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ROBERT TOWNSEND: Well, good afternoon, everyone. Thanks for joining. So this is 14.04, and the title is Economic Science. You'll see why momentarily.

So in terms of who we are, I'm Professor Townsend. I'll be teaching the main lectures. So what is this course about? This is about not just theory and certainly not just data. It's about the combination of theory and data from the perspective of economics as a science.

So in that respect, it may be a little bit different from classes that you're used to. It's not to memorize theoretical material and know which way to shift a curve. It's not just reading empirical literature and discussing it. It's the more challenging and more fun job of bringing those two things together.

Background quickly, just in case you're worried about it-- we do assume you've had multivariate calculus as well as basic economic theory in 14.01. There will be some use of linear algebra, statistics, and some language having to do with algorithms and computing. But you're not to worry about that because if you are not familiar with the level that we need, and it's not a very deep level.

In terms of the readings, all the class readings and the relevant textbook chapters, there's not one single textbook for the class. There's four or so. But we carefully selected the relevant sections of those textbooks, and you don't need to scramble to find them because they're on the class website.

So each topic in each lecture has a set of readings. One, two, or three will be designated as a star. And that's because they're really the basis of the lecture or provide key complementary reading material.

You are responsible for those in terms of exams, and you'll need them for problem sets. There are other things on the reading list, recommended readings that I hope you will engage in and enjoy. And in fact, those could be subjects for discussion in Piazza.

We're going to focus on theory and applications. We're going to be using empirical and theoretical papers. And ideally, we are combining them.

As I was already alluding to, this is not an easy thing to do. One has to learn how to do this. And I'm sure you cannot do it on your own, so I strongly encourage you to participate in the lectures, and recitations, and interactions.

But anyway, please engage when you're online and avoid texting, tweeting, emailing, blogging, et cetera, et cetera, shopping. You may think that you can multitask, but typically quality of learning would suffer. So now we get into the more fun part, which is what are we going to be studying in this class.

And I'm going to go over the spirit of it, economic science, and talk about the economies we're going to be studying, and then go through the syllabus in a kind of a broad way, not trying to read everything that's there. So I'm going to draw on these authors-- Frisch for thinking about economics as experiments, Matzkin for a review of some of the fundamentals of vocabulary of econometrics, Angrist for randomized and natural experiments, Varian for big data and the need of theory for causal influence, and Lucas on what are models, what are artificial economies, and what is the role of models versus data, and how does computation help us. So that's just an outline of what's coming.

Frisch opened his lecture in 1926 with an article entitled "On a Problem in Pure Economics." And to quote him, he said, "Intermediate between mathematics, statistics, and economics, Econometrics"-- he kind of invented the term-- "has as its aim to subject abstract laws of theoretical political economy or pure economics to experimental or numerical validation, and thus to turn pure economics, as far as possible, into a science in the strictest sense of the word." Or to put this more in layman's terms, he's saying economics is not just about theory, it's about validating theory. So just like the linear accelerator at Stanford bombards particles to see whether the outcomes are consistent with the predictions, that's our framework for thinking about actual economies, by running experiments on them to validate them and to do policy.

This is a graph from Burns and Mitchell, a book, *On Business Cycles.* And if you look closely, you'll see these dates are pretty early. They run from 1875 to 1900. And as a business cycle goes, it's talking about depressed activity versus upswings and so on.

And you can see the ups and downs. You might be interested to know that the National Bureau of Economic Research, which is now housed here in Cambridge, actually began in Columbia, where Burns and Mitchell were working on this. So Koopmans reacted to Burns and Mitchell's book, which was quite famous and obviously had an enormous influence, arguing about whether measurement is enough, which he says, no, we need theory. And we need the whole enterprise to be about understanding and utilizing the framework for policy.

So there's a bunch of quotes here from Koopmans in this famous article, Measurement Without Theory. He says, "The author's scientific strategy has measurement and observation preceding, and largely independent of, any attempts to really explain" the variables. But he, Koopmans, believes there should or could be more of a purpose-- that more is meant, namely, a genuine explanation of economic fluctuations, with the idea that there are a few extra economic phenomena that are accepted as data without inquiry. But most of it has to do with phenomenon being generated by assumed behavior of individuals and the interaction of the behavior in markets.

