WILLIAM BONVILLIAN: So today, we really kind of talk more about the system, the kind of third direct innovation factor, and then about these indirect factors that are important and significant, but not as powerful, I'd argue, as the direct factors. But first, let me just recap last week just really in a few seconds, and then give us a glimpse of what we're getting into. So last week, Robert Solow, the great growth economist, developed-- really created growth economics-- developed the theory that the dominant causative factor in economic growth was, quote, technological and related innovation, a phrase that you'll hear all the time here.

And then we followed up that discussion with talk about Paul Romer and his work on human capital engaged in research as a kind of second key direct innovation factor. That's the talent base that has to be behind the R&D system. We read Dale Jorgenson who told us that, yes, in fact, this innovation based economic growth model is in fact correct.

That's what happened in the IT wave and he showed us, in effect, how that occurred. The model was you do an invention or a core group of inventions, they begin to scale up, applications pile on them, they enter into the economy and really begin to scale up in the economy. And eventually, over time, become a true innovation wave. And we'll talk more today, as you know, about innovation wave theory.

We also read a piece by some Merrill Lynch analysts, and the fundamental point in that piece was that industry is very interested in innovation, but they're only prepared to fund the very short late stage of it. So somehow, even though the evolution to innovation is a very long-term process, the financial sector is only going to dive in as close as they can to certainty-- in other words, at a very late stage. So those were kind of our four core readings.

And one other idea in that Merrill Lynch piece was this notion that innovation needs to move through a series of stages to kind of get there. There needs to be an early vision-- kind of a visionary who will set out what could happen. And then enabling technologies evolve that become technical enablers for the evolution to an innovation wave.

And then there's going to be substantial talent on task. In other words, people have got to be-- researchers have got to be working on this in significant depth in order for this thing to evolve. So it's going to take a community scale kind of effort. So the first class left us with two direct or explicit innovation factors. And we could in a-- oversimplify them and put them in shorthand, but we could say you've got to do R&D and you've got to have a talent base staffing that R&D system.

And we worked on a definition of innovation as a system for introducing technical advance, and we talked briefly about innovation waves, which we'll spend more time on today. So that's a quick recap of last week's discussion. And Chris, you and I can follow up so you catch up on some of the issues that came up there. And I've posted the slides to the STELLAR site which will help as well, but I'd be happy to talk to you further about it.

So let me just do a quick snapshot to open up today's discussion. So that's Thomas Edison. That's his idea factory and that's the group that does the light bulb. It's the light bulb and you can see the idea factory-- this building in that scheme at the top. And then you can see the farmhouse back behind which is where Edison lived with his wife except that he never spent any time there. He was in the idea factory pretty much 24/7.

I just want to give you a feel for what innovation is like when it starts to take off. And this is a good-- Edison is a classic example. So he-- very limited education. He was homeschooled by his mother. He's probably pretty dyslexic. We don't quite know that, but it's probably the case. As a kid, he understands the early evolution of the telegraph and he develops kind of a newspaper sales scheme during the Civil War where he gets the newspapers ahead of time in Cleveland, gets them out to the trains coming into Cleveland, and then sells them on the trains.

And he's kind of kept-- in other words, he kind of beats the news cycle and then unloads newspapers on these early commuting efforts as people are coming into the city. He gets his big break by scooping up the child of the telegraph operator. So trains had to operate by telegraph systems-- they were a crucial technology to enable trains to work.

And the telegraph operator for a train system is very important, but also obviously serves a larger community communications purpose. So the kid of the telegraph operator is down on the tracks-- train is coming down the tracks. Edison, as a boy, sees what's happening, rushes, scoops the child up, barely escapes the train. Needless to say, the telegraph operator is appreciative, so he trains Edison in Morse code and how telegraph operations work.

So he becomes an expert on telegraph, which is obviously early electrical technology. And he becomes a master at it, and then he becomes very interested in technology itself. So over time, he goes to New York-- he develops what becomes, in effect, an early stock ticker, which can-- what we would call multiplex. In other words, you could receive multiple telegraphing signals and communications over the same line, which obviously was a key enabler for keeping track of stocks.

So he becomes very close to the scions of Wall Street, including JP Morgan. He gets to know them all because he's like their enabler. And then he sees this thing in Ansonia Connecticut. It's not-- it's a much bigger version of this, but there's this kind of gimmick-- these nine foot tall polls with a spark, because they're positive and negative a spark travels across-- looks really cool.

People are wondering around-- they don't know what to do with it, but they're awestruck by this kind of electric movement of lightning going across the two poles. Edison has the idea-- oh, light. So he takes the-- he makes his money on Wall Street, he takes all his money out. He goes off into a farm in Menlo Park, New Jersey out into this rural area.

He hires this team which consists of an interesting mix of artisans-- like, there's an incredibly important glass blower here, which heralds back to the MIT glass lab which I always buy stuff from. And there's also scientists and engineers in here, but a lot of people who just know how to do things who are very good at sort of mechanical tinkering. And it's an interesting team, and he has to take this idea of this weird arc that he saw-- these nine foot tall couple of poles that he saw in Ansonia Connecticut and turn it into a light bulb.

It's not an easy job and it's very intense. There's only a certain amount of money-- the money is going to run out. He's gotta get this thing done before he runs out of cash. And they work literally all the time. They're always on it but they're having the time of their lives.

So there's a wood stove in here over in-- I'm not sure-- maybe it's in another corner. But around midnight, they all gather around the wood stove and they're-- rap music has not been invented yet, so they do doggerel verses which they throw at one another-- insulting and funny and this incredible doggerel verse back and forth going on. And they all have big cherry pies and apple pies at midnight and gather around the stove.

It's a very intense effort. And actually, Edison is away for so long from the farmhouse which is further back on the property that at one point, when he comes in at like 2:00 o'clock in the morning, his wife pulls a revolver on him thinking he's an intruder because she's seen him so rarely. Fortunately, she doesn't shoot.

But there they are gathered on the idea factory, and eventually they come up with the core concepts. The vacuum tube obviously is core here and the right filament is core here. They come up with a working model of the electric light. There's only one problem-- there's no electrical system. There's no nothing.

So they've got a wonderful application for a nonexistent system. So the real innovation here is not simply the invention, it's creating the whole system. So they have to envision-- they have to think of what an electric utility might be. They envision the utility, they envision what a generator would be.

They have to think through all these early safety requirements. So it's an incredibly big thing that they're launching. They're launching the electrical system, not simply the light bulb. But the light bulb is the enabler that's going to enable them to sell the system. Eventually, they do a big demonstration on a couple of city blocks in New York-- everybody loves it.

Gas lighting is not what you call optimal since you have a good chance of blowing yourself up. And the nation eventually switches over, but I just wanted you to see what that innovation moment looks like. And we'll talk about great group theory, and this is certainly a great group. But that's the moment we're after in this class. That's the moment we want to understand.

We want to understand how that innovation emerges from the group, but importantly, how it scales-- what happens to it. So that's kind of a little-- that's story time for today's class. Now we'll do serious work. I want to get some other basic ideas down. So we talked about some basic concepts last time. I want to put a few more on the table.

Steps in the technology development process. So we talked a little bit last week about three of those steps, but let me put them into a larger context. So typically, you're going to have to go through a series of steps here to actually get to really scaling a technology up.

We talked last week about having a vision. We talked last week about supporting enabling technologies. Then you're going to do your particular invention. Idea-- you're going to need to do some research to perfect it. You're going to need to develop a prototype of it.

Then you're going to need to go through engineering development. Then you can start to think about production, and manufacturing that prototype, and then eventually scaling up to commercial production. You've got to have a supporting infrastructure system and there may be additional applications that you can use and pile on here. And then you've got to go through a series of generations of the product.

