made this country as wealthy as it has. And so, it is a very difficult time when we actually have to all pull back.

And you know there are some individuals that would argue that you shouldn't pull back. You should keep on spending, because if everybody keeps on spending, then somehow, magically,

we will be, stay richer. That doesn't quite work. There's an adding up constraint somewhere.

So wealth, if it's lost, you know, it's lost in a certain sense. And you can't create something out of nothing. But I think there are some issues about government's role in being able to maintain a certain degree of spending.

So we're going to get to that in a few minutes. But you're absolutely right. This is a very big change from where we were just even a few months ago.

Other implications of adaptive markets is that limited arbitrage, the so-called free lunches that we talked about, that can exist from time to time. There are free lunches on occasion, because you can think of the free lunches as opportunities that a certain group of individuals in the economy have identified which may not last.

And so over time, those arbitrageurs end up getting eaten away by the arbitrageurs. But they still do exist from time to time. Free lunch programs may not exist, in other words consistent arbitrageurs time and again. That is much, much more difficult to come by.

But as a result, strategies will wax and wane through different cycles. And the way it does so is exactly the same way that a beautiful, green pasture can come and go based upon ecological dynamics. In particular, a green pasture becomes a favorite spot for sheep to graze on. And after a while, as the sheep graze and get fat and multiply, they have more and more effect on that pasture.

Pretty soon, with so many sheep grazing on that same pasture, the pasture is depleted. And after it's depleted, what happens to the sheep population? It declines. And the population declines, the pasture grows back, and the cycle begins all over again.

Well, I have news for you. That pasture, you can think of as profits. And the sheep, you can think of as all of you. You're, the investors.

And if it's profitable for you to invest in something you will keep doing it, and doing it, and doing it until there's no more pasture. That's what happened with mortgage-backed securities.

There's no more pasture now. It's pretty much gone. It's going to be hard to make money in that market for a while.

So all the sheep, they're going to go away now. And over time, it will come back. It may take a while, but it will come back.

And that's where cycles come from. It's the exact same mechanism. This is not an analogy or a metaphor. I'm describing exactly the mechanism by which certain biological entities interact with their environment. And we are biological entities. We're creatures.

And we interact in our environment. The only difference between us and sheep is that we consume dollars instead of grass. And so the dynamics are really very much the same.

And the bottom line, I said, is that survival is all that matters. What any business cares about in general is surviving. And as you push for survival, a lot of the effects that you see in typical evolutionary systems will emerge in economies.

So let me talk specifically about some very, very concrete examples of these kinds of dynamics. I'll give you just a couple. The first example comes from the hedge fund industry, and in particular, from very, very simple-- a simple observation about the efficiency of the stock market.

When we talked about the random walk hypothesis a few weeks ago, we mentioned that the idea behind the random walk is that if prices fully reflect all available information, then certainly, you shouldn't be able to predict what's going to happen to prices tomorrow based upon what happened to prices last week, right? In other words, just because we had a positive return over the last five days, that positive return shouldn't give you any hint as to whether or not the next five days will be positive or negative, because all the information of the last five days has been incorporated into today's price. So at every point in time, it's a fair game. It's a Martingale.

Well if you believe that, then what that says is that the first-order autocorrelation of monthly stock returns should be about zero. In other words, the correlation between last month's return and this month's return should be statistically indistinguishable from zero. Because if it weren't, if it were strictly positive or negative, then you'd have information to be able to base a trading strategy on, right? For example, if it were positive, then if last month's return were positive, you can bet the next month's return will continue to be positive. So you'll make a bigger bet on the stock market. You'll develop a trading strategy that can beat the market.

Efficient markets hypothesis would say you can't do that. You can't come up with these kind of trading strategies. In other words, stock prices follow random walks. Autocorrelation should be 0.

All right, well, let's take a look. This is the rolling five-year serial correlation coefficient-- first-order autocorrelation coefficient for stock returns on a monthly basis for the S&P composite index from January of 1871 to April of 2003. That's a lot of data, right? And if these are five-year rolling window correlations-- so every five years, I'm going to calculate the correlation coefficient between month T and month T minus 1, and it should be 0. But let's take a look at what happens.

In the 1800s, the late 1800s, there was a fair bit of positive correlation, correlation around 40% or 50%. And then, towards the end of the century, the correlation goes down, then it goes up. Then it goes way down in the early 1900s. Then it goes up, then it goes down, then it goes up.

