

[SQUEAKING]

[RUSTLING]

[CLICKING]

**SIQI ZHENG:** And let's get started here because today, we have a lot to talk about. And we also have our guest speaker. Professor Golding is here, so he will need 30 minutes-- 20 minutes. OK. And so since Ed is already here, I'm going to first introduce Ed. And later, you can-- just so we can just switch.

So Professor Ed Golding is the senior lecturer at Sloan School and also the executive director of the MIT Center for Finance and Policy-- Golub?

**EDWARD** Golub.

**GOLDING:**

**SIQI ZHENG:** Golub Center for Finance and Policy. But most importantly, before coming to MIT, Ed was the head of the Federal Housing Administration between 2015 to 2017, and also was a senior advisor in the US Department of Housing and Urban Development, HUD, and also in the senior executive at the federal home loan mortgage corporation, Freddie Mac, from 1989 to 2012.

So basically, Ed is a big expert and a huge national reputation for the visionary leadership in housing finance policy. So today, that's why I got Ed here, to talk about the housing finance and the climate risk, how to consider climate risk in housing finance. At first, it was not considered at all.

Now it's become a lot of problems. Now they started to wake up and consider climate risk in all the mortgage risk appraising. So that's what we'll be at last 20 minutes. But before that, I still have one hour to talk about this third lecture of the climate and real estate.

Today-- so basically, for the first climate real estate session taught by Juan, that's basic climate science and how to consider that in the real estate sector. And the second one, taught by me, also some basics and the techniques, like the apple-to-apple comparison in the DID setting, how to quantify the impact of climate risk on real estate values. For that one, basically I just stopped at the residential because I run out of time.

But today's lecture will be not very like basics. It will be a lot of topical discussions. Because now, this is such a new area. It's such a emerging area. No matter it's in the industry, like the mortgage, like the banks, or in academia, it's very new. So it's not very established, the theory or framework and methodologies to study this.

So today, I will just touch on a few very frontier topics. There is a lot of debate and puzzles, and people don't know how to do and like that. And I want to get your thoughts on this. So for today's topics, always, we don't have an answer. We don't have an answer.

It's not like DID or the model and data things-- no answer. But just put these things on the table for your consideration. But also, which means if you want to look into this, maybe there will be very good opportunities for you, no matter for your future jobs or your future research. So that's for today.

So, yes, last time I spent a lot of time for you to understand the DID. So we use the before-and-after hurricane data to quantify, before and after and, also, treatment group and control group to quantify the climate risk impact on residential real estate.

In the paper I mentioned the most, and also in the reading list, is a Hurricane Sandy paper and New York City. Remember that? And then, for that paper, they look at residential housing. And then they quantify a long-term permanent price discount of 8%, remember? That's Hurricane Sandy and New York City. And the 8% is a permanent price discount after that.

And then so many other papers also found similar results-- Miami and, also, Texas, all the things. Then we talk about, OK, now let's think about switch to commercial real estate, not just the houses but commercial real estate-- office buildings, shopping malls, hotels, and, also, apartments. So basically, I want to use a few minutes to cover this.

But first of all, I want you to think about, and tell me some, your thoughts about what's the difference, why I have two separate subsections. One is on residential, last time, and the other one commercial.

So because they share a lot of things. When you think about hurricane and flooding and wildfire, all those climate events, they will cause damage, physical damage, no matter which kind of properties, just buildings. And then they may increase the insurance costs. And then, if this place becomes so vulnerable, people leave, and all will decline.

So what is the common ground of commercial real estate and the residential? And what are the differences when you think about this climate impact? Do you have some ideas why we have this, we want to make this special for commercial real estate? Any thoughts? All the things are the same? If we use commercial, we also get that result, 8% or something, as an impact? OK, Marco.

**STUDENT:** Well, it's different, one is to be, and one is to save. And residential is more to each unit and the families. But commercial is more business, is different language.

**SIQI ZHENG:** Different language? What kind of language?

**STUDENT:** Just all the contract and terms will be different.

**SIQI ZHENG:** OK, contract will be different, yes. OK, yeah?

**STUDENT:** I think, for residential, the owners and user are the same party. For commercial, they are different.

**SIQI ZHENG:** OK, that's also good. But think about-- yes, that's a fundamental difference between commercial and residential real estate. But let's link to climate risks. Think about climate risks.

**STUDENT:** And we're back to that commercial realtors, maybe, you think they have and the residential--

**SIQI ZHENG:** Nighttime, when people are sleeping. OK, good. And what else? Yes, please?

**STUDENT:** So commercial risks, they tend to be on the ground floor. So they might be more impacted by if there's flooding happening, where residential there are multiple floors, so there can be less impacted.

**SIQI ZHENG:** OK, good. So all those are very good, valid factors of the commercial real estate versus residential. And let's think about how people will feel. Because last lecture, remember, I talked about belief. I talked about whether people really believe in climate risk or not.

And then what do you think? If we compare these common households, like us, common people-- of course, in this classroom, we have a stronger belief, and we are more sophisticated in terms of the climate knowledge because we are educated by MIT.

