Transcript of CleanLaw Episode 28: Joe Goffman Interviews Gernot Wagner on Climate Economics, November 4, 2019

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Robin Just: Welcome to this episode of CleanLaw from the Environmental and Energy Law Program at Harvard Law School. In this episode, Joe Goffman, our executive director, talks with climate economist Gernot Wagner about his latest paper, showing how climate economic modeling can account not only for predicted damages linked to climate change, but also for the uncertainty and risk associated with climate change.

Robin: Gernot also talks about his work with the late Martin Weitzman, one of the most influential climate and environmental economists who ever lived. We hope you enjoy this podcast.

Joe Goffman: Let me say hello to a long-time friend and some time colleague, Gernot Wagner, formerly of Harvard University and now at New York University. And Gernot, let's start off by asking you to give us your current title.

Gernot Wagner: Let me look that up. So I teach at NYU, that is in fact true, and my formal title is I'm a Clinical Associate Professor at NYU's Department of Environmental Studies, and then Associated Clinical Professor at the NYU Wagner School of Public Service.

Joe: You used to be here at Harvard University, and so let me congratulate you again on the opportunity that you earned for yourself at NYU. Before we dive into the subject matter at hand, I want to do a little bit of a preview of what we're going to talk to you about today, Gernot.

Joe: First, you and two coauthors recently published a paper about economic models for climate, and it seems to have had some implication about pricing CO2 and different ways of looking at not only its potential damages but also risks associated with it. And in your background, you were the coauthor with Martin Weitzman of a very important book about climate called Climate Shock. And since, unfortunately, we just lost Marty Weitzman who passed away a couple of months ago, I may ask you to reminisce a bit about your experience writing that book with him, both for general purposes but also because I gather that the recent work you did is in kind of a direct lineage with the work that Professor Weitzman himself had done and some of the work you did with him. So let's hope we have enough time and strength to cover all those topics.

Joe: One other thing I should mention is that we're recording this on Wednesday, October 23rd, 2019, and just this morning Naomi Oereskes and Nicholas Stern published an op-ed in the New York Times that seems to very much touch on the same topic that your recent paper did, and in some ways, if I've read both your recent paper correctly and the op-ed correctly, your paper provides something of a remedy to the analytic problem that Professor Oereskes and Lord Stern identified. So let's try to cover all those things, and let's start by asking you, Gernot, to talk about the paper you recently published.

Gernot: Sounds like a plan. So basically the origin story behind this paper was financial economics meets climate economics. So about a quarter century ago, 1991, so a bit long ago now, Bill Nordhaus, who shared the Nobel Prize last year for his contributions to climate economics, and one of the key figures in the founding of the discipline. So a quarter century ago, he published the first version of his DICE model. Dice is in the name. It is about risk, it's about uncertainty, and so on and so forth.

Gernot: Well, around the same time, financial economists came up with better ways, or what they of course call better ways of incorporating risk and uncertainty into models of decision-making. And for the most part, those two literatures, the financial economic one on the one hand, the climate economic one on the other, were basically running in parallel. Those publishing in one, of course, knew of the other and vice versa, but at the end of the day it was sort of either or. Pick your poison, pick your discipline. Until fairly recently.

Gernot: So a few years ago, sort of insights of the financial economic literature, which very much deals with uncertainty and risk head-on. Something that sort of is in DICE's title, in the name, in Bill Nordhaus's model's name, but that the DICE model itself just doesn't do quite as well. It wasn't built to do that. Not to sort of Bill Nordhaus's miscredit here. In many ways, he was so early developing these first climate economy models, his own model, that the financial economics literature just wasn't far enough yet to have developed those concepts.

Gernot: But by now, right? A few years later, a couple decades later, there is what I would call sort of parallel ways of looking at the world. Parallel ways of looking at a risk.

Joe: Let me just do a little bit of a restatement of what you said and why I think it's important, and why I think a lot of listeners might think it's important. In the public discussion or the discourse in the political world and the policy world and the world of experts, there seemed to me and your paper revealed it, at least retrospectively, kind of a disconnect between the models that people were looking at and talking about, and the qualitative description of what climate changed posed in terms of a threat. The models, the climate economy models,

were focused on damages which relied on predictability, but there was a lot of use of the term uncertainty, and a lot of use of the term risk. And it seemed, it sounds like, that the uncertainty and risk wasn't really reflected in the climate economy models.