During the 1970s here, there's a bit of a period where it goes down, then it goes up, then it goes down, then it goes way up. It shoots way up in the 1990s. And then, since the 1990s, it's been relatively low. And actually, if you extended it to the last few years, you'd see that it's still pretty low.

This diagram shows that market efficiency, as measured by the first-order autocorrelation first of all, it's not zero. But more importantly, it does not decline monotonically over time. Markets are not getting more and more and more efficient.

There's a cycle of efficiency. There are periods where the market is very efficient. And there are periods where it's not. And these periods are determined by the population of investors that are interacting with each other.

There are periods where markets are extremely efficient, because you've got very sophisticated investors in the market. But during the 1990s, that wasn't one of them, because what was happening during the 1990s? Who was trading here? Anybody know?

Who? Tech. But who were the traders?

**AUDIENCE:** Everybody was.

**ANDREW LO:** Exactly. Retail investors, everybody. You know, the librarian, the pharmacist, mom and pop, grandma, they were all trading on E-trade on all of these various different trading sites. And as a result, the market became relatively inefficient. And you can see this. You can see this as clear as day.

By the way, right around here was where some of the equity market neutral hedge funds, like DE Shaw decided to go into business and made a lot of money in this period. It's gotten a lot harder now, no doubt. But my guess is that over the next few years, you may see markets becoming more inefficient.

Why is that? Why might that be over the next couple of years? Any guesses? Yeah, [INAUDIBLE]?

**AUDIENCE:** Because people are pulling out of the market?

**ANDREW LO:** Exactly. People, particularly sophisticated investors, like hedge funds, are pulling out of the market because they're getting blown out of the water. They're losing a lot of money. They don't have enough to run their businesses. They're pulling out.

And so whatever's left may not be as efficient as it once was. That's adaptive markets. That's all.

Economic systems are not like physical systems. We're not approaching any kind of steady state limit. We're interacting with each other.

And during certain time periods, we're going to be very efficient. And then, by the way, finance there is going to work quite well. But then there are going to be periods that are crazy. And during those crazy periods, market prices may not fully reflect all available information, in which case, markets will not be as reliable as finance theory makes them out to be.

So when you apply your 401 techniques, you've got to start by asking the question, do those assumptions that we made, do they hold? Is this a reasonable period of time for which finance theory will dictate what prices should be? [INAUDIBLE].

**AUDIENCE:** If expected return of the stock markets let's say 10%, then the other correlation shouldn't be zero. It should be around-- there's supposed to be some correlation when the market is efficient is when the next--

**ANDREW LO:** No, because remember, the correlation is the covariance divided by the variance in excess of the mean. These are deviations from mean, right? So it doesn't matter if it's 10%, or 20%, or 5%. If there's a trend, the mean basically subtracts that trend off.

Yes.

**AUDIENCE:**

There are a few dips like, [INAUDIBLE] like [INAUDIBLE] does a dip. Like do you have an explanation about like why that happened?

ANDREW LO: Well, the explanation, at least during the recent periods, I have one for you. I don't know about going back here. I can conjecture. But there are a lot of other things going on here that I can't say that I've really researched.

But over here, I can tell you what happened, which is that the internet bubble burst. And then retail investors, they left the market. And who was left but sophisticated, institutional traders. And they took advantage of whatever correlation there might be. And that basically bit away any other profits that might have remained.

So over the last, I don't know, maybe five to eight years, long/short equity market neutral and long/short equity strategies, that are the basis for taking advantage of these kind of correlations, have grown dramatically. And the profits have declined significantly. Markets have gotten more efficient. And you know, I would argue that during certain periods of time, for example, during the 1950s, during this period, there were situations where markets got more efficient because certain institutional investors came in, and retail investors left.

So by looking at the population dynamics of the market ecology, you see, I mean, that language that I just used is language that evolutionary biologists would use. It's not something that economists would ever say. How many of you actually heard of an economist or the words that I just uttered? I don't think you have.

You'll never hear it in microeconomics, because microeconomic they treat all consumers as the same. Maximize expected utility subject to a budget constraint. Or they treat all producers as the same. You can maximize profits subject to a production function or resource constraint.

What economists don't recognize is that there are different populations of consumers and producers. And these populations arise in different ways. They're different species. And different species have different characteristics. And so by studying the different species, you will come up with different insights.