So that's a lot of stuff to get through. So the US typically thinks about innovation as, like, in the vision idea research realm, but it's a much more complex process that has to be mastered to actually get from the discovery to the innovation. So there's models for technology change, and we'll talk more about those in a later class, but just a couple of core ideas to put on the table right now.

Technology push-- so we talked a bit about the innovation pipeline last week. Technology push is typically where you support research, something emerges from that research in effect, and then enters into widespread use-- typically a commercializable product. So in effect, you're nurturing and developing a technology, and you're pushing it towards the economy.

Technology pull, or sometimes called demand pull, is a different model. So in this case, the market will create an opportunity. The market may create a niche or someone may spot the opportunity or the niche. And in effect, the market is going to pull that technology out-- is going to be, in a way, the enabler for that technology to evolve.

So these are two very different processes, and we'll talk more about who does which. There's incremental innovation and there's radical innovation. So incremental innovation-- as a definition here, it improves function, aesthetics, performance, efficiency, manufacturability and so forth.

In other words, modest incremental steps. It's very important. We all kind of love radical innovation, and there's actually good evidence that radical innovation will lead to a really disproportionate profit impact. In other words, if you can launch a radical innovation, the gains can really be big, and that will become an important idea when we talk about venture capital later in the class.

AUDIENCE: From what year to what year is that-- is the scale of that graph?

WILLIAM BONVILLIAN: Now you're calling on me to really look closely. I don't know how many years. This is a '97 study out of the Harvard Business School, and I just don't remember, Martine, how many years this covers. But I'll be happy to look that up for you because I don't see it on here.

But it's gotta be at least a 10 year look, I think, to be meaningful. So I don't want you to get the idea though that one is better than the other. That incremental or radical are better than one another. I just think-- the Wright Brothers aircraft would be a good example of a radical innovation, but you and I would not want to take the Wright Brothers aircraft across the Atlantic Ocean. We would rather do the 787.

So incremental can be extremely important. Historically, industry does the incremental. That's more of a technology demand kind of model-- a technology pull kind of model-- as opposed to the radical, which tends to be more out of a technology push research base. And we'll talk more about those things as time goes by, but I wanted to get those out on the table. So although radical may be more profitable, incremental is easier, and obviously, there is much more incremental advance. Max?

AUDIENCE: Regarding the technology push, is that more funded by governments and big institutions, universities, or?

WILLIAM BONVILLIAN: Yes. Because in our system, as we talked a bit about last week, research is predominantly funded by government and the actors are universities, and development is predominantly funded by industry, which tends to be a more incremental advance. And there's something also that you just kind of need to keep in the back of your minds, which is product cycle theory.

That products go through cycles-- go through evolutionary stages. So a firm defines a product, it develops a market for it, then it standardizes the product. And then typically over time, one design will tend to dominate. And then the number of competing companies with varying designs will tend to shrink.

And over time, the product will sometimes become a true commodity product. High volume, the price goes significantly down, and the profit margin is much lower, so the uniqueness of the product kind of ebbs. At that stage in the US system, the production often goes offshore. That's the moment where it occurs where the commodity production begins.

Barriers to entry increase at this point because only a modest number of firms on a standardized product tend to dominate. And the surviving firms have to have the capacity to keep advancing their technology, keep making incremental advances. They've gotta be able to master large scale production, they've gotta have strong distribution and marketing arms, and they've gotta have the management talent to kind of work across all those pieces. Matt?

AUDIENCE: Could you explain just briefly how you go from the number of competing companies reducing [INAUDIBLE] commodity [INAUDIBLE]?

WILLIAM BONVILLIAN: Yeah. I mean, think about things you see all the time, like search engines. How was it that Google really came to dominate the search engine business? Or think about operating systems-- how was it that Microsoft really came to dominate the operating system world?

So that's just-- consumers tend to lock into the dominant product. How was it that apple came to dominate iPhones-- Although that's obviously up for grabs every few years.

It's not to say there can't be entry of others into these fields, but the barriers to entry tend to get higher because how many firms can really master all these skill sets? That's pretty sophisticated. Does that help?

AUDIENCE: Yeah. I was just thinking about, like, I would expect stiffer competition to lead to that commodity market where you have a lower profit margin.

WILLIAM BONVILLIAN: Yeah. So you really have to systematize the operation to be able to continue to make strong gains out of that more commodity product line. And then typically, you've got to keep driving the costs down as well.

Now this is not eternally true, and you began to poke at some of the problems in this model. You can think about ways of disrupting this pattern. So for example, some companies are learning how to do continuing radical innovations.

That was-- Apple is a good example of that. That was Apple's magic. It does the Mac, and then it does the iPod, and then it does the iPhone and so forth. In other words, it's able to continue to do pretty radical innovations on a continuing basis.

What enables a company to keep-- that ability to keep innovating. Because it's not-- there are only a handful of companies in the world that are over 100 years old. They burn themselves out. Globalization obviously spurs competitiveness, and it spurs entry and increased competition. It speeds the product cycle, so it can be disruptive of this traditional product cycle.

There may be-- and we'll talk about it more in our next class-- but a kind of rebirth of manufacturing process improvements that could disrupt this cycle and change it. And there's now a very interesting service sector that's not hard-product based that's emerging, and the possibility of tying services to hardware. So an Apple iPhone is a classic example of a hard technology that is also a service delivery model.

So we're getting these combinations in interesting new ways. That will change this product cycle as well. So it's not a eternal, but I want you to get an idea product cycle theory. And then our final idea before we dig in on the readings-- dynamic versus static competitive advantage.

So David Ricardo, great economist in the 19th century, develops essentially a theory of static comparative advantage. That advantage would be intrinsic to a country typically based on natural resources, and his famous economic example was-- and we talked about it a little bit last week-- but England has a lot of rain, has a lot of grass-- it can have sheep, it can do wool very well. And Portugal doesn't have that much rain, doesn't have that much grass, but it's great for growing grapes, so it's going to do wine, England will wool.

Each has a natural comparative advantage based on a resource advantage and it benefits both to trade. Portugal expands its market for wine by growing outside its own borders. England expands its market for wool by growing outside its borders. There's a benefit to each. So that's the kind of 19th century concept that's the heart of free trade theory.

That's a static comparative advantage. Starting around the middle of the 20th century, something very different began to evolve. A dynamic comparative advantage, and this is based on growth theory. In other words, if you can be innovative and you can lead innovation waves, you can capture a lot of the early gains of that innovation wave.

It's Solow innovation based growth theory. So that is a dynamic advantage created by-- and we have to understand the menu-- but investments in R&D, and education, and efficient governance, those could all be inputs-- and we'll talk more about the system later today-- into a dynamic comparative advantage. Now a dynamic comparative advantage is not eternal-- it may get lost.

And we're going to talk about some work by Paul Samuelson who laid a lot of that thinking out in a famous 2004 article in one of the next couple of classes. So the US created, in many ways, the biggest innovating economy in the world coming out of that World War II period. So it built a competitive advantage based on innovation, which had been evolving in Europe.

And countries like Britain and Germany had been doing something similar starting in the second half of the 19th century, but the US really scaled that model up and really built a very strong early stage innovation system. It became the richest nation on earth. That was its model, that was its comparative advantage.

Now the problem with a comparative advantage based on innovation is that others can figure out how to innovate. England is always going to have rain, and sheep, and wool, and Portugal is always going to have sun, and grapes, and wine. Those are inherent, static comparative advantages-- they are not going to change. An innovation advantage can change.

So the US had an incredible mass production system coming out of the end of World War II. Japan figures out a better innovation model based on quality production and takes consumer electronics and large parts of the auto sector. So that's how a comparative innovation advantage can erode.

So it's powerful-- you can get very rich as a nation and as a society-- but it's also up for grabs. Anything so far on this? Any questions so far? All right. And these slides will be parked on the STELLAR site and accessible to you. So these underlying foundational ideas will be around for you to glance at.