Gernot: Yes, right? It is at least not reflected in the way that financial economists would like it to be reflected. And just to be clear, there is lots of talk of the importance of taking risk and uncertainty seriously. But actually, in this case Bill Nordhaus's full credit, in the very first publication of his DICE model in the Science Journal, he concludes that it should be emphasized that this analysis has a number of important qualifications, of course, as every model always does. Including the economic impact of climate change. That's a bit ironic, right? That's sort of what the model is supposed to be about, while he identified it as one of its key qualifications. And then, he goes on and basically says, "It abstracts away from issues of uncertainty."

Gernot: So despite the name, DICE, casting the die, throwing the die, it was very clear from the beginning that... you mentioned the word before, deterministic, right? That essentially what's in dice, what's in this climate economy models, is what can be quantified. Yes, there are provisions for the stuff we don't know, for the Don Rumsfeldian known unknowns. But frankly, again, by definition, they are not part of the core estimate here. That core estimate is, "What do we know? How can we quantify those damages? How do we incorporate them into what some consider the world's most ambitious benefit cost analysis?" Figuring out what one ton of CO2 emitted today, and yes, that stuff sticks up there for a while, right? Half of it is still there about a millennium from now. What that ton emitted today does in terms of damages over its lifetime, discounted back to the present.

Gernot: So the very model's structure is about what we know, what we can quantify. Meanwhile, this is many ways is the emphasis of those focused on risk, focused on uncertainty, is that maybe the real problems are with the stuff we don't know. Not necessarily the unknown unknowns. Those are important, too. We just don't know anything about them anyways. And yes, we need to be prepared for those too.

Gernot: But more importantly, it's about the known unknowns and how one might incorporate tail risk. The risk of at low probability, high impact events, into one's analysis. That's really where financial economists know quite a bit more, frankly, than the typical climate economist, where it becomes pretty clear that using the kind of modeled structure, the kinds of insights that financial economics gives us, leads to potentially very different conclusions than the standard climate economic view of the world.

Joe: So you basically took the sort of qualitative or verbal description of risk and uncertainty, and the known unknowns, and using financial risk analysis, we're able to not only incorporate those into the analytic exercise, but actually produce some numbers.

Gernot: Yes. And just to be clear, we are not the first ones to do this. We cite a review article that reviews about a dozen or so efforts that had done something similar before. Basically use financial economic sort of modeling structures to make sense of price at each ton of CO2 emitted today, or to cost, its social cost. I guess what's new here, what makes this different is we call our model EZ-Climate. EZ has a very nerdy implication, Epstein-Zin, two economists. One actually, Stan Zin, teaches here at NYU. The two of them, together with a couple others, one in particular, Wile, so come call it the Epstein-Wile-Zin preferences. Most call it Epstein-Zin. Poor Wile gets dropped.

Gernot: But what these two did was come up with a new way, in many ways, to conceptualize how one might think about incorporating uncertainty. There's a bit of history here, too. By now Epstein himself has published at least one prominent paper sort of fundamentally criticizing this model structure, whereas his coauthor Stan Zin sort of went the other way, and in many ways is still using and showing how this insight plays a role and ought to be used more broadly. So Epstein isn't very happy with us using this. Zin is very much happy with us using this for climate risk.

Gernot: But there's something else here, too, a second meaning. EZ also of course stands for easy, simple. And that's really what we are going for here. So implementing these Epstein-Zin preference structures very quickly results in these massive modeling exercises. Now, there's nothing wrong with that. We have more powerful computers today than we did 20 years ago, so yes, of course, let's use that. Of course. But frankly, what it means is sort of many of these models are simply these vast, black boxes. And like the DICE model, it's very difficult to see what drives what. What are the important assumptions? What are assumptions that don't matter all that much to the final outcome? And that's what often makes it very difficult to frankly use one of those models to then kick the tires, figure out what drives the results.

Gernot: Meanwhile, our model tries to sort of go back to basics, create the simplest possible version of a model like this, to truly be able to test what each of those different assumptions might mean for the final outcome. And yes, we do plenty of model runs ourselves in this first paper. Lots of others have tried that, too, and basically it's possible to do this in sort of a simple, open, modular way. To frankly allow sort of the average grad student to play around with this model and sort of come up with his or her own results based on his or her own preferred assumptions.