But the reason that we don't have very many insights yet is because we don't even speak in these terms. And therefore, we don't measure the data in this way. For example, if I wanted to today, the number of retail investors versus institutional investors versus broker dealers versus hedge funds-- if I want to know the biomass of the different species, I wouldn't know where to

look.

There's no database that has this information, because we're not collecting it. We don't even collect the information in the way that would be the most amenable for analysis because this is such a new framework. So you've got to have the framework first to figure out what questions you want to ask and what data you want to collect. , And ultimately after you do that, over time, you'll be able to see these kind of patterns emerging. Yeah, question.

**AUDIENCE:** [INAUDIBLE] contradicts the view of market and the [INAUDIBLE] of market and permits that say [INAUDIBLE] market the more [INAUDIBLE] the more [INAUDIBLE]

**ANDREW LO:** Absolutely. Absolutely, it does contradict that. Yeah, this is why I leave this material to the last lecture, because, you know, I feel that it's inappropriate for me to spend an entire course in Introductory finance teaching you what my pet theories are as opposed to the mainstream. You need to know the basics of what's out there and how people use the tools. So that's what we did for 90% of the course.

But I also would feel it inappropriate for me to perpetuate certain myths and let you leave this class without at least understanding that there's a debate going on, and that there's some uncertainty about exactly what theories apply when. So you're right. This does contradict the conventional wisdom. Yeah.

**AUDIENCE:** All right, [INAUDIBLE] correctly, the points of [INAUDIBLE] rational investors. So right now, [INAUDIBLE] market. What's wrong with that? I mean, after all, we're on a path to an ineffecient market again, right?

**ANDREW LO:** There's nothing wrong with any of this. You know, you have to keep in mind that I'm not making any value judgments whatsoever. What I'm trying to explain to you is a way of thinking, right? So I'm trying to give you a way to reconcile the various different kinds of market theories that have been proposed, the behavioral versus the rational.

And what I'm arguing is that neither of these theories are complete. They each focus on one aspect of the market during one period of time. And what you need to do in order to put it all together is to develop a super theory that allows you to understand how both of these subtheories are integrated with each other. And I think this is what it does. OK?

**AUDIENCE:** [INAUDIBLE] had said that, [INAUDIBLE] show us pretty much has a problem, because hedge funds are pretty much pulling out as a result [INAUDIBLE]

**ANDREW LO:** Yeah, but there's nothing wrong with that. Hedge funds are pulling out. And markets will become less efficient over the next couple of years.

**AUDIENCE:** I think it'll be more efficient, because people that have [INAUDIBLE] market, right? So--

**ANDREW LO:** That depends on who's left. That depends on who's left in the market. If it's institutional investors and other sophisticated investors, you may be right. But I would argue that there are going to be regular investors, like you and me, that are going to be left in the marketplace. And we're going to be running for the hills or running for the big returns.

And that's going to be what drives the market for the next year or two. OK? That's going to be different than the other periods where you see inefficiencies occur, because the smart money stayed in, and the dumb money pulled out. I shouldn't say "dumb money". That's kind of value judgment. The naive money, the inexperienced money, the retail investors-- they're the ones that pulled out, you know, here.

And so here, you had tremendous amounts of retail money being applied. But retail investors, they ended up losing a fair bit of money going forward. And what was left here is the hedge fund money.

What I'm arguing is going to happen over the next year, what has already happened over the last year, is that hedge funds have pulled out a lot of their money. So who's left? Ask yourself, who's left?

When you think about analyzing a market, don't just look at it as a mathematical object and say, I'm going to write down the CAPM, and this is what is going to tell me. If you do that, you're thinking like a physicist, not like a biologist. A biologist would say, what are the species that are here in this ecology? And once you tell me that, I'll tell you what things are going to happen over the next year or two.

So let me go to now how all of this applies to the current crisis. I'm not going to talk about the details of it. We've already spent a fair bit of time this semester talking about the crisis, talking about subprime mortgages, securitization, the role of all of the various different folks that were participating.

But I want to make the following point based upon the material that we covered last time. And that is the fact that pain protects. This is a very important, but rather obvious point, that I

suspect many of you may have overlooked. And let me just describe to you a very simple illustration of it.

Have any of you run across people that have had like temporary nerve damage? You know, their arm goes numb for whatever reason. Anybody see what happens to that arm, you know, over the course of a couple of weeks after the nerve damage sets in? Anybody know? You have seen situations where that happens? Yeah, Mike.