And then he goes on-- I don't know if this is tongue in cheek or just soft selling-- "I am not sure whether a still further objective is included, which extrapolates the idea of explanation to prediction, within "the narrowest attainable limits, the effect of economic policy on the movement of economic variables. He actually says, I feel that prediction is actually the most important objective of the analysis of economic fluctuations." So again, it's not just measurement, it's measurement with theory for understanding, and with that baseline conducting policy assessments.

Business cycles are still with us, although this discussion may seem a bit dated. So I give you a contemporary example, which is measuring, understanding, and predicting the economic impact of COVID-19. And we will return to this theme periodically throughout some of the lectures.

Matzkin is about econometrics, and she delineates the ingredients here quite well. We have an economic model describing the agents who are involved, their objective functions, their information, the way they're interacting. The econometrician tries to fit the economic model to the data and has to make the following distinctions-- first of all, which variables in the model are observable and which are unobservable? Also, which variables are determined outside the model versus those that are determined inside the model-- exogenous versus endogenous?

Variables determined within the model are usually determined by the choices of agents, by their interaction with each other. The model also contains a list of functions and distributions. Some of these functions are primitive, exogenously determined. They may be observed or unobserved. And others are determined within the model itself. They're not deep concepts, but important to remember-- observed versus unobserved, exogenous versus endogenous, parameters versus functions versus distributions.

Josh Angrist on running experiments, as in randomized controlled trial versus quasi-natural experiments. So he's referring here to a genuine randomized controlled trial engaged by Fehr and Goette, where they selected some bicycle messengers to receive temporarily higher wages, and had a control group that did not receive the increase. And then you compare across the two groups.

The study showed that increase in wages did make people work harder. And because it was temporary, it didn't really change lifetime wealth. So one is able to out the impact of income changes as opposed to wealth changes, or in the jargon you'll learn, we can identify the intertemporal substitution of elasticity and its magnitude.

But Josh goes on to say experiments are time-consuming. They're expensive. They're not always practical but. This frame that we use of experiments is still very helpful, especially because human institutions or the forces of nature step into the breach and provide natural or quasi-natural experiments.

So an influential paper by David Card looked at the Mariel boatlift. Fidel Castro temporarily allowed free exodus of Cubans to the US, and they came to Miami. There was a 7% increase over a period of three months, and that can be used to study the impact of immigration.

Another example is the destruction of public housing in Chicago, where they literally were giving residents alternative places to live, and then dynamiting the building and blowing it up. And it's documented that they chose in effectively a random way which building to blow up. And so you can compare what's happening in public housing that remains versus what's happening to the residents who have been moved elsewhere.

And to a degree, the financial crisis also provides something of a series of natural experiments in banking. So I'm not sure how many of you have heard this term, "big data." It's quite widely used and attracts a lot of attention.

And Varian is talking about that. Machine learning specialists are primarily concerned with developing high-performance computer systems that provide predictions in the presence of challenging computational constraints. Data science is a somewhat newer term, concerned with prediction and summarization, but also manipulation, visualization, and other tasks.

However, the shoe drops-- most important area for collaboration involves casual inference. Machine learning has its part to play. It deals with pure prediction. But there's a difference between correlation among variables and causation.

And he gives this example, which nowadays is a bit more nuanced than it was when he wrote it, a classic example-- there are often more police in precincts with high crime, but that does not mean that increasing number of police in a precinct would increase the crime. In other words, what he's trying to say is which way does the causality go-- from police to crime or from crime to police? And just seeing a correlation between police and crime in the data does not tell you what the outcome would be of increasing the number of police.

So Rubin who's an advocate of-- who's thought of as in the behavioral group-- is actually in agreement that we need to think about the causal impact of treatment to compare outcomes of an intervention to what would have happened without the intervention. You can't do it alone with data. You need some model to do that.

Lucas on artificial economies-- one of the functions of theoretical economics is to provide articulated, artificial economic systems that serve as laboratories in which policies that are prohibitively expensive to do in actual economies can be tested through the model at much lower cost. But he goes on to say that to do this well, it's really important to distinguish the artificial model economy as sharply as possible from actual economies. So this is a bit subtle.