Joe: What I just heard you describe in terms of the EZ approach, is that you managed to create some transparency.

Gernot: We've tried to shoot for transparency. But yes. And actually, not to make too much of what we tried to do here... Yeah, let me toot my own horn here. So it took us quite a while, frankly, to make it simple. This is sort of the Mark Twain, right? If I had more time, I would have written a shorter letter. Well, in this case the first iteration of this model might have taken us a few months or so to try to get right. Overall, it's taken us maybe five years total. And most of that was spent trying to simply things. So we actually, even before I arrived here at NYU, we worked with a group of NYU grad students actually, in a Financial Engineering program, who're very good at programming on the one hand, and understand these financial models on the other.

Gernot: We basically gave them our original code which had all the features, all the bells and whistles, but frankly was fairly convoluted at the time. And basically the task for their Capstone Workshop, for their master's program, was, "Could you please take this code and make it as simple as possible?" Not simple in the sense of making it run faster. It was already running pretty fast. It was doing pretty well on that dimension. But to simply make the code itself easily understandable, make it modular. Make it in a way that if I want to tinker with just one little aspect of this, I'm able to without basically mucking up anything else. I leave everything else in place, change one little equation, or I change one input, and see how the results change.

Gernot: So that really took up most of our time, at least when it came to coding this model. And yeah, I think the result in many ways is... obviously I'm slightly biased here, but I'd like to think it says it does. It creates a calculation. It creates a calamity economy model like this, like a few others have done before, but does it in the simplest possible way. Now just to be clear, simple is relative, right? It still runs in a programming language that one first needs to learn, Python, which is a fairly standard language but on the other hand still, it's not Excel. It's not an Excel spreadsheet that everybody knows. But still, within that it doesn't get much simpler to use.

Joe: So it sounds like from the point of view of other people who might want to use this tool, there's some agility, there's some transparency, and there's an added degree of user-friendliness. But let's turn to your paper and look at some of the results that you reported. I think one of the things that is noticeable is that you and your colleagues create an argument for high prices at the beginning, not necessarily starting at say, if you're looking into policy design, a lower value say carbon tax rising to a higher value later. But rather, starting out with a pretty high price in terms of the value of carbon dioxide removal, or in terms of upfront investment.

Joe: Do you want to sort of explain that and elaborate a bit?

Gernot: Basically the core conclusion that's also in our title, "Declining CO2 price paths." As far as publications go, of course, sort of the most insinuary thing ought to be upfront in the title, to draw attention to this. Basically for the most part, when one looks at the sort of idealized way of approaching climate policy, the standard approach is you start low and you increase ambition over time.

Gernot: Okay. What's the logic behind that? Well, there are competing forces here, there are trade offs. One the one hand, it costs money to transition to a cleaner economy, or at least that's the assumption, right? Some arguments to be made why it may not be as expensive as economists typically assume it would be. But nevermind all of this. It is costly, right? Transitioning from dirty to clean energy costs money. Okay, so that's one.

Gernot Wagner: Second, climate damages accrue for the most part, plenty of them hitting home already, but many of them, many more will hit down the line. Decades, centuries hence, when stuff really hits home. And it's this fundamental trade off typically, and the discounting of those climate damages later on, that leads to this sort of fairly standard conclusion that carbon prices start low today and increase over time. It makes sense. There are intuitive explanations of it. It's very simple to see how that is a standard way of looking at the world. It comes out of Bill Nordhaus's DICE model, lots of models like this.

Gernot: Our model turns this conclusion in many ways on its head. And there's a few reasons why, but here is sort of one of the more fundamental one which is built into the very modeling structure. Which is we assume uncertainty today about climate in the near and not so near future might be pretty high today, but over time some of that uncertainty in fact resolves itself. Or put differently, people living in 2300 know more about the climate in 2300 than we do about the climate in 2300. Now, when I say this aloud right now it seems obvious. Of course, duh, how can you not assume that? But actually, it turns out the very structure of some of these other climate economy models basically assumes the opposite. Assumes that the further out we go, the less we know about the climate. Which in one version of the world, yeah, that sort of makes sense too. The further out you go, the less we know today.

Gernot: But that's not really the operative question. The question is in fact, "In 2300, do you know more about the climate in 2300 than people today do about the climate then?" And I think put that way, it seems completely obvious, to me at least, how one would think about this any other way. Well, if you take this logic, sort of lead it to its logical conclusion, sort of have it be the fundamental model's structure, that is one of the main driving forces behind this declining CO2 price path, or set of declining price paths, in the long run.