But think about common people, residents, versus commercial real estate owners. What do you think? On average, who will believe more about climate risk and understand more?

**STUDENT:** My guess is the residential, only because commercial real estate owners are more worried about the bottom line and worried about the financials, which climate risk and climate mitigation is going to impact. So maybe it's harder for them to be convinced that there's more dollars and cents to go on.

**SIQI ZHENG:** OK. They care more about the financial value, and that matters a lot, and the bottom line. For the residential, anyway, you have your own house. You need to live there. And then you get flooded, then you need to find a way

So we have three major differences here I want to highlight. Of course, also, all the factors you mentioned just now also valid. But most important thing from the literature, or from all the industry, they said, first, Commercial Real Estate, CRE-- it's not our own CRE, it's commercial real estate, also CRE-- first, more sophisticated investors.

There is a big survey, 2020, to study how this for the institutional investors. Because the commercial real estate always owned by big guys, like BlackRock and all these Boston Properties, REIS, and the big asset management companies.

Those institutional investors, the senior managers, they did a survey. And they found that these 439 executives, they understand more because this is more relevant to their daily business, the bottom line. So they understand more about climate risk.

And also, they have a team. They have their research department, and they have a team of MIT graduates doing the modeling and all the work. So they are more sophisticated. They understand more. So that's why you see all the headlines on the media now. They want to understand how they can respond to the climate risk to cities, to your portfolio, and to your assets.

Secondly, the more important thing is they are big, always because they are big. Because they are big, they have the capacity to hire people, to hire researchers, to study this. They are big, so they worry about their corporate image.

And also, many of them, then, BlackRock, they are fiduciaries. So they have the huge responsibility for the small investors behind them give money to them to invest. So then, no matter it's a social responsibility or their own interest, they need to stand up and say, we are responsible. We need to address this. We need to put high standard on ourselves.

So that's the second reason that you will find, actually, the commercial real estate sector will respond faster and earlier to climate risk because they are big. They have the capacity. And they care about the effects. Put a simple word-- care about the effects. And that's so important for them. If they say, I don't care, then underlying all the small investors behind them, they will not give money to them.

The third factor, also very important, is also because they are big. I always get to this. They are big. Since they are big, so they are always easily targeted by the regulators, like Ed Golding, before you came to MIT, regulators, and also the mayors.

The city mayors, as I mentioned, all the city mayors, all the state governors, they all pledge 2030, 2040, 2050, net zero. And then, after they pledge, after they talk to the media, and then they come back to office, they say, how can I achieve that?

And then they start to target these big guys. Because for example, New York City, for example, Boston, for those big cities, the commercial real estate, actually, is the majority of the total energy use for the building sector because there are high-rise buildings downtown, all the area.

So they say, you must do this and that. You must meet my cap of the carbon. If you don't meet, you pay the penalty. You must renovate your buildings. And also, easier for them to control because they are big. They are so, so, so visible, and they are rich. So they target this.

They won't target it as a small household, and they are poor, and then become housing affordability problem, other problem. So target is the rich guys, big. So that's why commercial real estate really is responding very fast, faster, than the residential households.

And this is a reading I highly recommend you to read. That's in our reading list. This report is, actually, a survey, a literature review and analysis of the literature. And it's James Clayton, a very good professor. And they started this. They started the review-- so many papers.

Then they give us a very good framework to understand the commercial real estate owners, the impact of that climate on that. So I put a person here. Say this is the owner of the commercial real estate. And then you can see they summarize into three major channels-- three major channels. And then you have many, many small channels.

So the first channel is effect on cash flow. So that's commercial real estate. This is the owner. The owner owns the commercial real estate. Then you have the rental income, like that. There's office buildings.

And then you know that if later will become flooded and wildfire and you cannot get tenants, then you lose either the physical damages to your building or you just lose tenants because you are in such a bad location and a reduced income. So that's a cash flow effect. Then you say income and then other things. So that's one channel.

And another channel is increased cost. That's this one. These two are together with the cash flow. So income reduce, and the cost increase because you need to do renovation. You need to do all the resiliency, investment, the other things to elevate your floor and change all the systems. So that's a lot of cost.

So that is effect on cash flow. Anyway, it's so negative. It's become smaller and smaller. And the higher discount rate, that's because it's such a high risk. Think about future. This cash flow is now, for now, if you are in a flood zone and, unfortunately, got flooded. So that's for now.

But think about future, next 20 years, 50 years. So then, because the risk is so clear and the climate scientists have probably a report and other things, then the expected growth is so low and the risk premium is so high, anyway, then you will have a higher discount rate. So that's another thing will damage the value.

Finally, very hard for you to get financing. You go to the banks, you go to the equity market-- sorry. Your building is in such a vulnerable location, the future risk is so high, and so many hurricanes hit this area, we cannot lend money to you, or we will charge you a very high cost of capital.

So then there's a higher cost of capital. And for this, I say after midterm, I will discuss more about this. But anyway, you know these three big channels-- cash flow decrease for now, future risk, higher discount rate, and hard to get financing. So that's all bad news. And the commercial real estate price must go down. So that's the basic idea. Any questions here?