Insofar as there is confusion between the statements of opinion as to the way we believe actual economies would react to particular policies, and confused with statements of verifiable fact as to how the model would react, then we're not using the theory effectively. In other words, people will make statements about what they believe will happen as a consequence of a policy change. And the danger is we may not know, and they may not be clear, if their prediction of what would happen is based on data or based on the logic of a model.

And then going on, if we have the model, we can see the predicted outcome based on the logic of the model. And then we can go to the data and see which statements of opinion are accurate or not. So that's Lucas's view of the science of economics. And in other words, instead of being pushed toward what would seem to be an attractive goal-- to make models more and more complicated so that they're more realistic-- Bob Lucas is actually pushing the opposite point of view, which is to earmark them as artificial, potentially relatively simple, so that we can understand the logic of what the models predict.

Well, as I said, keep them relatively simple. On the other hand, economists are getting better and better at writing down and analyzing models. And one of the innovations that has happened over the years is not just the mathematics, for which Bob Lucas is well known along with his economics, but also the ability to compute solutions, which he feels is neglected in the history of economic science but which is, in fact, an important consideration.

So you guys are all MIT students. I probably don't have to say this, but we in this class are also not going to shy away from computational issues when they arise. And I will take you through some of the algorithms and share those with you.

Now I want to turn to the description of five economies. And they're also partly representative of the kind of economies we're going to be studying in the class. And then I'll get back to economic science, and we'll talk about how we're going to analyze them.

So let me focus on economies for now. So the first economy, the medieval village economy, consists of about 300 households. They can grow wheat with plows, oxen, and of course, land. But the land is not consolidated. The land is spread out over the various fields into long narrow strips, quite fragmented-- on average, something like 30 to 60 strips for each household.

Second economy is a Thai village economy. Households are growing rice and they're growing it in paddies, not in scattered land. If the monsoons are overly abundant, households with low-lying land will experience flooding and households with land on the rise actually do quite well.

But the opposite is true in a medium to dry year. The low-lying land does well and the land on the rise is subject to a drought. So there's a lot of variation, a lot of risk.

All households in the Thai village are obliged to transfer a certain amount of their crop to the local temple. Buddhist monks run the temple. Then the households with low crops in a given year can request an allotment from the temple stocks.

And they don't even necessarily have to repay right away. That's a function in subsequent years of whether they get their yields back up. And otherwise, remarkably, there's no borrowing and lending in this village, just this institution.

The third economy is drawn on a description of Oaxaca in Mexico. It's a set of villages, not just one. The villages are separated from each other by nontrivial distances. Sometimes it's flat land on a plain. Sometimes there were rivers, and valleys, and other topographical features.

Each village specializes in production of a distinct good-- could be baskets, or pottery, or textiles, machetes. They produce a lot of that good and relatively little of the other ones, but each village values the commodities which it does not produce. And then trade occurs in a series of regional markets.

The fourth economy is similar, except that when traders meet in these geographically separated markets, they're observe to give up produced goods, not for other goods but for paper notes, which are IOUs promising to pay goods in the future or pay money in the future. So these notes are observed, and used in exchange, and circulate around the regional markets.

The fifth economy is from Malinowski's book *Argonauts of the Pacific.* It's another set of islands-- well, villages, but they're on islands. And they form a circle.

So typically, residents of each island embark in canoes on trading expeditions, traveling either in a clockwise or counterclockwise direction to the nearest island neighbor. If they're traveling in a clockwise direction, when they reach the beach of the island of destination, they give up their cargo to those neighboring Islanders in a series of elaborate ceremonies. The goods go one way and distinctive white-shell armbands come back.

If they were traveling in the other, opposite direction, counterclockwise, and they reach the nearest island, they unload the cargo and receive distinctive red-shell necklaces. I'm not making this up. It's in the book.

These armbands and necklaces are entirely used for these ceremonies, to prohibited to be used for other things. And it's very, very rare for cargo to arrive without the shells and armbands going in the other direction. So at this point, you may be a little worried that we're about to study villages and anthropological works, but let me draw an analogy that is revealing about the way economists think about modeling economies.

Lucas-- the same Bob Lucas I mentioned before-- talks about trees bearing fruit, which is an agrarian metaphor, but he didn't really mean a village. And Lucas doesn't like villages very much, actually. He actually meant financial markets. So a security is an asset like a tree that bears dividends like fruit. So this is the language that allows us to go back and forth from something concrete, like a tree in a village, to something a little more abstract, like financial securities.