**AUDIENCE:**

I was going to say, somewhere there was a little girl who couldn't feel pain at all. And she had the-- she kept clawing her eyes out. And she was completely bruised because she just bumped into everything.

**ANDREW LO:**

That's right. It's interesting. When you see these individuals, they look like they've been in a cat fight with a tiger. You know, they're scratched, bruised, you know, they've got these incredible wounds.

And you ask them, you know, what happened? Did you get mugged? Did you get beaten up? And they'll say no. It's just walking around.

It turns out that if you can't feel in your left arm, if it's numb, then you won't know to pull away when you scrape it on the edge of a sharp chair, or you get pricked by some kind of tool. You won't know to pull back. You might just keep pushing forward.

And you know, there goes a scratch, and a cut, and a puncture. If you can't feel pain, you can't protect yourself. Pain protects.

If you think about any kind of measure you have ever taken that has protected you, whether it's pulling money out of the stock market, whether it's getting out of a burning house, whether it's avoiding a certain situation because you know that it would likely turn into a very bad accident, like driving after you've had too much to drink-- if you've ever done anything that involves pulling back from taking a risk, it's because you have felt pain, either current pain. Or you have felt the memory of previous pain.

Now let me ask you a question. Suppose none of you are feeling any pain. Will you actually be able to control yourself from taking on certain risks?

So this gets back to the crisis that we're in right now. If in 2004 or 2005, you were at one of these financial institutions that invested in these kinds of securities or these strategies-- and

not everyone did. So I don't mean to make a sweeping generalization. But a number of very large institutions seem to have overextended themselves.

What I want to argue is that this is not something that is very easily preventable unless we impose certain restrictions in advance, unless we decide before we ever enter that situation that we're not going to do something, because otherwise it's going to be impossible for us to avoid doing it when it feels so good, when we are in no pain. I want to be even more specific. It turns out that financial gain, monetary reward, actually stimulates the same reward circuitry that cocaine does.

I'm not kidding. This is not an analogy or a metaphor. It's a physiological fact.

Neuroscientists using fMRI machines had individuals play games involving real money-- not a lot of money, but enough so that it actually registered. And it turns out that they found that when people made money in the MRI machine, that their brain released dopamine into a region of the brain called the nucleus accumbens. This is exactly the same thing that happens when you take cocaine.

Some people have said that making money is better than sex. You know what? That's actually not an exaggeration. It stimulates the same kind of neural circuitry.

And when you are in this kind of a mode of reaction, when your nucleus accumbens is being hyperstimulated by dopamine, it will be very hard, almost impossible for you to pull back and say, no. I don't want to. That's what an addiction is, frankly. And for extended periods of prosperity, which we have had over the last 10 years, it's become virtually impossible.

I'm not condoning it. Don't get me wrong. I'm not arguing that these excesses are just fine and we excuse them. I'm actually explaining a biological fact about how all of us are hardwired. When we're making money, it's very hard for us to pull back-- so much so, that as a society, it is possible for us to overextend ourselves. And this actually is one role that regulation can play.

You know, economists have argued that government should be involved because we have public goods. We have externalities. We have incomplete markets.

But I think that economists have missed the most obvious motivation for regulation, which is regulation is a means by which society prevents itself from doing the things that it knows it

doesn't want to do during those periods where it is incapable of stopping itself from doing it. Right? This is why some people put their potato chips on the very top shelf in their kitchen. They know that they shouldn't be having too many. So they make it harder to get it so that when they get it, you know, it provides some kind of distance. And that doesn't work so well. I can attest to that.

But I'll give you another example I'll give you another example that's a little bit more direct. In every state in the United States, we impose fire codes on builders, fire codes that require you to have a minimum number of exits, to have well-lit exit signs that you can see, to have visible fire alarms, to have sprinkler systems in the ceiling. All of this stuff costs money. It's actually very expensive to put it.

Do you ever wonder why we have those? In other words, why not let the free market work? Let people be free to choose.

Those of you that are nervous Nellies that are worried about a fire, you will simply pay more for buildings that have all these goodies. And then we can have other buildings that don't have any of these protections. And let people be free to choose.

Why don't we do that? That's a perfect equilibrium from an economist point of view. Well, you know why?

It's because in that free-to-choose world, none of you will choose the more expensive building. And the reason is simple. It's because when you assess the probability of a fire on any given day, you put a weight of zero to that event.

