TPI SPECTRUM SERIES 2024

Beauty Contests to Auctions: What Is the Next Step?

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Scott Wallsten:

Good afternoon. I'm Scott Wallsten, president of TPI, and I'll be moderating this fireside chat, which is part of TPIs Winter Spectrum series. This year marks the 30th anniversary of the first spectrum auctions, which have helped foster a wireless revolution around the world. We're fortunate to have with us today two people who are among a group that's truly responsible for making auctions a reality and heralding in the wireless stage. Evan Kwerel from the FCC, and Paul Milgrom from Stanford.

When Evan won the Paul Volcker Career Achievement Medal, the awarding group summed up the importance of both our guests. They said, "the market-based FCC auctions were conceived and implemented by Evan Kwerel based on many of the theories of Nobel Prize winning economists, Paul Milgrom and Bob Wilson." It's not overstating the case to say that Evan, Paul, and some others, helped create more consumer surplus around the world than just about anyone else. So, today we're going to talk about the history of auctions, how we got there, how unique the process was, and where we're likely to go from here to the challenges that we face ahead.

Now, to set the stage a little more and remind people what an enormous development these auctions were, let me take you back to 1994. I was at Stanford working on my PhD then and at the time, not every grad student had their own computer, so we spent a lot of time in a room in the econ building full of PCs. During a PCS auction, now I can’t remember if it was auction one or four, I was in there working, and a stampede of economists came barging into the room to check online how the auction was going.

You could practically feel the air leave the room as they sucked in their breath and held it, waiting for the results to load. It takes a lot to make economists stampede, and the auction did the trick. I don't remember whether I've ever finished what I was working on. But it's really an honor to have Evan and Paul with us today. Thank you both for joining.

Paul Milgrom:

That was auction one, by the way.

Scott Wallsten:

It was auction one. Okay.

Paul Milgrom:

I remember that one too. It was the summertime and there was an eclipse right during the auction. I remember a lot of detail about that time. Yeah. There was a conference going on at Stanford and people wanted to know what was happening here.

Scott Wallsten:

That explains why so many people came in. I remember that. Let's start by going back before the auctions. Tell us a little bit about the path leading up to making spectrum auctions a reality, including what kind of opposition there was and how was that opposition was overcome.

Evan Kwerel:

Well, before I talk about that, I just wanted to one, thank you for inviting me. And two, just to give a disclaimer to note that whatever I say here are my personal opinions and don't reflect the opinions of Federal Communications Commission, their staff or anybody else. So Paul, can I start with that? But please feel free to interrupt me because you were a part of this. So, first you asked about opposition to auctions, and I think the primary opposition, as far as industry groups, was the broadcasting industry.

And while I don't think it was ever publicly stated, my understanding was that broadcasters were opposed to auctions, not specifically because they were worried that their spectrum would be auctioned, but because they were concerned that the FCC adopting a market-based approach to spectrum management might lead to Congress imposing fees on broadcasters for the use of spectrum. So to use whatever the cliche is, they didn't want to go down the slippery slope, or have the camel get his nose under their tent. So, they were opposed to it.

And I will also note that there were, what I would consider, policy concerns on the part of legislators. And concerns that you still hear today, and which, I think, are generally fallacies, but I think there are certainly plausible concerns. And I know that this is the case because we had

hearings in 1986 on it. And two issues that came up were, first, if licensees had to pay for their spectrum, some worried that they'd have to raise prices to consumers. And they were also worried that somehow that auctions would lead to greater market concentration and warehousing. And I could try to debunk those, but I think at least economists would argue that they're not valid.

But let me just mention the factors that led to passage of auction legislation in terms of overcoming the opposition. There were two main factors. One was a need for government revenue, and the second was that the existing system just wasn't working anymore. So, let me very briefly elaborate on those two points and then I will stop and let Paul chime in, or Scott, if he wants to add things.