So today, we move to our discussion leader system, and so here's how it's going to work. I'm going to talk for 10 minutes or so-- 12 minutes, something like that-- about the readings. And then each of our able discussion leaders is going to in turn take that reading. So Beth has got Nelson and did you have Atkinson?

AUDIENCE: Yes.

WILLIAM BONVILLIAN: Beth somehow got the really two hard readings. I don't know how she lost in the jump ball. But lily will take the next couple of readings, and then Martine will follow up with actually the really fun stuff as we get towards the end of the class. So we'll have to make sure we find full time for it.

But let me start with Nelson. And he's our third grade growth economist-- a Columbia professor of economics. And he writes in 1993 this really interesting book about national innovation systems-- a comparative analysis. And he essentially puts out another-- a third innovation factor. So we've got Solow's and Romer's, and Nelson really adds a third.

He develops this term national innovation system. He's not the first one to use it. An economist named Chris Freeman at the University of Sussex in Britain actually is probably the first to use that term in looking at the Japanese economy. But he in this book really kind of spells that out.

So he talks about how the technological capabilities of a nation's firms and other innovation actors are a key source of the nation's competitive palace. Does the term national innovation system still make sense in what is a much more globalized world? This is, after all, being written back in 1993. A lot has changed.

It is a much more integrated, globalized world. Is it still a term that you can look at? If Nelson was sitting here, I think he would argue, yes. He would say that enough of the factors that go into an innovation system are still tied to national investments. That you can still do a national analysis, but it's harder.

And we'll talk about what some of those national factors are in a bit. And Nelson here uses the same broad definition of innovation that we've been using so far in our first two classes. And he refers to it as the process by which firms master and get into practice product designs and new manufacturing processes. So it's not the invention, it's something much larger.

So let's do some background-- some of his background points. He argues that capitalism is destructive and disruptive. That's a term from a great economist named Schumpeter. Destructive capitalism occurs via innovation.

It's not necessarily the first innovator that gets all of the rewards or even most of the rewards. Sometimes, the second follow-on innovator captures a lot of the rewards because they pick up from what the first innovator's mistakes were and improve them. But a nation's concern, therefore, shouldn't be necessarily with sponsoring the first innovator. It's got to have a broader concern about innovative capability.

So again, if the dominant causative factor of economic growth is technological and related innovation as Solow taught all of us, Nelson goes on to start to think about what do you do to make sure you're getting a lot of that? And his point is that you need a system to be able to do that. A system of actors that can be connected and influence, and affect, and drive your innovative outcomes.

So who are these institutional actors? Universities, firms, government agencies, and the policies around them. And he argues that, yes, there can be a common analytical framework across nations by looking at these actors. So this is a really important idea that's at the heart of today's class.

Here it is. Innovation is a system and you can look at the strength of that system based on the strength and connectedness of the actors in that system. So you can now go to any nation region area and you can start doing an analysis of just how strong that innovation system is by looking at the strength of the actors. Things like the firms, government agencies, universities, related policies.

You can do an assessment on innovation strengths, so this is a key tool. And a lot of your-- a lot of the paper in this class is going to be built around this Nelson system idea. He goes off and makes some interesting points about the relationship between science and technology, which is also really a point about the relationship between basic research, and applied research, and development, and between university research, government sponsored research, and firms.

And his point is that new science can give rise to new technology and vise versa. So he cites an example of science leading to a technology such as electricity, and he cites Faraday and so forth. He cites chemistry as science as a follower. That it really came out of a whole series of pretty practical professions.

Some other examples. Gibbs creates the whole science of thermodynamics because he's analyzing steam engines. That's where he develops his thesis. Edison is the other way around. Edison is trying to do a very practical electrical technology-- the light bulb-- but he stumbles into science, something called the Edison effect, which actually is kind of an early way of looking at electron theory, as part of that. But this development of electricity yields all kinds of follow-on scientific advances.

Aircraft technology starts with the Wright Brothers who are-- these are mechanics, these are tinkerers-- but then leads to very deep aerospace engineering. The transistor is an attempt to solve a practical problem-- high speed switching-- and yet that leads directly to solid state physics-- a whole new field in physics. Computing yields computing science.

So it's a two-way street here. Science can yield technology, but technology can also yield science. So you've got to have that two-way street operating, which means that you've got to have some connection between the forces in your society that are more focused on technology, which is typically firms, and the research side and vise versa.

The limits of science. Again, innovation is not simply the invention. It's bigger and it includes design. So you engineers in the room will know what we're talking about here, but that really means choosing the right, quote, "mix of performance characteristics," for example in designing a modern aircraft wing.

It's not enough to get the discovery right. You've gotta get the design right too. In other words, you need to select the right mix of performance characteristics. Who are these innovation actors? First and foremost-- and this was written in 1993-- is the industry lab.

So in 1993, something like Bell Labs, or the great GE labs, or the great IBM labs. These dominated, in many ways, the industrial innovation landscape. They are by and large gone. That has dramatically changed since 1993. Now it's not that large firms don't do R&D. They do a lot of it and that number is growing, but it's increasingly D and less R.

Also there's a reminder here that R&D is only part of a larger innovation picture. So things like management and management organization-- organization of R&D can have major roles here too. So actor number one is industry. And at the time he writes, it's industry labs.

Now that's a much more dispersed model now, because industries have largely abandoned their old labs that used to a lot more fundamental work to really development processes and rounding up innovators, and in some cases, acquiring them like in the biotech sector. But industry is still a central player obviously. There are also university laboratories. You all are familiar with those.

The government laboratories like the great labs for the Department of Energy or the Department of Defense. Then there's a whole public sector support system that's an actor here as well for R&D, and there is an element historically that has supported industry R&D, particularly through the Defense Department. So one way to look at this is the actors.

The actors will be different in different industrial sectors. They're going to look different, and they'll be a different mix, and they're going to organize differently in different industrial sectors. So steel is really different than aviation. These are differently organized things, but you can see-- you can nonetheless look at the innovation actors in a system and look at their strengths and weaknesses.

Complex technologies require supply chains, and therefore customers and users play a role in the innovation system because there's a whole feedback system that comes in. So the customers play a role for complex technologies particularly. So it's not only the actors I've gone through so far. Customers can be brought in and users can be brought in.

So you've got much closer to an idea of an innovation network here, and we'll talk a bit about Rycroft and Kash to kind of spell that out. So he does a comparison. He compares the US innovation system in the 1945 the 1975 time frame-- he compares that to the Japanese innovation system in the '70s and '80s.

It's a very different innovation systems, hence, help driving the theory of national innovation systems. So in that time period, the US firms tended to be larger in scale. They served a continent-sized market. The firms spent more in the US on R&D. The government spends a lot more on R&D at the time, particularly because of the defense mission.

US university research was stronger as a result of some post-war decision making that the US made. And most US goods were sold into US markets. So that's some framing ideas around the US model. Japan is really different. Japan is very resource poor, so it has to have strong exports to be able to get the resources. So it's got to be an export led economy.

Whereas the US can organize essentially on national consumer markets, Japan has got to expand globally. R&D in Japan in this time period-- and still pretty much to this day-- is more tied to industry than is the case with the US. There's less fundamental research. There's much more applied and development support from government.

And there are, from government, very explicit technology development policies at this time. So that's just a way of looking at two different countries and beginning to think about their different innovation systems and some of the underlying factors that will drive them. He argues that there's several basic categories of countries. Large high income, small high income, and then lower income countries.

Countries without resources have to have an export orientation, and he cites Germany, Japan, Korea. The US, and to some extent the UK and France, have a national security orientation for their innovation systems. We justify a lot of R&D investment for national security reasons in the US. Other countries don't do that.

There's differences in the governmental role. The US government tends to be a lot less interventionist in the innovation system, in the economy in general than, for example, Japan was in this time period. So there are country differences. What's innovation's success? Strong firms, in Nelson's mind, is the critical factor.