I don't any of you came into this classroom today thinking hmm, if there's a fire, who am I going to have to step over to get out of that exit? Maybe you are thinking about that. That's why you guys are sitting here.

But we don't think about it, because it's not part of our cognitive process to focus on every possible eventuality. We don't have an infinite computing machine on our heads. So we assign certain events zero probability.

And when you do, you will pay nothing for it. So there will be nobody that will pay for sprinklers, in which case, it won't get done. And as we know, when it doesn't get done, eventually, you have a fire. And during that fire, you really wish you had those sprinklers. And it'll be too late to put them in at that time.

So we regulate. We regulate because we know ourselves. And we know that during certain situations, we will not act in a way that we would like ourselves to act. So we prevent ourselves from doing that by developing these laws that we just simply have to follow. Well, that can be done as well for problems like leverage credit and so on.

So the point is that risk management doesn't work unless we are able to experience pain and fear. And profits are a very potent anesthetic. They're like a drug.

And the more profit you have, for a long enough period of time, you become a lot less anxious about asking questions, because you're not feeling any pain. You're not feeling pain, so you won't ask the tough questions. And you won't scale back the risks while everybody else seems to be doing just fine.

So the point is that proper balance is the key. We have to have a proper balance of fear, greed, and logical analysis. And if we know that there are periods where that proper balance will be out of kilter, that's the role that regulation can play during those periods. OK?

So what do we what do we think about going forward? Well, clearly the fear of the unknown magnifies the problems that were in. Flight to liquidity is likely to persist.

And we really are going to have to think more carefully about developing better analytics. And ultimately, what we're going to see over the next couple of years is a tremendous period of innovation-- some of it good, some of it bad. But we're going to use the current situation to really improve and expand the current infrastructure for the coming decades.

So as one of the Obama transition managers mentioned, a crisis is a terrible thing to waste. The next year or two is a golden opportunity for us to take advantage of the crisis by motivating ourselves to change the regulatory infrastructure. Right? If things are going well, then there's no point in trying to change anything, right? Don't mess with success. You've heard that before.

The point is that right now, we're in a situation where we can actually change something. And so the adaptive markets would tell us that this is our way of creating that infrastructure to build for the coming growth.

So in conclusion, I would argue that finance and economics are a lot more like evolutionary biology than they are like physics. We really have to take a look at the evolutionary

perspective. And the bottom line is whether or not you are going to survive. That's what we all care about. That's what we ultimately strive to do.

And if you understand this about markets, you'll have a much better chance of surviving. So from the perspective of 401, the material we've learned in this course, we've gone over the rational approach to analyzing value in various kinds of market interactions. And just be aware that for the most part, that may work reasonably well. But for extreme circumstances, periods of extreme wealth, as well as periods of extreme market distress, prices may not be in-line with what our analytical framework suggests. And at that point, you need to reassess and try to come up with alternatives.

What those are, we currently don't know. We don't have a good theory for what happens when the traditional analytics break down, because up until recently, nobody would be even willing to consider that the traditional analytics would ever break down. OK? So this whole area is relatively new.

And as I mentioned, at the beginning of this lecture, if you do a search for adaptive markets, you're going to only find my name attached to that at this point. It's not really a theory that's come into even common parlance, never mind general acceptance. It's a conjecture at this point. It's an alternative to the current received wisdom.

But the hope is that over time, as we understand more and more about these interactions, we'll be able to develop alternative. So then, I'm hoping that a few years from now, I will be able to tell all of you, this is a theory for markets when they are normal. And this is a theory for markets under certain kinds of distress. And at that point, we will have a complete theory of markets under all circumstances. But we're still a few years away from that. [INAUDIBLE].

**AUDIENCE:** There are a number of economists the value that the financial sector in the US was already among the most regulated sectors. But partially these regulations caused [INAUDIBLE] Fannie Mae and Freddie Mac. And so actually, I would argue for the opposite. And do you think that the regulation should be fixed because it's wrong, or you should add more?

**ANDREW LO:** Well, I don't think we should add more. I would argue that we don't need more regulation. We need better regulation, smarter, more adaptive regulation.

So to your point, the banking sector, which is where the majority of these problems sit today, the banking sector is the most regulated sector of all in all of the financial world. And the next

most regulated sector is the insurance sector. And you have problems there, too.

So on the one hand, you could argue that gee, it's all this regulation that's created it. I don't believe that either. And the reason is that a lot of these problems started in 1999 and after when we actually dismantled some of the regulation, in particular the Glass-Steagall Act. We dismantled that in 1999.