One of those economies, the fourth one, mentioned IOUs. They were bills of exchange historically, and now they're called repos. So these treasuries used as collateral to back loan, called the repo contract. And that repo will circulate where the original borrower becomes a lender, and the repo contract goes down the financial chain, and then comes back.

And that strange Malinowski economy I mentioned to you is actually a close analogy to Bitcoin. Because Bitcoin tried to keep track of histories of things to condition outcomes. And they realized they need to "color" the coins in order to distinguish more history.

Nowadays they do it differently. But there was a period where Bitcoin was featuring colored coins. And that's very similar-- the economics of that is very similar-- to these seashells in Indonesia.

So I've gone all the way from villages, if not primitive economies, to not only modern-day financial markets but also to Bitcoin. And I'm, in the class, going to maintain and come back periodically to a study of Bitcoin of blockchains and distributed ledgers, thinking about it as innovation in the technology.

So what is a distributed ledger? A distributed ledger technology refers to the processes and related technologies that enable nodes in a network or some arrangement to securely propose, validate, and record state changes to a synchronized ledger that is distributed across the network nodes-- a bit long-winded. We'll come back to it.

Is it important? Yes. This from Harvard Business School colleagues, Iansiti and Lakhani, a quote from them. "Contracts, transactions, and the records of them are among the most defining structures in economic, legal, and political systems. Yet these critical tools and the bureaucracy formed to manage them have not kept up with the economy's digital transformation. They're like a rush-hour gridlock trapping a Formula 1 race car.

With blockchain, we can imagine a world in which contracts are embedded in digital code, stored in transparent shared databases, where they are protected from deletion, tampering, and revision. In other words, the entire landscape can change with these new technologies. Although the Harvard Business School colleagues are trying to be neutral, their enthusiasm is evident, and there's a lot of controversy about Bitcoin and about blockchain.

So Satoshi Nakamoto-- we don't know if he's real or not-- this is a pen name, presumably-- invented Bitcoin. And in doing so, he said, "What is needed is an electronic payment system based on cryptographic proof instead of trust, allowing two willing parties to transact directly with each other without a need for a trusted third party." Well, this message was not lost on central banks, because Satoshi is basically saying we don't need fiat money, we just need Bitcoin, or Bitcoin can replace Fiat money.

So you'll see the Banker International Settlement with statements like, "Decentralized technology associated with cryptocurrencies, however sophisticated, is a poor substitute for the solid institutional backing of money." Or Denison, Lee and Martin, two of whom are co-authors of mine at the New York Fed, "People do trust third parties.

They trust central banks to provide currency and reserves. And they trust derivative payment systems that are run by named and trusted institutions-- he has in mind commercial banks-- that maintain the ledgers and the operating system. Trustless, expensive, decentralized systems are not needed."

Many of these distributed ledger platforms promoted by the industry use the word "disintermediation." Now, if you view it kindly, what they mean is third parties are extracting monopoly rents. But if you're a regulator and you see someone trying to disintermediate the financial system, you're going to be a little bit worried about that. So it's a very interesting, a very controversial area. And every, I don't know, five or six lectures or so, we'll come back to the theory and data that we've been dealing with, and ask questions about Bitcoin, and see what we can learn through the lens of economics.

So I listed previously five economies and the comment that they're metaphors, including for the study of modern economies, including all the way through Bitcoin and things that are happening today. Here's a partial list. We're going to study the medieval village economy.

We're going to study village India, northern Thai villages. We're going to go from villages to local economies as in Oaxaca, in this case Thailand, to regional economies to the whole national economy. So we're as much talking about nation-states as we are about individual villages.

In fact, we'll go to the United States and talk about local, state, and the US national economy. We will be looking at US financial markets, as well. Here and there we'll talk about China, which you might say started as a village or a bunch of villages, and has become a very important international player. So that's a list of economies.

Now, what do we mean by an economy? When we model them, there is a systematic way to do this that you will learn. And that is, when we write down an economy, we mean to specify the commodity space. And within the commodity space, we'll talk about the preferences of agents, their endowments, and the technology available to them.