They have got to do all the translation, moving from discovery, to fit a whole raft of tasks that they've got to perform in this translation task. So without strong firms, you got a serious problem in your innovation system. But there are other factors. Education and training, trade policy, fiscal policy, public support of university research. These are all elements, again, in the system.

But he places the firm kind of front and center. And given what firms look like in 1993, you can kind of see why. It's a more complicated, complex story now. How about an explicit governmental role in innovation? How direct should that governmental role be?

So he's fine with the earlier stages. He notes that there's a whole ongoing debate about how far down the innovation pipeline the government should intervene. That's been a longstanding US debate, and we'll get more into that as the class goes on. So that's our Nelson story. And Beth, why don't I turn it over to you to raise some ideas about Nelson that you saw, and to lead us in some and Q&A?

AUDIENCE: OK. So based on the questions that I got from people in the class, I kind of saw four trends emerge in things that we were curious about. One being the stuff we brought up in the beginning-- is considering a national innovation system as a better way to promote innovation, or do we look at a more granular level by looking at industries, or at a less granular--

[AUDIO OUT]

The second main topic area that came up a lot was just what are the best policies for innovation now, given that this paper is a little bit older. As the world has changed, what do we see as the best ways to move forward. Third theme that came up was technology spillover and how that can be used as an advantage.

And last was balancing these national interests versus the international relationships that have emerged in firms. So just a few summary points before we go into those. I'll read through some of the questions that I thought were especially enlightening.

Just the basis of using national innovation systems from Nelson's point of view is that countries have some similarities, but because of their differences in history, culture, their infrastructure, laws, financial institutions, policies, and investing, we see that there are inherent differences to innovation systems in different countries. And that for these countries to be successful, it's not just enough to have manufacturing-- that's not a substitute for technological innovation. So you need these strong firms that are constantly innovating.

And so he comes to the conclusion that national innovation systems, while they may seem somewhat contradictory term considering policies are different for different industries within a nation, are still useful for comparing how nations foster innovation. And so first I just think it'd be interesting to hear what people see as the appropriate way to treat innovation systems. Is it at this national level, is it at industry level, should it just be international interactions with each other? So I'd like to open it up to some thoughts on that.

AUDIENCE: I think there was one point that was made. I think it was [INAUDIBLE] reading. It said, like, it sort of depends on the industry as to whether an innovation system takes place on a national level or, like a firm level. Certain things, like aerospace, were often-- or defense oriented things were very isolated to the nation in question. But other-- like biotech type stuff could be more group effort between multiple things. So it kind of depends on the field.

AUDIENCE: I think it depends on what time period your analyzing it, because a lot of the readings spoke about past economic trends and, like, these big, long-term waves. But I forget which one of the readings stated that [INAUDIBLE] a lot of more global connection being impossible. The idea of a national level doesn't make sense as much as a global scale does. But I guess that's yet to be seen because we're still sort of in the same wave, I guess.

AUDIENCE: So you think it might be more-- rather than trying to make a generalization for how innovation has always happened, it's kind of depending on what kind of innovation we're seeing that might be how we want to describe the innovation systems going forward. And then thinking about policies for innovation, one interesting question that came up was how does national technology policy shape the focus of research being conducted and company pursuits? And then going off that, how should national technology policy shape the focus of research? So that kind of comes into that debate of how far in the pipeline should the government be intervening, or should it be kind of a societal call for action-- where should this come up?

AUDIENCE: Well, in general, the history of innovation, like, early on, usually it's not an expert anything that does it. Like the Wright Brothers weren't really experts in flight, and the reason that-- because they weren't experts that were able to figure out a different way of doing it. So probably the right area for government is right after the initial is then figured out.

When you kind of know there's something there, and now you can start pulling in resources. But innovation in general, it could be like making a sculpture or maybe that you need to make a house. So when it's time to kind of make a house and you need a lot of hammers, I think that's a good time for government policy. Before when it's like chiseling, that's better for individuals or firms.

Back to the idea of industry being incentivized through government funds, in general, an industry they'll do their own research when they have a monopoly. I guess if-- what used to happen which was-- I forget what company Apple took the graphic user interface from, but that was all--

AUDIENCE: Xerox?

AUDIENCE: Yeah, Xerox PARC. They were famous for having a lot of innovations that they could never take to the product stage, which is back to the point that you made on being able to take an innovation and also make it a product and put in some kind of industrial cycle. But government grants, like SBIR grants, are pretty good too for creating that kind of industry innovation, and I guess with better incentives.

WILLIAM BONVILLIAN: So Martine, you make a series of interesting points there, and let me back to the first one which you made. And you made this interesting distinction between a sculpture and a building. And I think historically in the US, the attitude has-- even though logic would say let's think about the building-- that might be the moment for government support-- historically, the government support has been at the earlier stage, at that sculpture moment before it turns into a building.

And that's pretty deep in our system. So in other words, it's historically been OK for government to support basic research, but when it gets within range of commercialisation, that would be a governmental interference into the marketplace. So most countries don't do that, but that historically has been a limit on the way in which we think about this stuff.

So when Nelson talks about whether there should be an explicit role for government, what he calls high tech innovation-- in other words, later stage work-- that's a controversial topic for him to take on. And when we talk about Charles Schulz later, we'll see kind of the dimensions of this debate come further. But what do you think? Is that--

AUDIENCE: What I'm curious is-- so there's two kinds of, I guess, kind of sculpture innovation. The only one I can think of that was successful with government intervention was kind of like when they're making the atomic bomb, because that was very much that we need a technology push. But in other cases, especially for the Wright Brothers-- I forget what the name of the person that the government was funding. He was the expert in aerodynamics at the time, but because his equations didn't work out, he didn't do it.

WILLIAM BONVILLIAN: Yeah, all his aircraft landed in the Anacostia River in big flames.

AUDIENCE: Yeah. Well, the way I think about it-- they say an expert is an expert in a field that's already been created. And a lot of time, this innovator is not going to look like an expert at all because the field has not been made. Like Edison, you really wouldn't say use a genius in any field, but he did figure out something and then he took it as far as he could go.

But another distinction too is that there's going to be that are going to team up with them. Example with Edison is that GE had a lot of issues with their transmission lines, and it wasn't until they got this one Hungarian immigrant called-- I forget his first name, but his last name was Steinmetz. He's like this very hunchback-- he's famous for never being in pictures because he was just very hunchback and short.

But he came up with these equations and he figured out all the-- he solved all the main problems with the technology. So I definitely think there should probably more study, I guess, on that-- on when was the government most successful with their investments. I don't know if they do that. I don't really know how the government works with innovation as much as you do. But in general, VCs--

WILLIAM BONVILLIAN: Don't worry, you'll be an expert by the time the class has [INAUDIBLE].

AUDIENCE: Well, in general VCs will look at their investments and then figure out why they won with their investment. So that might be a good way of looking into it-- like, in the history of the US, when do we make investments and how do they payoff? And also, like, what do we measure the success, because it probably won't be economic returns because the nature of the problem. But if you look at in terms of development, there's going to be a lot of hidden variables that we don't account for that probably need to account for when we measure that success.

AUDIENCE: I think Martine hit on something, which is how does the government choose sort of when to get involved? The only example I might have is SpaceX, because they get a lot of support because of just the way they transitioned sort of out of the space race. We have a lot of infrastructure at NASA who, like, no longer wants to focus specifically sort of on space exploration in a way that might be private or commercially available.

But you have this sort of technology spillover and all these resources that exist at NASA. They have a whole bunch of launchpads everywhere that they can't really take advantage of because that's not what they're geared towards, and they're trying to move somewhere else. But you have this infrastructure leftover, and we started sort of leasing it out to companies like SpaceX to sort of do launch demonstrations and things like that.