I think it's not definitely. I need to say all the topics I talk today, it's just some discussions now, the very frontier discussions in this industry and in the academia. So although we have this preliminary framework to understand, but you don't take this for granted and say, oh, of course, they will all happen together. No.

For example, our own Bill Wheaton, Professor Bill Wheaton, he is doing research. He's doing research, I think, in Florida or Miami. Anyway, so he is using the data from the apartments to do that research.

And then he found out, preliminarily, this cash flow didn't change that much. He compared apple to apple-- some apartments in the flood zone, some apartments outside of flood zone. Then he compared cash flow, not significant different. People still want to live there. People still want to, tenants still want to, live in those places.

However, he found a big discount rate increase for those areas because investors, they understand. The investors, they understand, for the long run, there may be a risk. So the cap rate increase, but the NOI doesn't change. So that's NOI and cap rate, remember from your roots in finance.

So this is the value. So for the Bill Wheaton's empirical study, this one same, this one going up because the risk premium. And he argued that, for the tenants, they only consider short run. They are not considering next 10 years, 20 years-- no problem. We are going to still rent these apartments. So that's fine. And investors worried. They are thinking about their holding period of 20, 50 years. So they worried.

So I just give you one example to say not all those three channels immediately happen for all the places, for all the commercial real estate. Some happen here. Some happened there. Some happens in other places, which means we need more research.

And now I'm going to introduce our research. So today's lecture, you will see, I impose many, many questions. And if you're interested to see, we just had our CCs prep to discuss topics. If you are interested in some of the topics, come to me. We can discuss how to do CCs together to look into these topics.

And one thing I want to say is this very interesting thing-- maybe we can do CCs together-- last session, Moody's came, Moody's Analytics. Kevin Fagan came. And he gave us a very good lecture on how Moody's Analytics, their research department, they are doing this climate risk modeling. And I just stole these two slides from his lecture.

Remember, he said-- then I asked him, actually-- so Moody's, you are doing this and how we can contribute. Because we are now talking about research collaboration. And he gave us all the data of the climate risk indexes for all the locations in the United States and, also, commercial real estate transaction data. That's the expertise. They become a member of my climate research team.

And then they say, OK-- and from Kevin, you know their idea is the following. They will first get some literature. They also do literary review. Then they got this disaster impact derived from empirical analysis. See here.

So they are not doing this empirical DID work by themselves. Instead, they are-- they are looking at papers. And they try to get papers to justify, to find this parameter as given. So that's Moody's.

I think they are now using 7% for commercial real estate or something, I remember. But anyway, they review many, many papers. They got this coefficient. They are now doing this work.

And then they have their engineering model of the event likelihood. Over next five years, next 10 years, what's the likelihood of flooding in this area, by far it is flooding. And then they combine them together. So this likelihood times the damage, that will be the damage to the cash flow, to the cap rate. And then they derive to model NOI. They model this.

So basically, they have this from the literature. If there is a event and the impact is x percent of the discount times the likelihood-- likelihood as in they have an in-house team to do this engineering model-- and then impact on NOI. They have scenario analysis. Then they have-- oh, for the future of the NOI, then they estimate the estimated lost impact on their properties and all the loans of the banks.

So that's their model. So then we discuss how it work together-- how it work together. Here, we say this one is our CRE's expertise. Because we are not going to just grab a number from all the papers because those papers, they have different data samples. They have different contacts. They have different research methodology.

We cannot just grab a 7% or 8% to the literature, then we just multiply with the engineering model. Instead, we will do a very good, thorough analysis of the real empirical. That's our expertise.

And then MIT has climate scientists. We have the Global Climate Research Center or something and, also, another Climate & Sustainability Consortium. So that's from the engineering school, from all the engineering school. Then we have a better model. Many, many people are now doing the modeling. We have the likelihood.

Combine these two. Then we should have a better model to predict-- forecast-- the impact of the NOI better than this. And Kevin said, yes, that's exactly what we need from MIT. So that's, basically, how you can see MIT and this consultancy work together to improve the methodology of how to quantify the climate risk on real estate.

If you are interested in this part or how you translate this into this part, I think that will be very good thesis topic. So then you can talk to me, and we can help. Even, as I mentioned, we can do a collaboration. You can be the thesis. And jointly, with Moody's you can-- jointly with Moody's and us, so that you get some exposure so that maybe later, this will help your job.

OK, give you a little bit of flavor of what we are doing with this. Because I have my colleagues from engineering school that are doing this. For this, we are doing. So this is a small flavor of this. That's my research we are now doing. Very soon, it will come out as a paper.

So hurricane and commercial real estate we understand. So our point is to estimate  $x$ . This is our purpose of this paper. So we look at these hurricanes. Then we got data. And we got this commercial real estate transaction from RCA. RCA is our, also, collaborator. They give us all the data.

Then we look at Hurricane Sandy from New York and Hurricane Harvey from Texas, so these two before and after five years because I'm going to use DID, Difference In Differences. So we got data from them. And then we have all these hedonic regression variables, all of the things.