As far as revenue, as you recall, Bill Clinton was elected in 1992. And in 1990, Congress passed this legislation, pay as you go, which required all new expenditures to be financed by new revenues. And it actually did make a dent on the deficit. It was effective legislation, but it put a tremendous amount of pressure on the administration to raise new revenues. Auctions were seen as an important source of new revenue because the spectrum was becoming increasingly valuable. The second factor was that demand for cellular licenses was so enormous that it put great pressure on existing methods of spectrum license assignments. There were about 400,000 lottery applications for the least valuable cellular licenses. So, the existing systems were failing and the government needed revenue.

And the last point I'll make on this was that underlying these two things, there was an underlying economic factor, which was that cellular technology led to a great increase in demand for spectrum and increase in value of the spectrum. If the spectrum wasn't valuable, you couldn't get any revenue from it. If the spectrum weren't so valuable, people wouldn't be clamoring for licenses. And that was the underlying economic factor that led to this. So, let me stop right there.

Paul Milgrom:

I think you could compare what happened in the US and what happened elsewhere in the world. When the first US spectrum auctions were run, the industry was very fragmented compared to today, with lots of different participants. If you take a look at what happened, let's say in the UK, or other places in Europe where the industry was more settled, the incumbents could figure,

"Gee. We know what spectrum we're going to get, we'd rather get it for free than have to pay for it."

And that became a special concern, echoing some of the things that you, Evan, said when the prices were so high in the UK and people were saying, "They're spending so much money buying spectrum, they can't afford to invest in infrastructure." They'd never heard of fixed costs apparently over there. But anyway, there were concerns about financing. But in the US it wasn't clear who was going to get the licenses. The incumbents weren't the ones who were getting it under the lottery system.

Evan mentioned, before the auctions, this huge number of applications was because anybody could apply. You could be a flight attendant, or a dentist, or whatever, and stick in an application to provide mobile service somewhere and you'd compete on the same basis as anyone else. There were so many applications, it was so overwhelming, that they adopted a lottery system. The real product companies were paying for their spectrum anyway, they were buying it from people who were being awarded licenses at lotteries. And that's not what was happening elsewhere in the world where there was more resistance.

And they ended up using other tricks, like putting in spectrum caps. For example, if there were four companies, nobody would be allowed to buy more than a quarter of the spectrum, so there wouldn't be any competition in the auctions. They did all sorts of things to try to keep the auction prices down so that the incumbents didn't need to pay. But the situation that Evan is describing was the situation in the US. And I agree that at that point there wouldn't be resistance from the wireless companies themselves. They weren't getting their spectrum for free, and they preferred this organized system to the chaos of the lotteries that had existed before.

Scott Wallsten:

One of the unique features of the process was how many different groups were working together to make this happen, including the FCC, industry, and academics, and there didn't seem to be a partisan divide. It's a process that I don't know that we've seen much of since. Maybe we could talk a little bit about that process because it really was something unique.

Evan Kwerel:

Let me, before talking about the first auctions that led to that, just note that there was bipartisan cooperation again in 2012 when the Spectrum Act was passed and Congress gave us authority to have a two-sided auction. And that was truly bipartisan. I mean, you had a Republican, Fred Upton, and a Democrat, Henry Waxman, who both supported it. So, things may have gotten more polarized now, but there was still polarization then and people did come together to legislate on spectrum. So, bipartisanship for the first auctions was not unique, but it was certainly rare.

The first thing I would say has to do with who was chairman. When auction legislation passed, we had an exceptional chairman, Reed Hundt. He generally put good policy above politics. I mean, you have to be political or you wouldn't be able to implement policy, but as a general matter, his first priority was, to ask, what's the right thing [to do]?

He valued economics and economists. He really appreciated economists. He was willing to take risks. And that's a critical thing, and I'll talk about that in terms of willing to adopt Paul and Bob Wilson's innovative, simultaneous, multiple-round auction design. Another piece was that he assembled a great team in the chairman's office. Don't underestimate the importance of those people.