And so I think-- but that only comes-- and I don't know exactly how that came about, but I think you might be able to facilitate those roles, where the government sort of has resources built up from things previously. And the industry might be moving in a different direction, and it might see more advantaged ways to pass off use of facilities and things like that. And sort of we have-- these launchpads at NASA we're trying to get away from-- I guess we have national labs now which are traditionally more basic research, but could be used to sort of bring in companies as sort of testing grounds for a lot of different technologies.

So I think energy might be a little bit more useful, and even biotech because we have supercomputers that are shown. But it's important to kind of identify that point which technologies might be a little bit more receptive to sort of that branching out. And I think it comes from maybe one of the latter readings, where it's, like you have to identify who's in the market and what are their needs.

And that conversation doesn't really happen because the government doesn't get to choose winners. But I think at some point, it's going to be necessary to kind of consult the necessary-- I'm going to use the word experts here. And then you don't really know who the experts are until you kind of bring the Wright Brothers in if they make a jump or a leap.

But I think it could have been facilitated if they had brought this guy in and found that maybe all of his experiments were crashing in the Anacostia river. So the government would have initially-- like, OK, his experiments are crashing-- we need to look somewhere else and we found the Wright Brothers. And so I think it's this-- the emphasis has to be on these public-private partnerships and facilitate those maybe a little bit earlier.

And bringing in sort of these industry experts who are shifting gears to new directions to kind of figure out what is the best role, because it's going to vary sector by sector. Because obviously, it wouldn't do maybe the Wright Brothers as much good if they had access to a supercomputer, for example. But it might do them good if they had access to sort of these landing zones or large areas of space [INAUDIBLE] to test flight developments and things like that.

AUDIENCE: Yeah, but kind of going back to your point and playing devil's advocate there, if we're not funding the sculptors originally, do we have concerns that there won't be enough that are taking the risk on their own to make the first steps before commercialization? Like, do we need to consider that balance a little bit?

AUDIENCE: I think that's an interesting question in terms of if the Wright Brothers were alive today, would they be able to get any kind of government support. And then you can think about, well, what kind of support, or how should the government be structured to support that kind of innovator?

AUDIENCE: I don't think it's necessarily fair-- I think you make very--

WILLIAM BONVILLIAN: So I'm going to ask everybody to identify themselves because we're all in film. We're all part of a movie. So just throw out your first name before you start so we all get to know each other well.

AUDIENCE: Chloe. I think you make a great point about the interaction between-- in commercial space, like between NASA and SpaceX, and NASA optimizing their resources when it's not really in their best interest to use them all the time, but leasing them out to private companies that can. But I think they do still sort of choose winners.

Like the Wright Brothers in the world of spaceflight, there's a lot of-- NASA would put out a bid for maybe a certain spacecraft bus or something. And then Lockheed and-- not so much SpaceX, but a bunch of different companies could submit proposals for how they might fulfill those design requirements cheapest and the most technologically successful. So I think that might not be choosing winners, but that is sort of one way that the government can support some innovation in the early stage and maybe encourage newcomers to take some risks.

AUDIENCE: Chris, by the way. I think where government has a really important role is probably galvanizing support, and especially initial funding, for potentially riskier kind of ventures at earlier stages. For example, I know in like biotech-- for example cystic fibrosis, that was a huge push by the government and some pretty national groups to get research on the ground and really focus.

And it took like 10 or 12 years and hundreds of millions of dollars, but they finally came up with a drug, Kalydeco which was produced by Vertex. So that kind of initiative I think is really useful. And national policies, like for example cancer [INAUDIBLE] or something like that, that set a precedence and places importance on development of these kind of drugs and creates some sort of importance and path for them to incentivize development throughout expedited patent approval and kind of maybe tax breaks or support for that R&D process. I think those can really help guide technology development as well as innovation, especially as firms are looking what to do next-- what to kind of put their money in.

AUDIENCE: [INAUDIBLE]. I think a really interesting undercurrent and something that I haven't really seen any of the economics readings talk about is game theory and the importance of potential cooperation. And I really see that as a potential role for the government as we move forward in technological development, because I think cooperation and particularly from a design-research standpoint, is incredibly important in identifying the competitive and dynamic and static advantages of the firm.

And I see it as particularly being an issue in manufacturing with robotics. The United States is not invested as much in our robotics infrastructure and now China is, and they're poised to become a global leader in the next decade or so. And it's really fascinating to think about the ways in which the United States is not really cooperating-- firms within the United States are not really cooperating with one another to align their interests to sort of dominate international markets as well as domestic markets. So that cooperation can be really important and it's not really something that I saw in either the Solow, Romer or Nelson reading, is that game theory component. And so game theory could be quite valuable when applied.

WILLIAM BONVILLIAN: So great discussion so far. You're really driving, I think, to get at Beth's underlying point which is what is the governmental role going to be in this mix. Where do you draw the lines, how far should it extend down the innovation pipeline, what are the different controversies?

So you all have laid out, I think, really nicely a whole set of examples about how we start that debate. But that'll be a central kind of issue in the class as we go along. So Beth, do you want to give us some closing thoughts here?

AUDIENCE: So I guess we have been viewing this in a very much US context, and that's obviously what we're most familiar with. But it is very important to think about what actions other countries are taking compared to what we're doing, and how we can learn from them and best compete with them. I guess the American system tends to lean a little bit more towards the kind of capitalist free market.

Once these companies emerge, it is seen as kind of unfair to support certain industries and certain companies, while in other countries that's more acceptable. And it is worthwhile to think about, is that something that we would want to move towards or is it better to kind of let these firms fight it out on their own? And as far as the relationship between national interests and international partnerships, kind of one closing question to consider is, how much should the governments be intervening and protecting their companies versus if that limits them from being able to kind of function on the international market, such as tariffs and other things that are protecting industries. Is that something that governments should be able to do, is that fair if other countries don't have those policies in place, and are we limiting which technologies are successful on the market by protecting ones that might not be as productive?

WILLIAM BONVILLIAN: Great closing thoughts, and the discussion leader system is working. Thank you for getting us off to a good start. Let me do some quick summaries and then lead into the Atkinson material. And Beth, we'll come back to you in a minute.

So in last week's class, we talked about these direct innovation factors. In other words, these factors that you really can't do without if you want to have a strong innovation system. And the purpose of that would be to drive economic growth, to grow economic well-being in your society in your economy.

So government plays a role in some of these direct factors. It supports almost all of university R&D, it supports governmental laboratories, it provides lots of support for the education system. And then it provides support for industry R&D in some areas-- particularly defense, but to some extent in agriculture.

So those are kind of-- if the Solow factor of doing R&D is a core factor, then you can see the governmental role here. But there's also a private sector and industry role on that initial factor. Of course, there's industry R&D which, as we discussed, is predominantly D, but that's what takes you through the prototyping, and engineering, and production stages.

And then industry provides the dominant role in training. So those are direct Solow-Romer factors that are tied to industry and tied to the private sector. But then there is a raft of indirect, or we could call them implicit, innovation factors.

So if Nelson is right that there is an innovation ecosystem, then there's a lot of pieces in that complex system. And government is supplying some of those pieces that have a role in the innovation process, but are not as direct as the first thing we talked about. So government is providing fiscal tax monetary policy, it's providing trade policy, technology standards, technology transfer policies.

It's providing government procurement, which buys a lot of technology, particularly in defense. It sets up the intellectual property system, the whole legal contracting liability system, the regulatory system in many, many areas, accounting standards, export controls. These all will have an effect on the innovation system and your ability to innovate.

But then there are these indirect factors that are is less critical than the two we've talked about, but nonetheless part of that system. So the private sector sets some really important ones. That includes investment capital which can be angel, or venture, or IPO, or equity, or lending markets-- is a private sector function obviously.