And by the way, that wasn't done by the Republicans. Bill Clinton signed that. So there's blame to share across both political parties. This is not a political problem, per say.

So we reduced regulation. We allowed banks to be more like hedge funds. We allowed hedge funds to be more like banks. And we got ourselves into the problem that we face today.

So it's not more regulation. We have to be smarter about what we're regulating. And that's what I'm hoping that we will do over the next few years.

OK, well, that's it. That's it for Introductory Finance. What I want to do now in just the last 15 or 20 minutes, I'm going to give you a near-death experience, because you get to see the entire course flash before your very eyes. I want to go over what we've done to-date and try to make sense of it all. And then I'll tell you a little bit about what you might be in store for with classes in the future.

So let's start at the very beginning. I started with this motivation-- mathematics plus money is equal to finance. And I hope that I've delivered on that. In other words, we've got very different approaches to investments.

At the one in the spectrum, James Simons, at the other, Warren Buffett, and, of course, Jack Welch in-between. And each of these individuals brings unique skills and insights into the investment process. And what we wanted to do in this course, was to try to distill some of the basic principles and the language of finance that all three of these individuals would agree are sort of the building blocks of understanding market dynamics.

And as we started at the beginning with this flow model of the economy, we said that we were going to study four components-- households, capital markets, financial intermediaries, and non-financial corporations. That's the financial system as we know it. And we began with those six principles of modern finance. Now I think you have a deeper appreciation for it. As I said, we were only going to be able to focus on the first few. And the latter principles were going to be underlying much of the theories that you would study beyond this course.

There's no such thing as a free lunch. That's a very basic principle that we used time and again in coming up with various different pricing implications. And P2 is the behavioral assumption that I argued we need for much of the theories that we developed. But what I just told you in the last lecture is that there are occasions where those behavioral assumptions, ultimately, are suspended or replaced with this kind of overwhelming emotional component. We prefer more money to less, prefer money now to money later, and we prefer to avoid risk.

P3-- all agents act to further their own self-interest. That's pretty straightforward. P4-- financial market prices shift to equate supply and demand. And then P5-- financial markets highly adaptive-competitive, and that risk-sharing and frictions are central to financial innovation.

I hope that throughout the entire course you've got an appreciation for all six of these principles. It's remarkable how such relatively simple ideas can have such dramatic implications as we've developed over the last 13 weeks. OK so there are four sections that we focused on-- the introduction, evaluation, risk, and corporate finance. And then the final lecture of "Try to put it all together."

For present value, the focus really was defining what an asset is-- a package, a sequence of cash flows, and the time value of money, looking at present value versus future value, and focusing on exchange rates between today, tomorrow, and other dates. That was sort of the key insight. And once you understand how to visualize the cash flows and move money through time, you understand a very significant portion of financial analysis.

And then we talked about some special cash flows-- perpetuities and annuities, which we use for virtually everything in terms of valuation. Very important ideas. And then we talked a bit about compounding and inflation.

Fixed-income securities-- Well, we talked about applying the very basic mathematics of present value to these pure discount bonds and coupon bonds. The relationship between coupon bonds and discount bonds, of course, is through arbitrage. And we also found that current bond prices contain enormous amounts of information about what's going to happen in the future.

We talked about spot rates, forward rates, yield-to-maturity yield curve, interest rate, risk. And then we focused on corporate bonds. And I spent some time giving the example of how repackaging corporate bonds, and things like mortgages, auto loans, and other securities,

could actually lead to some very, very attractive securities for a variety of different clientele.

For equity securities, we applied exact same framework to try to come up with a value of a future stream of dividends. And here, while the mathematics was pretty similar, the interpretation differed in an important way, because dividends are random, whereas, in the case of bond prices, the coupons are known in advance. So that's the difference between fixed-income securities, where the incomes are fixed in advance, versus equity securities, where there's randomness. What that randomness does is to make the volatility of these pricing models much greater. In other words, it's harder to pin down what the price of an equity security is, because in addition to all of the risks that a bond will face-- in other words, the risk of future changes and interest rates-- you get the risks of changes in dividends, earnings, cash flows, and so on.

We also talked about valuing companies using various different formulas, and then the idea behind PVGO, the present value of growth opportunities, and how that can actually lead to some tremendous valuation swings in a company that's based upon intellectual property. We then talked about a whole other set of securities that most of you probably haven't come into contact with-- futures versus forwards. These are weird securities in the sense that they're worth nothing on the day that you agree to enter into one of these contracts.