And perhaps, to be immodest, one of his key staffers, Don Gipps, and the chairman were willing to take a chance on me to figure out how to do the auction design. There wasn't a whole group of people, and it was a risky thing. Who's this guy? He talks a good talk. He seems to know what he's doing. I appreciated that. And of course, I had Paul Milgrom to rely on. He wasn't taking such a risk. Okay. So, that's the first factor, is I think we had an exceptional chairman.

Scott Wallsten:

Go back to that a little bit because you did have Paul, but there was no reason why, at the time, Reed would've known anything about Paul or auction theory. And so, you guys are coming into his office talking about this thing that's completely different and no reason to believe he would know much about it to begin with. Why was he open to it?

Paul Milgrom:

The other thing you have to keep in mind is they didn't have an auctions division back then. Nobody there was an expert in auctions. And they get this legislation that says, run an auction. And they say, "Well, who here knows how to run an auction?" Well, let's give it to what was then the Office of Planning and Policy, which also didn't know what to do. They said, "Well, let's ask Evan to write something up." And Evan writes this notice of proposed rulemaking, which he tried to read the auction literature, but he was making stuff up. The thing that came out there that he put out was wild.

I mean, it was filled with ideas, and it caused the companies to go out to auction to say, "What is this stuff? Is this good for us? Is it bad for us?" I got calls from a couple of companies. Bob got calls from lots of people, academics, who you cited in footnotes, which is how these guys even knew our names. I was just some auction theorist at Stanford. Why would anybody call me? How would they even know about me? Well, you cited my papers and footnotes in your notice of proposed rulemaking. So, I started getting these calls and that created the dynamic that drew in all these academics that ended up working with you and contributing.

Evan Kwerel:

Paul, I agree with you 100%, I wrote out some bullet points. And you nailed it, that's exactly right. You got bullet points two and three. You said it better than I could, and you said it with more knowledge because you were there, you were the ones that were called.

A corollary to one of the points that Paul made, which was that there was nobody in the agency, there was no auction division. It was completely new. It was done with a very, very small task force in OPP, Office of Plans and Policy. It was not bureaucratic. It was very nimble and had close communications with the chairman's office. I think that made a big difference. It didn't work like a standard large bureaucracy.

And my last point, which is to give some more credit to Paul in terms of how it happened and why it worked, was that Paul was committed to working with the FCC to make it work, to refine the design, show how it could work and make it work. And Paul, could you tell your story about how you paid for the Excel spreadsheet?

Paul Milgrom:

Yeah. When we designed this, we came up with this simultaneous multiple round design, and there were people out there saying, "No, that's way too complicated. It could never work. Nobody's ever done anything like that." And my client had been financing my trips to DC and so on. But when I said, "Well, I wanted to make one more trip, I wanted to code it. I wanted to show that it could be done by using the Excel spreadsheets of the day and have an Excel spreadsheet that a bidder could use to submit bids and have an auctioneer spreadsheet. And import the data from the bidder spreadsheets and apply the rules and show them, 'You can do this. It isn't that hard.'"

And the client said no, they didn't want to spend the money on that. So, I hired my own research assistant with my own money and had that coded. And the next trip to DC, I had it on one of those little three and a half inch discs. And when I visited the FCC, I handed it to Evan and said, "It works. You can run it on your computer at home. Here it is." And I gave him a three and a half inch disc that had the two Excel spreadsheets that would communicate with each other.

The one spreadsheet, if you put in your bids and you broke the rules, it would tell you no, that bid wasn't allowed. It wasn't very fancy by modern standards. But anyway, it guaranteed that you would submit only an eligible bid, and it processed the bids and it said, "Okay, it can be done."

Evan Kwerel:

I think there's two points to that story. One is the substance, that it was helpful. And two, it just shows the commitment that Paul had to making this thing work. And I think that was critical because it wasn't like he just dropped it over the transom and it was born perfect, immaculate conception or something. I mean, it required refinements. And Paul was willing to work with us to address various concerns.