Gernot: Now, here's another one. Technological change. It costs a lot more today to mitigate than it does in the future. Well, if it costs a lot more today and we know we do need to mitigate because of unmitigated climate change, we need to decrease CO2 emissions. Well, if it costs more, the price per ton of CO2 to lead to that decarbonization also ought to be higher. So all else equal, same uncertainty, same everything else, if it costs more to decarbonize- well, on the one hand, we will decarbonize less as a result, sure. But the price, all else equal, will probably be higher today than it would otherwise be. Well, over time, the cost of decarbonization decreases, the price to decarbonize also decreases.

Joe Goffman: One of the ways in which the paper has been read by people who have looked at it, and attempted to translate it for lay audiences, has been not just to feature what you described as the rationale for the downward slope of the price over time, but also have focused on the fact that the nominal price now, in the present and in the near future, is higher than the conventional models have shown. And that probably sounds to me like a way of being responsive to what Professor Oereskes and Lord Stern were trying to describe in their op-ed piece today, which is the so-called low probability but high impact damages or risks need to be priced in, given how much less we know now than we can expect to know in the future.

Gernot: Yeah, so that's part of the story. In many ways, actually, we go to sort of a great length not to mention our preferred price, based on our sort of assumptions in the base case scenario, right? There's lots of graphs in the original paper. Well, many of these graphs do in fact show what price per ton of CO2 comes out of our model, well, we go through great lengths not to even mention that price. But let me just do it now. So yes, it's a lot greater than $100 per ton of CO2. Which depending on who you ask is either a lot or still not quite enough. It's a lot relative to sort of the standard climate economy model pronouncements that basically show prices right around now, 2020 or so, of let's say $30, $40, maybe 50, per ton of CO2.

Gernot: So ours is above 100. Okay. What is that? First of all, just because we say it should be that high doesn't make it so. There's obviously a big political dimension to all of this. But then of course the big question is, "Okay, so what are some of the wider implications of having a price that high?" Well, one is if the price is $40. Let's start with that. The Obama Administration's social cost of carbon calculation comes up with a price for a ton of CO2 emitted right around now of about $40. Now, the current administration has a much lower price. Let's not get into that, lots of legal questions here. Let's start with $40.

Gernot: If $40 is the right place and California is saying its cap and trade system has a price of around $15, then it means California is sort of on the low side, but it's kind of doing the right thing. It's the same order of magnitude. A system is in

place. So let's tighten the cap a bit, let's do a few other things. But at the end of the day, what we are shooting for is $40. What California is doing, what the Europeans are doing with their emissions trading system, what lots of other efforts around the world are doing, it's sort of in the right ballpark when it comes to pricing CO2.

Gernot: Meanwhile, and there have been plenty of earnest economics papers written by some of my colleagues, some of my close colleagues, that analyze other policies like let's say the Swedish carbon tax that's around $120 per ton of CO2. Or German solar feed-in tariffs which used to be much higher than they are today, and were sort of around $600, maybe even $800 per ton of CO2. Very strong support for solar PV in that case. Very high cost relative to the Obama era, US social cost of carbon figure of $40. Well, if you look at those other policies, the Swedish carbon tax, the German PV tariffs, the earnest economic analysis, you basically have to conclude that the Swedes are too ambitious. The Germans are too ambitious with their climate policy.

Gernot: Now, that's all based on saying, "The right price is $40. What the Germans are doing is very ambitious relative to it." If the right price, on the other hand, is at least $100. Or like in our paper, we go to the great length not to mention a price at all, but we basically say, "Look, there's lots of uncertainties, we just don't know. But let's present some very lower-case conservative calibrations here, and none of those get to a price below $100." Well, suddenly what the Swedes are doing, maybe even what the Germans are doing, is suddenly in the money. It's sort of in the range, in the ball park of possible climate policies, in terms of their relative strength.

Gernot: And conversely, what happens with California cap and trade, what happens with the European Union Emissions Trading System may well be entirely unambitious relative to what is necessary. Or looking at California specifically, there's cap and trade with its carbon price of around $15. There's the low carbon fuel standards which have an implicit carbon price of something like $150, 10 times as much. Well, looks like the low carbon fuel standards look much better than the overall cap and trade system in terms of its strength. Cap and trade ought to be tightened by a lot to get to a price like this. And it may not even be possible to get to that high a price, at least not politically, with cap and trade alone.