So one way to remember this is like a PET economy. It is not the most favorable way of thinking about it. But PET is in preferences, endowments, and technology.

And it is possible, when you're learning the tools of how to do the analysis, to get so lost in the notation that you'l forget about the applications. So I want to keep coming back, even on the early building-block lectures, to the idea that we have a common way of constructing economies that will allow us to consider dynamics, allow us to consider geography, and allow us to deal with risk and uncertainty as in states of the world.

So now, I want to be more specific about what we're going to be doing in the class. And I'm going to do this in two ways. The first is to go through the main headers so you'll see the content, and the topics, and a bit of the methods.

And then I'm going to come back and kind of selectively look at the smaller print and make some auxiliary points. Well, today is Lecture 1. We're talking about economic science.

Then starting Thursday, we're going to focus on the building blocks for constructing economies. As I said, preference, endowments, and technology. And we're going to try to use that material right away. So we'll be engaged in conducting some partial equilibrium applications and experiments.

So the building blocks are consumer choice, consumer behavior, and production. This is the traditional way to teach micro, but it tends to consume much more of the course than we will. I want to get the basics down and build on the basics, as I have been saying. But here, you may lose track of the fact that we're doing these building blocks which we're subsequently going to use when we're constructing economies.

The next section, Lectures 5 and 6, talk about decision-making under uncertainty, focusing on risk and on linear programs and dynamic programs. And I'll come back to that momentarily. Then lecture 7 through 9, we finally get to entire economies. We'll develop a concept of welfare called Pareto optimality.

And we'll right away move toward applications, risk sharing and dynamics in village economies, including social networks, supply chains, impact of health shocks. And here right away we'll get into the impact of COVID as a function of whether or not there are these insurance networks. And we'll merge this with supply chains and production as in lecture 9.

Lecture 10 is about financial accounts and management. So it will talk about income statements and balance sheets, and household financial statements generally, and then also talk about cash management, which brings us to Bitcoin. I promise Bitcoin in distributed ledgers. "Ledgers" means "accounts," so this is the natural way to start talking about Bitcoin, and ledgers, and management.

Lectures 11 through 12 start to bring in obstacles to trade, in particular private information, where we need to think about contracts and mechanism design. So we'll do this in theory and we'll add an application right away. And we'll actually do several applications.

Lectures 13 through 15-- these three lectures are going to deal with the definition of a competitive equilibrium, or Walrasian equilibrium, in the general equilibrium setting. And we're going to use it for prediction, namely what is the impact of trade or tariffs? What is the impact of not only real, but also financial liberalization and repression? We'll do that in Thailand and we'll do it in the US.

Then lectures 16 and 17 deal with whether or not competitive equilibria are Pareto optimal, and with issues of existence of competitive equilibria and Nash equilibrium. These two lectures, 18 and 19, are a juxtaposition of the micro and the macro, the macro being dealing with aggregates from the top imposing the structure, basically from above, versus juxtaposed with the micro and the data, where we can talk about whether anything can be really identified, talk about identifying, identification, and falsification.

And the last two lectures focus on the failure of the two welfare theorems, which have to do with whether competitive equilibria are optimal and whether optimal allocations can be supported as competitive equilibria. Those two theorems can fail, but there are interesting consequences of that. Namely in those economies, we have value intrinsically worthless but valued money.

We can talk about the value of Bitcoin, for example, and other cryptocurrencies. And we can talk about monetary policy. And indeed, we can focus on bubbles, and not whether bubbles are bad necessarily, but ironically, whether they're big enough.

So those are the broad headers I'm quite excited about the class, and teaching the class, and interacting with you. Hopefully, going through that, you can see how much material we will cover and the importance of the material.

But let me come back a minute, without going into the details of everything here, to let you in on a secret of the strategy. So when we get, for example, right away on Thursday to consumer choice, we'll be talking about consumption sets, and rational preferences, and utility functions, and properties of various things, which is extremely important. But we jump into an application even in that lecture, which is utility maximization subject to budget constraints.

And in order to do those things, we need our first major method. So we're going to talk about constrained optimization and the use of Lagrangian programs. So the not-so-secret secret is going to be that we're training, hopefully, learning the methods of analysis, as these theories and topics come up. Usually in every lecture or almost every lecture, there's something about a method that will be very powerful that I'll want you to learn. And we will take the time to go over it.