Paul Milgrom:

I had to answer the, it's too complicated stuff, from others. And I just had to show you, "It isn't that complicated. Here, I can do it on my own computer." Is what I had to show.

Scott Wallsten:

This is also maybe a good place to talk about how far things have come and how much it's evolved, because the broadcast incentive auction took massive amounts of computing power. Talk about the development of the complexity of the modeling and how increased computing power has mattered. And because, like I was telling Evan earlier, I think it's now illegal to have any conversation without talking about AI, how machine learning and AI are helping with the simulations and so on.

Paul Milgrom:

I can talk about the complexity of that. First of all, the problem was inherently complex because when you're trying to pack the remaining broadcasters into a fixed amount of spectrum, that's what's called the graph coloring problem. It's a famous problem in operations research and computer science, and there's a branch of computer science called complexity theory. This is what's called an NP-hard problem, which means it's very hard, even for computers to do this in the optimal way. And so hard that there don't exist any algorithms that are guaranteed to do it fast and actually do it in the optimal way.

So, when I made my contract with the FCC to do that, they told me to put together the team I needed. I got Kevin Layton Brown, who did some research as to who actually solved problems like this in practice, and Kevin was the guy. He was a brilliant computer scientist, and he had a rack of 2000 processors in his lab, at the University of British Columbia, that were running experiments and algorithms that would work well for a problem very much like this. They were looking at the graph of television stations, as they existed in North America, and the interference patterns, as it existed in North America. And we knew we would be packing some subset of the existing stations.

And so, we were generating sets that might arise from the auction and running experiments on how to tune the parameters. And so, this was machine learning about algorithms. The machine was learning how to find an algorithm that would run reasonably well in real time for the actual problem that was being solved. And that took years of computer time with lots of processors in parallel running experiments to come up with this. And I'm only describing some of what Kevin

did. It was his early successes with that however that convinced me that we would be able to run the kind of auction we ran.

And I remember we needed to be able to check whether there was room for a TV station, in a minute or less, to have any kind of real-time processing. And the median run times, when Kevin started, were all longer than five minutes. And when Kevin was finished with this step, the median run time, which meaning it was only 50%, I don't want to exaggerate what the accomplishment was. But it dropped from over five minutes to a seventh of a second. And I said, "Okay. With that kind of improvement, I'm going to anticipate that we will be able to run these things fast enough to actually do." So, our auction design was predicated on Kevin being able to get very fast run times, which indeed he did. And it helped the auction run really well.

Scott Wallsten:

We have a question, before we move on. It's from Johannes Bauer. I don't know if he's just on the hall from you, Evan, or not right now. That's right. Says, "Thank you for these insights. Since the 1990s, you've been involved in many additional developments that have advanced the theory and practice for auctions. Could you give a few more insights of what kept this partnership working in such a productive way, given different commissioned chairs, changes to the politics and so on? And did Stanford facilitate any of the work?"

Paul Milgrom:

Okay. That sounds like it's aimed at me. Stanford didn't really do much, as Stanford. There were several other people at Stanford who were really interested in auctions. Of course, Bob Wilson was there for one. Andy Skrzypacz, Mike Ostrovsky and Ilya Segal, who joined me in the work on the incentive auction. So, there were other scholars who were interested in it. And there were other countries who were interested as well. I ended up advising Canada, the UK, and Australia, basically all the English-speaking world on auctions, and a little bit in some other countries as well.

And then, we got called upon by bidders. So, all of those things provided an incentive and funding, actually, for the research that we did, the continual funding around the world. And then, it wasn't not just the FCC, it wasn't all just radio spectrum either. The auction theory we were

doing earlier was about how best to sell one thing at a time. And the kind of auction theory that we were doing after 1993 was not about that anymore. It was about, what about multiple heterogeneous things? What about electricity? What about internet advertising? Right now, I'm working on issues about water rights.

There are many, many potential applications for market processes that involve multiple heterogeneous things being sold, and how do you best do that? And that turns out to involve entirely different sets of ideas than what we were working on before. I mean, there's a whole new area of research that opened up because of those of us in the academic world being focused on a different and more relevant set of problems.