And most importantly, the RCA data-- this is commercial real estate-- is different from the residential. I'm not going to do a residential because there's so many papers already on residential. So that's why I chose to do commercial.

For the commercial-- and the good thing is, for that data set, we even know who are the buyers and who are the sellers of these big commercial buildings. Then we can dig out the buyer and the seller attributes, whether they are national institutional investors or they are local or whether small, that, and even their beliefs, whether they believe in climate change.

So then we have 10,000 transactions in New York City and 15,000 in Texas-- not in New York City, New York state. Then I'm not going to do this, but you can see this is very familiar if you still remember what I taught last session of the DID.

This is the transaction price. And this is the DID. This is the interaction term of the surge. The surge is the damage. It's surge damage. It's a lower damage, medium damage, or high damage like that. And this before and after-- post.

And then we do all the things. Then we quantify. This is our baseline model. We quantified the impact of this hurricane on the commercial real estate. And you will see, in Texas, because it's in log, 3.5% decrease after Harvey. And for New York City, it's 1.5 decrease after Hurricane Sandy.

So I'm not sure this is universally applicable to others, but that's our data set of the commercial real estate. Then we quantify the impact. Based on Moody's model, if they want to use us, our results, they will grab this coefficient-- this coefficient-- to their model and multiply this with their likelihood engineering model. So that's our contribution to the Moody's.

And then you will say, why is it small? Well, if New York state is even smaller and, in some counties, why is it not 10% or 15%? Why is it, like, 3.5%. Of course, it's a very random number, but do you have any idea to justify this number? Any thoughts? [INAUDIBLE]? No?

So you would just accept any number I gave you. [LAUGHS] Is that right? Later, if you go to Moody's to do work, and we collaborate, then I will give you a number, and you will believe in me?

**STUDENT:** I have two ideas. First one is we know that New York City is doing a lot of actions on building a wall to protect the city from climate risk. And the second factor I'd consider might be that New York City's housing price is more resilient, or there's much more demand than the Texas housing market, so the price tend to stay higher.

**SIQI ZHENG:** OK, very good. I think that's two factors, very valid and very good. But I also want to add another thing is the information. So information, the new news-- this hurricane is bad news, is a piece of bad news, shock-- and whether this shock is old news or new news.

So the thing is we look at-- actually, you know, this FEMA, they did a very bad job of the flood zone. They gave the flood zone, say, this is the flood zone. Flood zone means 100 year. There's 1% every year likelihood of get flooded-- 1% flood zone. That's a flood zone.

FEMA said, this is a flood zone. And then all the people, especially for these sophisticated investors, they understand a lot about flooding and climate risk. They understand if this building is in the flood zone, then very dangerous, very risky. If the building is outside flood zone, better.

So they just use the FEMA's old version, always out-of-date flood zone. They don't have money to update their flood zone map frequently, so out of date. However, the market participants, they use this to update their information, the belief. They say, oh, dangerous-- OK-- area.

For those places, they already understood it's risky. So this new hurricane is not a new news because they understood the hurricane already. This area, Texas, got hit by so many hurricanes in the past. And then they also know this is a flood zone. So it's old news.

This old news, then, already capitalized into the price. It's not like, oh, I don't know anything. Suddenly, tomorrow is a hurricane. Then I immediately adjust my price down by 10%. No, they already understood, so they already capitalized the bad thing into their price. So additional hurricane hit and won't cause a huge discount because already capitalized.

If this is new news-- and first, you don't know. For example, this one. I thought this one, this is relatively safe because outside the zone. But this hurricane just hit. And this got inundated.

That's very possible because the flood zone is out of date, and every hurricane is different. So this got inundated. Then this one is new news. So this one, you will see a big discount.

So we tested this. We tested outside of the FEMA zone compared to the inside of the FEMA zone. You will see outside zone really got flooded, have a much larger discount, because this is the negative new news, so this one. This one already capitalized, already negative. Already, price is relatively low.

So that's the one factor I want to add. But just know the other factors also hold true. New York City is a huge demand. And no matter what, people still want to have their office headquarters there, so a strong, strong demand.

And New York City may be very rich. This invites all the resiliency, so the investor won't go panic. But for some small places, they have no money to invest in resiliency. And then the companies flee. How many say, oh, I don't want to stay here? Then they have a discount.



So that's another paper. So this is my paper. This is my paper, working paper, but we will soon publish. This is another paper. This is another paper already published, a still working paper. But anyway, you will see this that, actually, they are saying, for those who get hit at a big discount, and they only not get hit, there are smaller discount. But it's information. It's a information channel.

So Sandy directly hit New York-- big discount-- and Boston nearby. But they also feel, oh, it's risky. Now, I understand. Even in the Northeast, we may still get hit by that-- some discount. But Chicago, no discount after these events.

So that's all about this. I think I throw some new questions on the table without clear answer. But I hope you understand my point here is what we can do to contribute. Maybe later, it will become your expertise when you take on your job is to understand how to quantify this to go to the real estate valuation.

We are now real estate valuation-- NOI and the cap rate. NOI is current. Cap rate is future uncertainty. And they work together to influence the V. And then we quantify this.