Consumer behavior, which is Lecture 3, is an elaboration on the application, which is what happens and how do consumers behave when prices are moving and their incomes are moving about. So there's some abstract stuff you may have seen before about normal goods and Giffin Goods. Instead of just memorizing that stuff, we're going to go to an actual economy, which is China, where the authors actually did one of our randomized controlled trial experiments, and varied prices, and looked at whether or not demand actually went the wrong way-- demand went up when prices go up.

And then we'll learn some more tools. We'll make this distinction between compensated and uncompensated demands, duality, Slutsky-- doesn't mean anything now, probably. But again, we're building towards statements of if you had data, could you use data to accept or reject a model. So the mapping from the theory to the data, as Lucas would have put it, is happening with the ingredients at the end of Lecture 3.

Lecture 4 is on production. That's the second building block. And there we do production functions, inputs and outputs, return to scale. But again, we jump to an application, which is profit maximization, which is the analog-- firms maximize profits given prices, consumers maximize utility subject to prices and income. So we'll go through that and derive some properties.

And then up pops another method, namely, we need something called the Envelope Theorem. So when we get there, we can go over what that means. And then we jump back, at the end of this lecture, to some fake economies. Robinson Crusoe economy is one of the economists' all-time favorite-- an island populated by one person, essentially. But that immediately leads to international trade, two-country examples. And I'll show you some work that Leontief did on Input/Output matrices that is actually relevant for understanding Google search algorithms and for studying the great East Japan earthquake.

And on this topic of decision-making under uncertainty, we will talk about risk and measures of willingness to get out of risk if you had the option to buy insurance. So we will go through some important concepts. But then we will immediately apply it to the medieval village economy that I've already referred you to, and including land fragmentation.

And then for methods we'll be focusing on linear programs. And that carries over, not just to this topic. But we will use linear programs frequently from this point on through many of the other subsequent lectures.

And coupled with linear programs are dynamic programs, where things are happening over time. And the application there is going to be, why were these medieval villages starving to death every 12 years, even though in principle, they could be storing grain? They didn't do it much. And the method is going to be dynamic programming and value functions.

When we get to Pareto optimality, of course, we'll define what it means. We'll talk about the Pareto frontier. We'll have our first genuinely spelled-out economy, an Edgeworth Box Economy in the abstract. I'll show you a way to determine the set of efficient Pareto-optimal allocations for any given economy.

And then we have another tool, separating hyperplanes. And I'll define it and show you some pictures. And then we go right away to an example, which has to do with how would you know whether an economy is really efficiently allocating risk or not?

In fact, the next two lectures do that in much greater detail, going to Village India, which I mentioned was one of the economies we were going to study, looking at relationship between consumption and income, and then go back to the medieval village economy, and try to understand whether the way they were dividing up land into those narrow strips would or would not be consistent with an optimal allocation of risk bearing, and under what circumstances.

And then we throw production in there, as well. So now we have risk, consumers, and production. And we'll talk about risk and return, and risk premia, whether they share idiosyncratic household-specific shocks, what to do about common, macro-aggregate shocks. And this part of the lecture ends with the role of gifts, the role of social networks, and the transmission of shocks in villages.

The transmission of shocks is actually a health shock. It wasn't a COVID shock. But it does give us a way of thinking about the impact of COVID in terms of impacting a household, and whether or not they have formal or informal coverage to cover that bad shock, and if they don't, how the impact can spread around to other people that they've been interacting with. And I don't mean the spread of the virus. I mean the economic adverse outcomes that propagate, not the way the virus propagates, but through economic mechanisms.

When we get to household financial accounts-- I mentioned this already about five minutes ago-- we'll talk about ledgers and management. We'll talk about household financial accounts because we need them to understand ledgers. With the income and the balance sheet, we can talk about life cycle management.

And I'll show you a wealth planner, a life-cycle wealth planner that we implemented in Thai villages, and show you an analog wealth planner for the US. Then we merge to Bitcoin, for which you need to understand the statement of cash flow and the relationship between the flow and the stocks, as in the balance sheet and the cash flow, which will take us to thinking about alternative economies, for example Thailand, again, which is still using paper currency all over the place-- and we'll talk about whether that's efficient or not-- to Sweden, which has virtually no currency left.