Scott Wallsten:

Okay. Let's turn to... Sorry, Evan, did you want to say something? Okay. Well, let's turn to looking ahead now. So, if you read any paper on spectrum options, it usually starts off by saying, "We used to allocate licenses by beauty contest..." And then, by lottery, as Paul noted. "And now, we've seen the light and we use auctions." But in some ways, we've really just backed the process up a little bit, right? There's still so much of spectrum licensing that's done by beauty contest. For example, the decision, is it going to be exclusive licensed? Is it going to be unlicensed? Is it going to be shared?

That's still beauty contest with every party coming in and lobbying for their preferred view. And I don't mean lobbying in a bad way, that's their job to present their points on this because we don't have another way of doing it. Are there ways to bring market mechanisms into either that decision, or how far back can they go? At what point do we run into the possibility theorem that someone's setting the rules that determine the outcome?

Paul Milgrom:

There's a whole bunch of things that come before you do an auction. You studied the price system in a graduate economics course 20 years ago, and you read about general equilibrium theory and how everything about resource allocation could be determined once you had the correct prices. If there were market clearing prices, then you would get an efficient allocation.

Many of us learned to think markets are the ultimate solution for everything. But it's not right. Well, there's nothing wrong with the theory as it exists, but the problem formulation is strange.

It starts with given items, no externalities. The truth is in the world there are lots of externalities. You can't have a broadcaster operating on the same or adjacent spectrum to where mobile broadband license is used. The way the property rights are defined, what the overall plan is for the use is not so well decided by a bunch of incremental moves, just trying to improve things. So, some amount of planning is needed. And what we've learned to do over the years is to push the boundary a little bit. We did, for example, in the incentive auction, decide on the boundary between how much broadcast television would there be and how much mobile broadband there would be. That was made endogenous.

And some places where there's package bidding, we haven't done much of that in the US, but certainly in Canada and the UK and elsewhere, where whether somebody was going to be there at all and by a big chunk of spectrum, or not be there and not by any spectrum, that became possible in some new auction designs. But we've learned to do that optimally in general. And the further we get away from just making incremental moves and hill-climbing to get toward an optimal solution, the less effective the traditional market system becomes and the more planning is needed to coordinate all the pieces of the changes.

Taking into account externalities, taking into account the need for packaging, taking into account the need for adjacency if you're setting up a wireless system and you want not just any pieces of spectrum, but adjacent pieces. And so, I'm not one who advocates moving entirely to market systems for all of the decisions that we take. First, you have to have a structure within which the market system can refine the allocation.

You can't have a market system determine everything about the allocation. These are computationally difficult questions. They're questions of what the property rights should be, they're questions about how to manage externalities that exist among different uses. And those all have to be considered before you get to the stage of designing your auction.

Evan Kwerel:

It's hard for me to add anything to what Paul said, but let me just make one point, which is I think... It has to do with unlicensed devices, and that's the holy grail. Typically, people that don't

understand markets that well think we ought to be able to find a way to use a market to determine the allocation of spectrum between exclusive licensed and unlicensed devices. But when you think about it for a minute, how are users unlicensed devices supposed to be included in a market mechanism where they would bid against exclusive licensees when, under the commons model, you can use the spectrum whether or not you pay for it.

Why wouldn't anyone be willing to pay for it if you can use it without paying for it? And yet, the commons model makes a lot of sense, particularly for things like wifi where there isn't contention when you use it within your own building for very short-range propagation. That's an important area. So, I think unless something drastically changes, we're stuck using administrative procedures maybe to make the decision about how much spectrum and what spectrum to allocate for licensed and unlicensed.

Scott Wallsten:

That's a little depressing, I think.

Evan Kwerel:

Paul, do you think I've missed a bone on that? Or what do you think?