Now I'm going to use another 20 minutes to discuss insurance market crisis. I think that will naturally link to what Ed want to talk about in the mortgage market, how to price the climate risks. But first, I think both of us, me and all of you, have some basic knowledge of the-- we use flood as example-- the flood insurance in this country.

At first, I didn't know. Even I don't know whether I'm paying that for my house here in Lexington. I don't know. So I dig into this. But this flood insurance now is a lot of debates. That's why I call it crisis-- insurance market crisis. Now it's in a crisis situation.

But now, first, we understand basics of the flood insurance program is called National Flood Insurance Program, NFIP. So this terminology we need to understand. Now we understand this. Insurance rate is determined by the location of your property with respect to the flood zones.

Now, go back to flood zones. I just said FEMA is the institution to publish flood zones. This is the Seaport area. You are now doing studio project here, no flood zones. You must make sure you understand your land, whether it is in the flood zone or not. Is it in a flood zone? I'm not sure. So who are doing studio right now? Yes, whether that area is in flood zone?

**STUDENT:** Some parts-- I think it was lots A and B of our studio was at risk.

**SIQI ZHENG:** OK. Some lots are in. Some are not, right? So because this is linked to our final project, so in your studio, maybe your parcel is here. There's lot-- some lots are here. Some lots are not in the flood zone.

So from the legal perspective of no matter whether this is real, will get flooded. But when you are located in the flood zone, unfortunately, you need to buy insurance, buy the flood insurance, if you want to borrow mortgage from the bank.

If you say, I'm so rich, I just put cash on the table and buy the house, \$2 million, then you are not obligated to buy the insurance. But you say, I can only pay the down payment, I need to borrow money from the bank, and your house is in the flood zone, you must buy the insurance. So that's the logic. That's the logic first.

And then the insurance premium is based on some parameters. And if you can reduce-- you can reduce the insurance premium by some strategies, although, unfortunately, you're building your house in the flood zone. But you can still help yourself, protect yourself.

For example, if premium for this space, they have a base flood elevation, another terminology-- BFE, Base Flood Elevation. You just think of the water level. It's the base water level if you get flooded. And if you are so low and you get flooded, \$9,500 a year-- big.

Now you say, OK, I will use some pillars to elevate my ground floor. And then you become taller, your building. And you have less exposure to the flood risk. Then you can reduce your premium to \$1,400 per year. That's big-- at first, the \$9,000. Now it's \$1,400. It's a huge decrease.

Then, if you further elevate, \$400 a year-- \$400 a year-- big decrease. This means-- you think about this-- if you are a household, you say, oh, how can I invest to elevate my house? Now, of course, you need the money. This is expensive.

Then you say, whether I elevate. If I elevate, I pay less insurance. If I don't elevate, I pay high insurance premium. This is your US money. So this is very interesting. Because-- I'm not sure whether, later, you will have a visit to Seaport-- so-- go ahead.

**STUDENT:** Just a quick question. Looking at the bottom note that these numbers are calculated for a single-family, one-story structure, and talking specifically about the Seaport, which I don't think people are going to build houses--

**SIQI ZHENG:** Single-family houses, yes.

**STUDENT:** --but multifamily. What's the relation? And what's the implicit costs for multifamily buildings, knowing that they are already elevated from sea level?

**SIQI ZHENG:** Yes. And it's not one household decision. If you are multifamily, you cannot say, I'm going to elevate. Then you need to have a committee to discuss the entire building, or the developer, to do this upfront.

This is a very good question, Carlos. And you see this one is from single-family perspective, is try to let you understand easily. So this is a very simple example. This one is more complicated, but the logic will be the same.

These commercial buildings and multifamily houses and all the commercial buildings you are going to do-- design your studio area, land area-- more complicated. But logic is still, you elevate, your insurance premium will go down.

And if you have a chance to visit there-- so I remember I had a conversation with Ioannis. Ioannis is one of your instructors from the building system class. I talked to him because he's now a big developer called WS in this area, built many, many buildings here.

In his area, his buildings, many of his buildings, are in the flood zone. Many of his buildings are in flood zone, which means, later, no matter whether they hold those buildings or they sell the buildings to other investors, the owners will pay very high insurance premium.

And then Ioannis told us, no, we are investing a lot to do this. They are investing a lot in this climate resiliency investment and elevate. This is very simple, but they are doing many, many other things. And they are doing many other things.

They elevate so much and to the extent the city agreed that they are out of the flood zone, which means, although physically, if you look from Google map, the buildings are in flood zone. But they elevate so much, and they have done so much, they are outside in the flood zone. Because the flood zone cannot just sit horizontal. They also understand the vertical side.

Then Ioannis use that as a selling point of their WS project in Seaport, see? OK, if you buy our properties, you don't need to pay such high flood insurance because we have done so much and got all of the flood zone approved by the city like that. Then you will see money.

That is logic. I don't know whether the market will believe that or not. We can observe. But as you know, this also the example that you can do something by yourself to reduce future insurance premium and also because of the risk reduction.