But the reason they're worth nothing is that these are bilateral agreements between two counterparties. And so both of you are willing to enter into this in a willing exchange of cash flow payments sometime in the future. The only reason you're willing to do that is because the contract from an objective standpoint doesn't have any NPV. And we see that the marking to market of futures makes a very big difference in terms of the liquidity characteristics of that contract. We see that today with what's going on in financial markets-- and that using these contracts both for hedging purposes and for speculation is a very key aspect of this whole industry.

Question? Zeke? Oh, okay.

Then the last set of securities that we spent time on in this course, is options. Options are different from anything else we've looked at up until now, because first of all, their payoffs are asymmetric; they're kinked. And by putting together a portfolio of options, we can get all sorts of weird payoffs. In fact in the various different exam questions that you might get, you will be asked to try to come up with different kinds of payoff structures. So you need to know a little bit

about how to put these things together and what the various different payoffs imply under different circumstances.

We also gave you a very simple example of an option pricing strategy, a model, namely, the binomial pricing model. Very simple, but it's actually one of the most heavily used in industry. And it's an extraordinarily flexible and powerful method, again, based on the principle of arbitrage, or no free lunch.

We then started introducing risk into the picture explicitly. We talked about the size effect, January effect, value line, momentum, accruals, and pointed out that all of these effects can lead to certain investment strategies. Whether or not the strategies are good or bad really requires a framework.

We didn't have a framework at the time. But I wanted to point out these anomalies to just mention that they are the basis for a number of investment products and ideas over the years. And so we really need to have a systematic way of thinking about how to evaluate not only these strategies, but the managers that tout them. Are they adding value? Or is this something that really you could do for yourself?

So we developed this notion of not so much picking a stock, or a good two or three stocks, but putting together a whole collection of stocks, a good portfolio. And we zeroed in on mean and variance as the key concepts to evaluate what is good and what is not good. And we deduced the main result of finance theory under uncertainty, which is the capital asset pricing model in two forms-- the capital market line for efficient portfolios, and the security market line for any kind of security or portfolio, whether it's efficient or not.

And this allows us to resolve the open question that we started with, which is, how do we determine what the appropriate risk-adjusted discount rate is? I've said at the very beginning, let the market determine it. This allows us to explicate how it is that the market might go about doing so, assuming rationality. If people aren't rational, this goes out the window. But assuming that they are, this is a complete theory for how you determine risk and expected return. And using risk and expected return, we now have a complete theory for capital budgeting, for how to evaluate whether or not you ought to take a project or not take a project, OK?

And last and certainly not least, we talked about the idea behind market efficiency, the idea that you can actually trust market prices, market rates of return, market betas, all of the

information that you glean from market data and apply them to your decisions. Can you trust them? And the answer is sometimes. When markets are efficient, when prices fully reflect all available information, the power and the wisdom of crowds is very, very compelling. But there are periods where the crowd is not a wise crowd, but an angry mob, like right now.

So you want to be careful and not talk to the market about evaluating your project when they're trying to lynch somebody or some financial institution that's out there, OK? And in order to reconcile efficient markets with these periods of insanity, I proposed this notion of adaptive markets. And at least it provides a consistent framework for thinking about these periods of craziness, as well as periods of market calm.

So that's it. That's it for 15.401. Where you go from here depends upon what your career objectives are.

If you're interested in pursuing investments, if you want to be a trader, a portfolio manager, or get involved in pension asset management, what you want to do is to focus on the investments direction, things like 15.433 Investments, or 15.437 Options and Futures. And we have a number of practical pro seminars that are taught by practitioners, like Seth Alexander, the current Chief Investment officer of the MIT Endowment, or Phil Cooper, former partner of Goldman Sachs who has his own private equity company. There are a number of these practitioner courses, as well as the theoretical courses that we offer that I would encourage you to take.

If, on the other hand, you're looking for something on the corporate financial side-- project finance, corporate financial management, that kind of approach requires that you learn more about capital budgeting, mergers and acquisitions, corporate finance, so 15.434 is a good course, and certain accounting courses. You might want to take financial accounting. Those are the directions that you may want to take if you're interested in pursuing that career path,

So both of them I think are extraordinarily exciting. They all rely on the material that we've covered in this course. And so, you know, you now have the background to be able to handle any and all of that material.