Paul Milgrom:

Well, I'd want to think about it some more. There are ways to charge for unlicensed spectrum. The device makers that use the spectrum could pay for it and so on. And we do usually try to allocate between competing uses where the competition is simple to allocate between competing uses by who's willing to pay more. And we know that that leads to some amount of inefficiency because there then may be people who aren't willing to pay, and there could be some unused spectrum on that account, but those inefficiencies need to be balanced against one another.

So, I'm not 100% sure that I agree with you on that one, Evan. I guess it's okay for us to have some disagreement on this in this discussion. But unlicensed spectrum has been immensely valuable. I mean, there's no doubt that wifi has been incredibly valuable in our economy and the uses that have been made of, especially wifi, but other kinds of unlicensed spectrum as well have added a lot of value. The question of how you would charge for it, if you were charging device

makers and whether that would work, I haven't seen the study of that. And until I do, I'm not willing to jump to a conclusion about it.

Evan Kwerel:

It's also the question of whether you'd want to charge for it, as Paul was saying, I mean, to the extent that there isn't contention when you have very short propagation because of low power limits. Maybe there isn't a reason. I mean, maybe it's inefficient to charge.

Paul Milgrom:

Well, I'm talking about how you decide the boundary, how much of the spectrum there should be. And what you'd like to be able to do is say, "What's the marginal value of additional spectrum? And how do you get that information except through a market?"

Evan Kwerel:

One of the things it has to do with licensed sharing, where you can imagine, and some other countries have done that, where they limit the number of companies that can use it and they have to have a license. And that is sort of a hybrid with this. But if you run it on a commons model where anybody can come in at any time, at any later point, it's very hard to see how this could work. This is a deep and difficult question, and I wouldn't put myself up against Paul in trying to figure it out, but I would enjoy talking about it.

Scott Wallsten:

It's something that I would hope both of you work on because it would be another... You can get your second Nobel Prize. Let's go to a couple of questions. And so, first here from David Goldstein at the USGAO, who asks, has anyone looked into whether the winners of spectrum auctions tend to experience winners curse by either winning a bid that was greater than the actual value of the spectrum? And let's broaden that question a little bit. This was discussed a little bit this morning. How do we know if an auction's been successful?

Paul Milgrom:

On the first one, there have been some auctions where it appears that the prices in the early days rose to some outrageous levels. Also, in advising bidders, I know a number of bidders whose statement about the auctions go something like this. They say, "All of us would be better off if they didn't allocate this spectrum at all, because in order to keep up with our competitors, we're going to have to spend money and buy spectrum to stay in business, but our profits aren't going to go up. And if anything, they might go down, and we're spending this money and enjoying no increase in profit."

So, we do hear that. I have heard that from bidders more than once. So, this question about whether there's a winner's curse, well, there's a supply side curse here that these guys have to buy and don't necessarily cover. And yet when the industry has been so profitable, that's what they tell me. But I take all of the grain of salt because there've been enormous profits made in this industry generally. Did I missed some part of the question there?

Scott Wallsten:

No, no. I was just waiting to see if Evan wanted to add.

Scott Wallsten:

But we have another question. Have there been developments in spectrum auctions internationally that have surprised you and do you think we should try?

Paul Milgrom:

Well, internationally, one of the things that has happened, at least in the English-speaking world, is a lot of combinatorial auctions, which have gotten a lot of resistance from bidders because they've done a better job of extracting value in many cases. Another thing that's happened internationally are these spectrum caps, which have a whole mix of effects. When you put in spectrum caps that you limit incumbents, you also limit competition. And sometimes that leads to lower prices.

Sometimes one of the things we've seen going on in other countries is limiting all the incumbents so there's room for new entrants, which can be beneficial to consumers if it's done well.

Although, personally I haven't been engaged in any studies on that. So, I'm not going to comment on how well I think it's been done. My first impressions about that are mixed. What else has gone on internationally? I guess those are the two big ones. What do you think, Evan?