This is another example for you to understand. This New York building-- just know, the other one is Massachusetts. This is a New York building. And if you will do this and that, mitigate the properties against the flooding can significantly reduce the flood risk and insurance premiums.

For example, elevation-- move up-- and put a basement infill. Just infill your basement. Otherwise, your basement get flooded-- problem, damage. You infill the basement, you have no basement now. And just then will reduce.

And also, move your machines and equipment from the bottom to the top if you have several floors. Because then, your mechanical system will avoid to be flooded, so then reduce and put a 1 times something.

So all these small and big investment, then you change the-- your real risk is polar. So your insurance premium will change. Just want you understand this is not fixed. I'll say, OK, in Google Map, you are here. Then you have the same premium. No. This will be determined, all those factors.

It seems that it's very complicated. It's very sophisticated, very good, very scientific, in this way. And I don't know how they derive those numbers, but it seems that they consider many, many factors.

However, there is a big question, high-level, big challenge related to the crisis, the insurance market crisis, is can we really insure against climate risk always? Can we always insure climate risk? If we can always insure, if the insurance system is perfect and we always insure, we don't need to worry. We just pay insurance premium up front.

Later, you get the damage, you go to the insurance company. They pay you back. Done. Then we don't need to worry too much. And what do you think, whether always can solve all the troubles? Please, go ahead. Why?

**STUDENT:** Some things are an unknown. You don't know everything. Some crises are unpredictable.

**SIQI ZHENG:** Unpredictable. But if we have a likelihood, like Kevin's Moody's team, they say they calculate the distribution like that. Do you think that can help?

**STUDENT:** It can help, yes, but there's still--

**SIQI ZHENG:** Still cannot. Any other thoughts? Can we fully insure climate risks? Any thoughts? Please.

**STUDENT:** So it doesn't insure against the loss of income during the period of when the disaster hits. So does it insure against that? I'm not sure.

**SIQI ZHENG:** OK. So the fundamental is the insurance system, the rationale of an insurance system, is the following is to stabilize income. So basically, insurance company helps all of us to stabilize the income, to move money from the good times to bad times.

Think about our health insurance. We pay health insurance money. Now we are all young, relatively young. We are not elderly. So our likelihood to get very sick or go to the hospital, or even die, very small. But we are still paying health insurance.

And when you are old and you have higher likelihood to get sick and get hospitalized, then you withdraw. So that's the basic logic of the insurance, to move money from good time-- you feel good, you have more income, you pay-- and later, suddenly, you are so unfortunate, you're so unlucky, you get a bad thing. Then you get insurance back. So that's the model.

However, the thing is, a systematic thing happens. It's now happening for the climate, which imposes a big question mark on this system, is the rising numbers of disasters. So if the climate change is still always static, like, we can always predict the next 50 years, next 100 years, the likelihood of the flooding, then we use this distribution to design the premium so that we collect the insurance money, the insurance company can collect enough money in good times.

So because this is 100% likelihood. 99 years, you are good. One year, got hit. So that's a 1% likelihood story. Then you use 99 years of the insurance premium you paid to cover your one year loss. That's the idea.

Now, unfortunately, because we are still emitting so much of the carbon and the rising number of disasters-- I think you heard from the media all the time, all this year, so bad and so many hurricanes and wildfires, this and that rising-- so then the distribution becomes not 100 but 2 of 100 years, 3 of 100 years, 4 of 100 years. So that imposes a big challenge to these insurance companies.

Because more and more disasters, they couldn't collect enough money from good times because bad times, they're more and more. Then they go bankrupt-- bankruptcy, almost, because they couldn't collect. But you can argue, say, Why not?

If we later say, oh, because we are emitting CO<sub>2</sub> so much. Now, it's not 1 out of 100 years. It's 4 out of 100 years. Then you just increase the insurance premium. They charge more. The insurance charge more, not \$10,000, but \$100,000 money in the good time. And move to the bad time still can work.

Do you think this works? You say, OK, the climate disasters are happening more and more frequently. So more bad times, less good times. So to make sure the insurance company can still collect enough money, then we increase the insurance premium so that they can collect more so that we are all safe. Do you think this logic can work?

**STUDENT:** I think if this part of the risk, essentially, become a normality, it wouldn't work at all. Because then it just doesn't make any sense to insure this property anymore. If, say, sea floor are going to rise 20 feet over the next 15 years, then all of your buildings, the ground floor are going to be in water. No insurance company will insure that.

**SIQI ZHENG:** OK, It's too much damage. You cannot save that area, even, right?

**STUDENT:** Yeah.

**SIQI ZHENG:** OK. That's very good. And other thoughts, whether we can continue to increase the insurance premium to move money from good times to bad times, to double, triple the interest?

**STUDENT:** I think it's going to be extremely hard because if you think about the plot, it's different from [INAUDIBLE]. It's not something one time, and you can come and fix the thing, and the future is just [INAUDIBLE] and plotting something permanently influence the house value. And if you're an insurance company, you have no insurance policy [INAUDIBLE]. In the long run, there you are going to lose is significant. You have incurred too much.