Management and management organization is really a private sector function in our system. The whole reward system-- the compensation system for talent is largely private sector set. So the private sector plays a huge role too in this complex ecosystem mix.

So the picture I want you to have is of a complex innovation system. There's direct factors, and if we include Nelson, we've talked about three. But there's a whole mix of other stuff there, and you want to get as many of those right in your innovation system as you can to have a strong functioning innovation system.

So it's not only the actors. You've also got to take into account this larger system as well. And we'll get, in a few minutes, into some of the indirect factors and how to look at those. But first we're going to do innovation wave theory. That's Rob Atkinson who's head of ITIF, a thinktank in Washington.

We talked about-- and I drew a scribble last week on the blackboard, but this is a better rendition-- what does an innovation wave look like? And just to recap from our discussion last week, there's a long build up and that can be 15, 20 years-- it can be longer. And then at some point, it hits a moment where it can start to scale up pretty quickly and spread into the society and economy. So there is a fast growth period here-- maybe that's a decade.

Then there's a period of more stable-- there's always a bubble and then there's a period of more stable growth. And maybe that's 20 years, maybe that's more. And then eventually, you reach kind of technological maturity. So the IT wave, the one you all are most familiar with that's still ongoing, long build up.

When do we start it from? Do we start it from Babbage, do we start it from Vannevar Bush's differential analyzer in the 1930s, do we start it from ENIAC-- 1946, the first functioning mainframe computer. We can start it at various points, but you get a sense for how long that buildup is. And then finally, we hit the 1990s and that incredible decade of growth in the 1990s. This very rapid scale up. Max?

AUDIENCE: Why is it in this diagram the buildup is not as long as what you pointed out last week? Like, last week, you had said it was 40 or 50 years [INAUDIBLE].

WILLIAM BONVILLIAN: Right. It depends on when you date it from, because everybody stands on everybody else's shoulders in the innovation process. Maybe we ought to date it Newtonian physics, right? [LAUGHS]

I think ENIAC is a pretty reasonable start date, but there's a long time between 1946 and 1990-- it's a very long period of time. So it's a longer period, frankly, than this in many, many cases. But then after the bubble-- and in the IT world, that's the Dot-com bust of 2001. Then all kinds of dot-coms fail.

And then the surviving firms are stronger and they go on a period of stable continued growth. I would argue that that's where we're on now in the IT innovation wave. Eventually, we'll reach technology maturity. The IT wave is complicated because information is a core organizing principle of the universe. It's like mass and energy-- it's one of those big things.

And if you're tying your innovation wave to something as fundamental and powerful as that, maybe it's more enduring. And we haven't begun to touch artificial intelligence yet. So maybe we'll get a lot longer run, Max, in our stable growth period-- maybe we have a lot more to go.

But think about railroads. You can think about somewhere in the first half of the 20th century, we reached a fair amount of technological maturity, particularly with the advent of the diesel-electric engine. So there are incremental advances in railroads, but the real challenging period is probably over for the time being. Beth?

AUDIENCE: So when we're looking at the stable growth here, it doesn't seem to account for, like, other things going on in the economy. So if we're using recent years for an example, you don't think about the financial crisis and how that's affected the economy as a whole. So is this just kind of a general upward trend where we expect to see some ups and downs from other causes, or have you captured those effects?

WILLIAM BONVILLIAN: Yeah. I mean, there's-- we could call them black swan elements that pop up periodically that disrupt everything like crazy. I'd argue that you could actually treat the growth in financial services as an innovation wave. That there were a whole series of technological areas of advance-- in areas like mathematics in particular.

But IT revolution accompanies that. You could actually add the technology foundation and the processes to really create global financial services system. And you can plot that growth, and sure enough, they have a bubble. The problem with the bubble in the financial services bust is that it just doesn't bring down a bunch of dot-coms, it brings down the entire economy. So be careful about innovation waves in the financial services sector-- be very careful because it messes everything up.

But I think you can actually-- I think that one actually works as a wave. Biotech for sure works as a wave. It's not nearly as big as IT, but nonetheless is significant. Matt?

AUDIENCE: I think my impression of that, reading Atkinson, was that because the timescale of the innovation is so much longer than the business cycle, the business cycles are, like, flips that are superimposed [INAUDIBLE].

WILLIAM BONVILLIAN: Very good point. They modulate through the process. Atkinson argues that in US history, there were essentially four phases-- for long waves in the US economy. So he argues that-- and different people can look at this differently. And look, there's big waves, and there's small waves, and there's wavelets within a wave, so it's not absolutely straightforward.

But he argues that in the 1840s, the development of small local manufacturing industries in New England around textiles and early machines, that's one wave. By the 1880s and '90s, that's regional factory based systems. And you know what those 19th century cities look like-- think about Pittsburgh.

By the 1940s, we're moving towards corporate mass production in areas like automobiles and aircraft. Then in the 1990s, he argues the new economy which is an IT based innovation wave emerges-- that's global, that's entrepreneurial, that's knowledge based. But that's his way of looking at innovation waves in the US economy.

We're familiar with the 1990s-- we just discussed that one, so I won't dwell on it here. The political system typically is slow to react to these innovation waves. It does not see them. John Maynard Keynes, the great economist who created Keynesian theory, once said, "practical men who believe themselves to be quite exempt from any intellectual influences are usually slaves of some defunct economist." In other words, they're operating off old economics and tend to perpetrate them.

Atkinson argues that the American old left was focused essentially on a mass production economy, which had been eclipsed by the time the IT wave emerges. The conservative political elements-- the Republican Party at the time and he's writing in-- was very supply side, classical economics based. They were worried about capital supply, and they were worried particularly about marginal tax rates affecting that capital supply.

So that wasn't organized around an innovation wave. That was organized around old classical economics. So in a way, both parties got organized around the two fundamental bases in classical economic theory. The Democratic Party around a broad definition of labor supply that includes education, and health, and things like that, and the Republican Party around a theory of capital supply, which was translated into tax policy. It's largely where those parties are today. They missed innovation based growth theory.

AUDIENCE: When did that start? When did that happen [INAUDIBLE]?

WILLIAM BONVILLIAN: I would say that the parties had locked into this by pretty early on in the 20th century. By the time of Franklin Roosevelt is when the Democratic Party locks into-- look, there's nothing wrong with capitalist [INAUDIBLE]. There's nothing wrong with labor supply. They're important elements and they need to be considered, and they're contributors.

We just know, however, that innovation based growth is the larger factor in growth, and the political parties haven't gotten there yet. So a real structural problem in the US system. Neither then embrace growth economics and spurring innovation, and that leads us to some interesting ideas about social organization.

So technology and technological organization is going to drive social and economic structures. So it's a really important point that he raises here, and it's I think one of the reasons why the subject of this class is actually really important. It's bigger than standing up cool technologies. It's a lot bigger than that because this class is not only about technology development, it is about the way society organizes itself around those technologies.

So Hagel, great German philosopher-- "western society is driven by the competition of ideas." Thesis, antithesis-- you all know the story. Marx introduces a very different concept into that conversation. He argues that in acquiring new productive forces, people change their mode of production, and in changing their mode of production, they change their way of living and they change their social relations.

So that's fundamental Marx philosophical perspective. That is called determinism in philosophy. In other words, the technological order of your society will be determinative of the kind of society you have. And that's how Marxism evolves. That's the fundamental philosophical underpinning. And he is seeing the Industrial Revolution drive systematic change in society in the late 18th through the 19th century.

That's what he's seeing. He's seeing this incredible class order evolve to match the very hierarchical structure that industrial organization, driven by the Industrial Revolution, requires at that time. Now, Stephanie, you had a question?

AUDIENCE: Yeah, [INAUDIBLE]. I was wondering [INAUDIBLE]--

WILLIAM BONVILLIAN: I'll get it.