Evan Kwerel:

I think that's right. The commentorial clock auction is pretty controversial. It's definitely not beloved by many bidders. And maybe it's true that it extracts more value, but at least the claim is that it's also quite confusing in terms of that the results from the clock phase and the results in the commentorial phase can be very different. And people are surprised. And there can also be budget constraint issues, as I recall. So yeah. I had wanted to... Well, Paul knows that I was very interested in seeing if we could develop a commentorial auction and ran several conferences on that. All I will say is it's a really hard problem.

Paul Milgrom:

It's where I began to come to understand that markets were not the final solution to everything. But again, the need to use assets in combination, limited specialized assets in combination, that's not something that markets are necessarily good at. That takes some amount of planning. There's still questions about who should do the planning, what role of government should be, and whether there are other agencies or entities that might be involved. But it isn't just a matter of trading and fixed prices that gets you to a good outcome.

Scott Wallsten:

Bob re-types the question. The incentive auction help broadcast coverage constant and use pre-computed matrices, is it possible for the auction software to suggest alternative coverage patterns to the broadcaster that could result in a better packing arrangement? Broadcasters could accept or reject those suggestions?

Paul Milgrom:

Yeah. I mentioned to you earlier that what we were doing was NP-hard. It was computationally very difficult. We were concerned about two kinds of complexity. One was complexity for us, the

stuff that was too hard for us to compute, and the second one was too complex for the broadcasters to bid intelligently. We had a lot of small broadcasters who we didn't want to pose extremely hard problems for them. So, we had talked about the possibility of selling interference rights. How much would you charge if you got only 90% of your coverage?

When we were working on the incentive auction plan, we talked about the other ways of doing it, and they were computationally much more difficult, and they were much more complicated for the broadcasters. So, the reason we decided that pretty much we either buy you out or we don't, is that that would be easy for the broadcasters to understand, it's just one price to come up with.

And it was easier to compute with because now if I need to make room for you, Scott, in the broadcast spectrum, I can buy 10% from Evan and 5% from somebody else. There became many, many more combinations of things that were possible. And just increasing the number of combinations increases the computational complexity. That would've been an enormous increase, and we decided it was beyond what we could guarantee the ability to do in reasonable time.

Scott Wallsten:

We're just a little over time. Let me ask, what research do you think is important to do in this area now? Or where would you like to see the FCC or maybe NTIA go with what we've learned so far?

Paul Milgrom:

That's for me?

Scott Wallsten:

It's for both of you.

Paul Milgrom:

So for me, I haven't been limiting myself to radio spectrum anymore. I'm looking at water rights and interference in that regard. I'm looking at electricity generation where we've moved from relatively low fixed costs, large marginal costs of consuming oil or gas to things that are basically all fixed costs, which are wind and solar and what affects that has on market. So

honestly, Scott, I haven't been thinking about the FCC's problems, so I should pass this on to Evan.

Evan Kwerel:

Yeah. Well, one issue that I've been interested in for many years, and this is something that John Williams brought to my attention, is the issue of adjacent channel interference. And one of the major barriers to reallocation of spectrum is the potential for new uses interfering with incumbents in adjacent channels, and the adjacent users can often block or delay reallocation. And one example that we've heard much about is the c-band with these radar altimeters.

A question that I have is, is there any market mechanism that could be used to compensate incumbents with legacy systems for a reduction in interference rights? And one of the issues that complicates this is you'd like to be able to do this well before a reallocation so incumbents and adjacent channels have an incentive to make their systems more robust or find other alternatives when they have plenty of time, as opposed to after the reallocation has been made.

But the problem is, who's going to compensate incumbents and adjacent channels if you don't have licensees, new licensees from the reallocation? I've thought about this and not made much progress, but that's something that I think adjacent channel interference is an important issue. And I don't know whether there's a market mechanism that could help with that, but I sure would like, if there is, to understand it and see if it could work.

Scott Wallsten:

Okay. Well, with that, thank you both for joining me today. I think that was a really good conversation. We really appreciate your time and look forward to talking with you again soon.