It's a virtually cashless economy now. They're worried about that. Instead of fighting Bitcoin, they're thinking about introducing a central bank digital currency. And we'll talk about that.

And Kenya is a poor developing country in between, where they have both Kenyan shillings, which is fiat money, as well as an electronic money, M-Pesa, which are claims on your cellphone-- basically cellphone accounts, cellphone credits. And we'll talk about some of the issues that come up with distributed ledgers in all those three contexts-- Thailand, Sweden, and Kenya.

We'll get to contracts next, which has to do with private information. In terms of methods, I'll share with you something called the Revelation Principle, which allows us to append some extra constraints onto things that we did previously and continue to use the same methods. Here, we'll need some lotteries to get the commodity space to be tractable.

And in this lecture, we'll go to those Harvard Business School professors and talk about smart contracts-- what it means, how to implement solutions to mechanism design problems. This part, again, is now, when you understand contracts, the language of smart contracts will make more sense. We'll do both together, and then we'll have applications studying contracts in practice for small and medium enterprise in Thailand. In this case, again, one of these lectures where we combine the theory and the data together to make inferences about what the obstacles to trade are.

So then we get to the Walrasian Equilibrium, competitive equilibrium. We'll define it, and we'll immediately apply it to the concept of trade across countries, the gains from trade-- or actually, who loses, not just who wins from trade-- and some well-known theorems about that, about the effect of trade on wages and input prices.

With that theory in hand, we'll go to two different economies. We'll go to Thailand and talk about villages as small open economies, what's been the impact on them of increasing trade within the economy, the impact on them in terms of the opening up of the financial system so that money is flowing more easily, which is the flip side of tariffs. And there are losers to liberalization, just like there are losers to trade. So the thrust of all of this is try to use the model with the data to identify who wins and who loses from trade.

And then, obviously, we'll be set up to talk about the US in terms of the thing now called the China Shock, which is the rise of China, the rise of China exports, into Europe and into the US, and the impact that has had on various states that used to produce goods, which are now not so competitive with Chinese imports. Regardless of your view, you can see the importance here. Because what's going on in the US and these policy measures that are adopted having to do with trade, and which used to be NAFTA and so on, and now it's pulling out of the Asia-Pacific Agreement and having this contest with China. So we want to look at those issues, not from a political standpoint but from an economic standpoint, to understand what we know about the beneficiaries and the losers, and ideally try to quantify that.

This section is also about the data available to do the analysis. Sometimes we have far less data than we wish that we did. And in particular, I have a section which I have to update periodically on what is the impact of COVID-19 on the US economy.

And again, we'll go back to what's the impact on income, looking at income levels, and ethnicity, and so on, but also what's the impact on the balance sheet and on debt. And we know some things, but you will discover that the integrated data is not available in the US. So there are actually surprising things we don't know.

Likewise, all this discussion about inequality, how much wealth the top 1% own-- that's much less securely measured than you might imagine. And we'll go into the reasons why. And we have optimality of competitive equilibria in existence. We have theorems-- existence of competitive equilibria, existence of Nash equilibria. For the Nash equilibrium, we'll go to a model of US financial markets and try to analyze why we see trade fails, where those repo contracts fail, and whether penalties could or should have been in place to prevent those failures.

I think I said enough about aggregation and identification already when I went through this the first time. And we end with when the welfare theorems fail, but not stopping there. The analogy with pollution is to fix it by selling rights to pollute.

We'll talk about how to handle externalities much more generally. We'll talk about failures of the First Welfare theorem when there's dynamics and an infinite amount of wealth. And likewise, when it fails, we'll see the emergence of money-- both fiat money and Bitcoin.

One word about Bitcoin-- when the former head of the New York Fed referred to Bitcoin as the adversary, he was saying something about there's nothing fundamental pinning down the value of Bitcoin. Well, if you're a central banker, don't throw stones when you live in glass houses, because there's absolutely nothing fundamental pinning down the value of the US dollar, either. And the same model will make clear that statement, and hence, why it's possible Bitcoin is volatile and danger, again, for fiat money, and remedies having to do with monetary policy.

And again, the course moves systematically, so try to keep up. Thank you.