AUDIENCE: --when I was looking at the syllabus, was are we going to talk about it some more? Because I guess I was curious if you were operating under the presumption, at least in the lecture and the ways in which we were supposed to be perceiving readings were giving us. Like, capitalism is good, or that capitalism is natural, or that capitalism is something that technology sort of-- or rather that capitalism perpetuates technology, technology works to perpetuate capitalism.

When I think there's really a lot of conversations, particularly arising in the last maybe two or three years, about the basic income guarantee and the potential for technology really eliminating the necessity for labor in [INAUDIBLE] economies. So I figured I would ask at this point when it became relevant because you had brought it up--

WILLIAM BONVILLIAN: [LAUGHS] I gave you an opening.

AUDIENCE: --there you go, yeah-- whether or not we're operating under the presumption that the free markets are good or desirable in the long run.

WILLIAM BONVILLIAN: That is really a big question.

[LAUGHING]

I guess I opened myself up to that by bringing determinism in-- using the excuse that Atkinson raised the subject. Look, that's not a dialogue that the US has had for some decades. We thought the Cold War was over and we thought capitalism won.

It's only in fairly recent years that we're actually starting to think, hmm, maybe there's some more elements here that we need to consider. Look, I think that's an open question. Obviously, this class is about innovation and it's about innovation in largely capitalistic systems, which obviously is the direction that the world economies have gone in worldwide.

So I think that's the reality. That's the reality we have. My personal view is that that's essentially a positive, but there are different views here. And we have to keep in mind how powerful the technologies that are coming out of these innovation systems can be for how we relate to one another as people-- how we organize our social lives.

So the prevailing technology system really sets parameters on the fundamentals of social organization. A few other thoughts along those lines-- Kondratieff who developed the fundamentals of wave theory back at the beginning of the 20th century. He viewed depression as a trough in a 50 year wave cycle.

Classical economists' view of depression was that they were waiting for wages and prices to fall far enough to enable a rebound. Eventually, everything is cheap enough-- somebody will buy it. Keynes took on that attitude. This is to point back to what you raised, Matt, about how does economic cycle theory interact with innovation wave theories. So we're right exactly at that point that you raised.

So Keynes agreed, but in the end he argued better intervene because in the long range, we're all dead. So don't wait that long-- better get on with it. Schumpeter definitely saw-- who's an advocate in economics of disruptive capitalism, destructive capitalism-- he saw Kondratieff's long waves theory, but he saw them as driven by innovation, not just in technology, but in the accompanying aspects. So production and distribution.

So it's not only the technology, but it's the production and distribution system too that he would add to that mix. So destructive capitalism, in the end, is based on radical innovation as opposed to incremental innovation, which means that if you really want disruptive capitalism and the potential gains of innovation that can derive from it, you've got to think hard about radical innovation, not just incremental advance. So in our system, that means in turn, you gotta think about that early stage R&D too, because that's the real contributor to radical advance as opposed to industries development, which is largely incremental. You with me?

So Atkinson argues that technology is the skeleton on which an economy is formed, and every half century or so, the skeleton changes as these waves come about. The changes are not steady. They can be very clustered. This is not a smooth wave.

There should have been lots of erratic lines in the wave theory diagram I showed you. Now Carlotta Perez is a great growth economist who taught at the University of Sussex and worked with Chris Freeman there, and she argues that it's not just the economy changes, but the politics, social relations, and the how and where we live that changes. And it's also how we organize our education system, and how our culture in turn, which is driven by some of these factors, shapes our beliefs.

So, quote, "the logic of the techno-economic paradigm reaches well beyond the economic sphere to become a general and shared organization common sense of the period." So here's an idea here-- a techno-economic paradigm. A paradigm that includes technology, but therefore reaches deep into economics.

So there's a driving paradigm in a society that connects these two. I'll argue later in class that the paradigm is even bigger than this. And that becomes, in a way, the order of things. So I think we'll kind of wrap it up here in terms of talking about Atkinson because we need to move on.

But Beth, you've got Atkinson as well, right? And I think, actually, if you speak into the mic in the center-- and I'll move this laptop slightly so you've got a direct line there. Thanks, Alberto.

AUDIENCE: So again, looking at the questions that people submitted, there are kind of four themes that came about. The first being, do we believe this is a new economy? This whole concept of the new economy that Atkinson talks about, is that something that we're on board with?

What is the applicability of long wave theory? Is it something that's unique to the US and to more developed countries, or can we apply it anywhere in the world? Are there actions that can be taken to minimize these troughs to shorten how long depressions may be?

And then a lot of just about what is technology's effect on society, and what it should we-- should the government be doing things to counteract technology's effect on society or is it a good thing that we're seeing these effects? So just a few points before we go into that that I found interesting. So Atkinson writes with the belief that this new economy is something that is permanent-- it's not just a blip. And I think that's something that we can kind of work with as an assumption when we discuss this.

But if you have specific things that you can point out that it is just a blip, I'd be interested to hear this too. And so the concept of this new economy forms new businesses, labor organizations, educational systems, cultural beliefs I think is especially relevant today as we're kind of seeing a lot of interesting political things arise. And it says with every disruption, entrenched interests will push back and may resist the change, and so I think that's something that would be interesting to discuss. So before we go into the social aspects, I want to--

WILLIAM BONVILLIAN: I just want to say, Beth, I really like that-- your last point here. In other words, we are seeing very significant social disruption today. And we may be able to connect it back to the IT innovation wave which, frankly, the upper middle class has ridden to unparalleled success, but left a lot of people behind-- maybe. Is that what you're driving at?

AUDIENCE: That's kind of what I was going to talk about. So I guess you can jump into that actually. So we talk about how these long waves increase overall quality of life perhaps at the national scale, but they do tend to be unequal. So should the government have responsibility for correcting this inequity, should it just be focusing on total efficiency for the nation as a whole, and how can it balance the idea that some parts of the country may be worse off while others are better off? So it's very broad and open.

AUDIENCE: Could you repeat the question one more time?

AUDIENCE: Yeah. So the paper claims that these long waves increase the general quality of life, maybe at, like, a national scale. But the benefits are likely to be uneven based on maybe who's most prepared to take on the technological changes.

So should the government have a responsibility to increase the equity? Should they be more focused on just total efficiency? How do we handle this and the societal changes that arise from it? I think there is some talk that that's kind of-- that wave of populism has been very evident in recent elections, so is that something that the government should be intervening with or should it be up to the free markets?

AUDIENCE: I guess I'll jump in. I think the major implications of innovation wave theory is just that we should always be nervous because if we don't get the next wave, then our economy is kind of screwed-- we won't be number one anymore. And so, like, some key technologies-- or also some examples of what could happen in the future is, like, there's certain asteroid belts that are worth quintillion's of dollars. So if we happen to say, oh, you know what, we're just going to not really focus on having rapid innovation in Japan. Or China says, oh, actually, we're not really focusing on this at all-- let's do a Manhattan Project for going into space and being able to mine. And they can go in and they can get quintillion dollars into their economy, then their GDP is looking pretty good.

Other implications are say somebody focuses a lot on biotech to the point where they can engineer diseases that only they can counter. And then they start doing biological warfare because they know the US has nuclear arms. So that's a different way they can branch out. So I guess it's kind of this idea of we're never really on top, or when you're on top, everyone is shooting for you, I guess.

Where we could say, yeah, we're number one, but also say we really need to keep innovating and think about how we're structuring it. Because the future is always going to be-- well, time is pretty much just indicating that change is happening all the time. So we probably won't be where we're at, and we probably-- I'm thinking we don't want to go down, but that's really up to the US and its citizens to decide every single generation.

AUDIENCE: I might come at it from a little bit different angle. I think we've been talking a lot about sort of a capital based innovation and how that might-- the IT boom and how things might be a little different structured on, like, a capital side. We might have-- just kind of look at the effect of human capital and in the universe of innovation.