**SIQI ZHENG:** OK, good. So it's very hard for the insurance companies because it's permanent damage to your house. Then I'm talking about insurance companies. I'm talking about this mortgage market, banks.

So I want to let you know this is a huge-- it's so bad situation, not crisis. But also, there's a huge demand for all of us to do rigorous research and, later, for your jobs, to contribute to this and try to, at least, improve some situation and help this system to work, function, more stably.

So then, just now, I talk about insurance company in crisis. And they cannot insure so much. And also, the climate risk in mortgage market, I think I will leave that to Ed because Ed is a boss of the Fannie Mae/Freddie Mac. You understand much more better than me.

But I think I only want to say one thing, and I want to ask a question, is the following. Of course, this. Fannie Mae and Freddie Mac, they have all kinds of economists. They hire a lot of economists to do this kind of research. They are so smart.

They understand the impact of climate risk on property values. They understand the loans they lend to this household and then, later, securitize and is sold to the investors are subject to these risks. They understand that very well.

And they even have this empirical analysis. And then these two big government-sponsored enterprises, they are backing all these residential mortgages in the country, especially median and the low-income households. These households can get their loans securitized by Fannie Mae and Freddie Mac. That's an implicit subsidy from the government to the mortgage market.

However, these two big guys, Fannie Mae and Freddie Mac, they said, we don't want to price differently loans with and without climate risks when we decide the rate, the mortgage rate, to the household, when we decide whether we lend the loans to the household. Why? They understand the real impact of the climate risks-- flooding, hurricane, and all those things on property values.

And if these houses in these places get hit, maybe will default. Default means loss to the banks and loss to the Fannie Mae/Freddie Mac. They understand all the empirical studies, which is work. Can this work, not work? Then they said, OK, I understand, but I don't want to consider. Why? Guess. What do you think?

**STUDENT:** Well, it just would disadvantage people who obviously want to live in climate risky areas, which, of course, you can say, you don't need to live there, live somewhere else. But there's histories of why people want to live there, and there are communities that are attached to that place. So it's very unfair.

**SIQI ZHENG:** Good. Good. That's a very good answer. What do you think. You're also from DUSP, right? OK. Talk about from this equity perspective.

**STUDENT:** Yeah, I was thinking about the equity perspective. Almost all public housing is in a flood zone, as well. So most of the people that are already in climate risky areas are people that aren't able to adapt as easily and would get priced out of the market eventually.

**SIQI ZHENG:** OK, yes. So, yes, that's exactly-- the social justice perspective. Because if you really accurately price the climate risk in those areas, coastal and, especially, those places, that may introduce discrimination in the housing market.

Because disproportionately, those low and marginalized communities, they are in the places they cannot move. Their mobility is relatively low. They cannot move out. Oh, yes, you can also move to the high ground. But it's very hard for them to move, to leave the community. They lose jobs, and it's like that. And if you price this, then you will compromise social justice because of this problem.

So they have to balance not just the efficiency but also the equity of the mortgage market and how, if you price, what's the consequences, unless you have another program to subsidize them. So that I will leave to Ed.

But clearly, that induce a problem. Yes, you are worried about equity. You are worried about discrimination if you price the climate risks. But if you don't price, that will be a big problem to the entire society, which is already shown here.

So then, from 2006 upward, there's so many new houses built in the flood zone, so many, because there's no additional cost. You just build. And then you can still get mortgage from the bank. They are not going to consider flood risk-- build, build, build.

And the house will go there to buy. There's so many new houses built. And they borrow all the mortgage from banks because they don't consider risk. Then they borrow mortgage in flood zones increase so much.

But for the houses really insured by this National Flood Insurance Program just now introduced, NFIP declined. They declined. Why? Because so many new houses built, and they are going to borrow money from the bank. And bank just lend money to them.

And then they all go to this NFIP to ask for insurance when NFIP run out of money. NFIP is a federal agency. They also need money to provide insurance. Just now, I already said, the insurance is in a crisis because the increasing number of these disasters.

And also, they are federal agencies. They can not increase the premium too much. Then nobody can pay-- out of reach of those households. So they have subsidized the insurance premium. And they have to cover more and more disasters. They run out of money.

They went to Congress, said, OK, I ran out of money. How should I do? Either the Congress give me more money or we cannot offer this subsidized insurance for those households in these areas.

So insurance rate decline. So that's a big problem. We cannot price the risk. Then more houses built. And they got mortgage. And the NFIP went bankrupt and ran out of money, go to congress. Congress, I think they give them some money, but they cannot continue endlessly give them money. So I think that's the current situation. I'm not sure how we can help. We will listen to Ed.

Now we have a new research with Fannie Mae. If you are interested in doing thesis on this, talk to me. So I see so many good research. This just got approved by Fannie Mae. We are going to do this.

We really want to say, if we want to change this situation, baby steps. The first baby step is to train appraisers in Fannie Mae and Freddie Mac. When you appraise the houses-- you know appraisal-- you consider location, and this and this.

Now, if there is a climate risk, no matter whether we will really take action to do that, but you need to do the science. You first understand how the appraisers, you can really price the climate risk into these loans.