But I think there's an important piece here where we see a lot of growth in the upper middle class because they're prepared to handle [INAUDIBLE] a lot of the sort of more human aspects of where we're going. But you see sort of this transition as we look forward into sort of management styles and kind of structuring things, which is a little bit more high level, which again lends itself to the middle class. Which I think if we were looking to, as a corrective measure for government widespread involvement, there is this sort of public need for the smoothing and transition.

So that, like, you see the highs for those that are high, but you don't see the aggressive lows for those that are low sort of passed over and made obsolete structurally by this innovation. And I think there's a greater need for kind of renewed investment in sort of this human capital. I guess at the end of the '60s, you had the GI Bill which helped kind of a lot of folks get reintegrated in sort of public education and greater institutional or secondary education at postgraduate increased sort of en masse.

For a lot of different reasons, that sort of helped ride the wave into the 1990s because of that. But these sort of things now, it's [INAUDIBLE]. There's a lot of different changes that may happen a lot of more frequently now and a lot more connected.

So there's less room for error because we can't really isolate ourselves in sort of this US national system. But as a general [INAUDIBLE] summary, I think you get a lot of these interesting events happening a lot more quickly, so the highs can get higher a lot faster and the lows can get lower a lot faster. And so if we were sort of to look for a governmental role, it'd be sort of probably smoothing out these lows rather than focusing--

AUDIENCE: Or insurance.

AUDIENCE: Insurance-- yeah. Investment backing and equity capital so you have-- you're more able to kind of take these shots.

WILLIAM BONVILLIAN: So Rasheed, that's really interesting, and you're driving us to a perspective here that innovation waves may be a way, at least in the shorter term, for the rich to get richer and to create a larger underclass, right? If we look at the Industrial Revolution, the workout period of doing the adjustments for the workforce-- I mean, that's a 100 year long project. I think that recent election results may tell us that we don't have the kind time to play with as we work out the latest innovation waves.

Now is an alternative to bring on another wave? And then maybe all waves are not the same in terms of their class, and structural effects, and deterministic effects. So if Martha's innovation wave around new energy technology that she spends her life on comes about, that may be a big net generator of employment overall as opposed to an IT software wave which appears to be less so. So different waves may have different kind of underlying structural features for the society.

AUDIENCE: [INAUDIBLE]

WILLIAM BONVILLIAN: [LAUGHS] Right, unless we get on it. Martha, you better hurry up. That's all I can say.

AUDIENCE: [INAUDIBLE]

WILLIAM BONVILLIAN: What are you saying this class was?

AUDIENCE: I wanted to come back to a point that Beth made right at the beginning when she said that we're going to work on the assumption that our economy is an innovation driven economy. And I think that all of us in this room are probably on board with that. A lot of economists are on board with that, but then Bill made the point that our two-party system is arranged mostly around these older views of economics.

So why haven't one or both of the parties sort of switched over into the more innovation driven economic theory? And if they did, couldn't we solve a lot of these problems a lot better? [LAUGHS] [INAUDIBLE].

WILLIAM BONVILLIAN: Well, Lilly, I'm happy to tell you I worked in the Senate for 15 years. I wasn't able to persuade them-- I just wasn't able to bring it about.

AUDIENCE: So just to play devil's advocate, what would that look like? How would it be different than what we have today?

AUDIENCE: I would say probably the supply side economic theory would take more of a hit than maybe the labor supply economic theory.

AUDIENCE: Well, if I make a comment-- Alberto, for those watching at home-- the thing that's been really jumping out at me when we talked about it earlier-- sort of like the big old beast of the military industrial complex, which from my understanding thrives not on radical innovation. They really love the incremental thing because it can suck out as much money as they can from the government. And if they can just stay like that, if they can convince all the politicians to give them money in funding of that whole business, that's why we're stuck in the 1950s because that's the system that works best for them. But to go back to what Rasheed said, I think--

WILLIAM So Alberto, I'd contest with you because I think it's fair to say that the military has brought on

BONVILLIAN: actually most of the big radical innovation waves of the second half of the 19th.

AUDIENCE: [INAUDIBLE]

WILLIAM BONVILLIAN: Well, radar turned out to be consumer electronics. And so--

AUDIENCE: What's coming out the F-35, I don't know.

WILLIAM BONVILLIAN: Yeah, what's coming-- I don't know what's coming out of that.

AUDIENCE: [INAUDIBLE]

AUDIENCE: [INAUDIBLE] Also Intel is funded originally by government.

AUDIENCE: Yeah.

AUDIENCE: Maybe I'm wrong.

WILLIAM BONVILLIAN: No, but it's a very good point. And I think the answer is that there's different forces in the military and there's huge conservative forces that want to perpetuate their existing operating systems. And it's actually hard to do disruptive innovation in the military because it really is a legacy sector.

So I think this play out between how you bring innovation into a legacy sector-- which the military has actually solved a few times-- is kind of an interesting idea, and we'll keep playing with this idea as we go on. So yes, the military has been able to launch disruptive innovation, but overall it's a legacy sector and a lot of it is resistant to innovation just as you suggest. So it's a very interesting balance.

AUDIENCE: Well, I wanted to go back something she'd said about education. That innovation waves don't have to, like, cause the destruction of classes of people as long as people are educated with the new skills that are associated with an innovation wave. Like you brought the story up about someone teaching someone else Morse code and how people would not be left behind by railroads if many of them learned to Morse code operators. And then in the future, I've just read a lot of things about what if coding and computational IT things become the new blue collar jobs [INAUDIBLE]. All you need to do is change the education system.

AUDIENCE: And then going to your point, [INAUDIBLE], I think that it's a little bit harder to sell growth theory to voters because it is long-term oriented. So if you give them the option, I'll protect your job today versus in 10 years, you might be a little bit better off because you have an agent that's just not going to sell.

AUDIENCE: It's also kind of hard-- I don't know. No, actually, to your point, [INAUDIBLE] about connecting the legacy sector innovation or the lack thereof to two-party interests. Because I think in particular, you don't really see modern companies that drive innovation sponsoring political activities and particulary lobbying, right? You don't see them sponsoring congressional candidates. You don't see them developing political candidate. And you don't see them launching political candidates out of their own [INAUDIBLE], right?

So I think it would be really curious to see the ways in which this election is now encouraging legions of scientists, innovators, technologists to run for office and to see the ways in which they align or don't align themselves to our two-party system. Because if they're-- the most important thing I think of more in political science is that if you're not at the table, you're on the menu. And so we're at the table right now and we all have this sort of vested interest in the ways in which the waves of technology are going to impact not only ourselves, individual stakeholders, but the communities that we're a part of and also the nations. Because spheres of influence matter a lot [INAUDIBLE]. So I think it would be really curious to think about the ways in which precisely legacy sector innovation is pushing-- almost preventing the development of political involvement between innovative firms and the two-party system.

AUDIENCE: I actually wanted to mention one of your points. You had said that it would be difficult to have people decide, OK, do you want to save your job today versus in the future. Well, maybe that's-- isn't that the purpose of government in the first place is to sometimes make unpopular decisions that will in the long run actually benefit a greater number of people? I mean, yeah, it's definitely a tricky subject.

And it's not-- there's no easy answer, but I at least think that-- that's why we're a representative democracy rather than just a straight up democracy. It's because then we want these people to actually represent us and to act in our best interests, even if it's not in the short-term. Ideally, we would say that, OK, we actually trust these people to see what our best interests are.

AUDIENCE: Yeah, I agree that's what I would want to happen. [INAUDIBLE].

WILLIAM BONVILLIAN: So I'm going to curtail this conversation because we have five readings to go and we're more than halfway through the class. So this is going to be a standard problem we're going to have all year, so we can get used to it. But why don't we take a quick five minute break now and come back, and then we'll tackle the next round.