So that's our project, to understand whether there is appraisal bias when you don't consider climate risk. And we'll see heterogeneity with variation-- different locations, different households, like that, this and that.

So that's our real project we are going to do in this coming year from now, a year, to quantify the appraisal bias because of the climate risk and then go there to train those appraisers. If you want to do this in the right way, you should do this and this. That's our project. And so that's the Fannie Mae project. So now I have two project-- Fannie Mae project and that Moody's project.

So we already talked about this federal agency, NFIP, run out of money because they're subsidized flood insurance and so many new houses and so many new mortgages that we run out of money. And from the other side, it's a low take-up, low take-up of the flood insurance, even if you are in flood zones.

That because NFIP ran out of money. And the other way is this very low awareness of the things. The households, also, they don't understand. And then they say, why I need to pay actual money? I don't want to pay. So that's a low take-up of the insurance, both from the supply side of the insurance-- no money-- and the demand side, that they don't want to pay extra money. And they very low awareness of the thing.

And then, at first, I couldn't understand this. I thought, it's mandatory, right? It's mandatory if you buy a house, if you want to borrow money from a bank, if you are in a flood zone, then you must buy the insurance that's required.

Then later, I got to know that, yes, when you buy the house, borrow money, you need to buy. That's mandatory but just one year. After a year, you need to renew. And many households forget about this. They don't renew. So you only, when you are borrowing money, that's exact year you buy. Then later, I don't want to renew. Then they just out of this thing, so only 20%.

Only 20% among household flooded in New York City-- Hurricane Sandy and Hurricane Harvey-- all the household got flooded, only 20%, they have insurance. That's a big problem. And of course, highly educated, they have higher take-up rate like that because they understand. For those who they don't understand, that's a problem.

Now the insurance market is start to wake up. They start to wake up. Oh, it's a big problem. We cannot stay in this way forever. Then they have the risk rating 2.0 arrow. They say, OK, we must make sure the insurance premium really reflects the risk, that we move money from the good time to bad time in the right way. That's kind of reform right now for the insurance market of 2.0.

So I will be very brief. But anyway, you understand. So this will introduce more and more differences, variations, in the insurance premium based on the risk increase and also because this national agency ran out of money, federal agency ran out of money.

And then, overall, all the households will see a increase. We will see a increase. Only about 23% will see a decrease. And all those will see the increase, and more and more increase of your insurance premium if you are in the flood zone.

Of course, a lot of pushback from communities and household, the home buyers. Why, we say, the insurance, the government, need to subsidize like that? But anyway, the thing is NFIP ran out of money. They go to Congress. They give some money but still run out of money, still will continue to lose money, so increase. And they reflect.

And then they also understand now, now the NFIP insurance premiums so inaccurate, although they have these numbers, or if you elevate, your premium reduce like that. But look at the country. Look at the country-- average expected annual loss for damage, climate damage, higher than the average premium.

All these dark areas, the real damage much higher than the premium. Only those places because I think this risk may be lower. And the coastal area is a wildfire area. All those places, hurricane places, insurance premium low, damage high, so cannot sustain.

However, low-income communities, very difficult for them, so difficult for them. And for example, this area is White Stone, Virginia. More than a fifth of the household fall below the federal poverty level. And they have to pay the premium higher, like 500% higher than, nowadays, the premium.

How can they pay? They are below the poverty line. And they are living in these vulnerable locations. And then they say, OK, risk rating 2.0 increase the premium to reflect the real risk. Then how can they pay?

And then another final point I want to make is another crisis is following. Now I talk about NFIP is a agency, federal agency, ran out of money because it's federal. So they subsidize-- subsidize. That can justifiably, and they subsidize, if the Congress continue to give money to them. And there are private insurance companies, also.

The private insurance companies is following the problem. I think this is the last slide. The states, depending which state you are in, if the states say, OK, we want to regulate the insurance companies, you cannot charge very high insurance premium because that will hurt all my people, then they say-- the regulators, they require home insurance, those companies, no matter you are public companies or you are private companies, based on the historical laws, not the future laws.

And then they say you cannot charge too high. If you charge too high, that will become a problem and will hurt the communities. Then we call it a high-frequency-- no, high-friction states.



And then the insurance, the private insurance companies, they are leaving those states. Because the private insurance companies, they don't have the obligation to subsidize. They will price in a market way. When they price market, they want to increase the insurance premium because they understand, we need to look at the future, not the past. Because all the disasters are rising.

And they say, we want to increase. The state governor said, you cannot increase. We have the regulation. You must look at the history, not the future. And we don't want you to increase the premium too high. Then they wave bye-bye. I don't want to run business in your state. It's hard. I'm losing money.

So they are leaving those states because, for those high-friction states, the loss and the rate are almost flat. No matter how big a loss you are, you cannot increase your rate. But they are leaving.

Then the households in that state cannot find enough insurance company to buy insurance, even if they want to buy. Because that federal agency cannot supply so much insurance, although it's very low rate. So those all the puzzles, and we don't know how to resolve.