Gernot: So essentially, an analysis like ours might point to the necessity to do lots and lots of other things, what is often called complementary policies, but which may actually need to be front and center when it comes to something like incorporating the full external cost of each ton of CO2 emitted, if the target for that level of ambition is at least $100.

Joe: So here's a way that, a long time ago when some of Marty Weitzman's work became more widely known, was talked about, and relating that to what you and your colleagues just produced. What we know is that what we don't know about climate might really hurt us very, very badly. And we need to figure out a way, at least analytically or in terms of looking at price ranges, we need to be able to translate that knowledge of the possibility of great damages, we need to translate that into some sort of quantitative expression. And that's where it sounds like ending the separateness or parallelism of climate economy models and financial risk models was a very important thing for your predecessors, and you and your colleagues to do.

Joe: In other words, if we know that there is some risk of severe impacts, we need to figure out how to price that. And financial risk analysts know how to do that so let's adopt to their know-how.

Gernot: The short answer is yes. The longer one, of course, this is a very generous assessment of what we have done here, right? Following in the footsteps of Marty Weitzman is frankly impossible for many reasons. But yes. And so Marty Weitzman had basically introduced some of the most potent critiques of standard climate economy modeling. Him and Bill Nordhaus have had epic debates about what's sort of the right way of looking at this problem is in the first place. And Marty would have been the first one to say that what he had tried to do is basically shift the burden of proof. So he didn't provide an alternative. He didn't say, "Oh, this is the wrong way of looking at things. Here is my way, here is the right way. So instead of calculating the social cost of carbon in a certain way and coming up with let's say $40, here is the alternative and the number ought to be much, much higher."

Gernot: So actually, I remember going back and forth with him on the book we wrote, Climate Shock. We never said that, "Here is our preferred number." Where there is chapter upon chapter, or a couple chapters specifically, targeted at precisely the known unknowns, and the tail risks, and the uncertainties and so on. And the only dollar figure that each ton of CO2 ought to command, the only social cost of carbon ever mentioned in those two chapters, is $40, is the Obama era of $40 social costs of carbon. We provided what I would think is sort of a solid critique of those calculations, especially because the uncertainty, the tail risk aspects of it. But we don't provide an alternative. We basically, at the end of the day, when sort of forced or since forced, sometimes forced to provide a number, we basically concluded by saying, "Well, if forced we would still say $40 is the right number," while emphasizing that it can only be a conservative lower bound of the true cost that each ton of CO2 costs, each ton of CO2 emitted costs.

Gernot: But at the end of the day, we came back to those $40. So yes, this new analysis basically tries to take the critique very, very seriously, tries to apply new ways of looking at the risk and uncertainty inherent in these calculations. And then yes, for better or worse does come up with an alternative number. Which I know, yet again, with sort of false modesty here, we try not to put in the paper itself or we didn't put in the paper, in some sense realizing that if we did that, that's precisely what everyone casually reading the paper would simply search for that number and then cite it, and sort of ignore the rest.

Gernot: I'd like to think it was a relatively good move not to do that, because frankly not a single journalist who wrote up the results here emphasized the specific dollar figure, largely because there wasn't one easily identifiable. But the emphasis of the broader conclusions, which was if and when you take uncertainty seriously, when you include it in the way financial economists would like us to include, and so on and so forth, there are these broad implications that that has, including increasing the price per ton of CO2 emitted today quite dramatically, almost an order of magnitude or so. At least doubling, tripling, at the very least. That's only one of the implications here.

Gernot: But yeah, at the end of the day it does try to take the Weitzman critique of some of the standard ways seriously, and try to incorporate that in the very modeled structure that we tried to come up with here.

Joe: You just said something that really is worth underlining, which is it's not the dollar value per se, it's demonstrating what it looks like to take risk and uncertainty and the known unknown seriously, as opposed to just saying, "Well, here's the social cost of carbon, and here's some hand waving about risk and uncertainty, and why the social cost of carbon dollar value is conservative." Essentially what you did was display for everybody to see, what it looks like when you take high impact, low probability risk or the known unknowns, or that which we don't know could really hurt us seriously, in an analytic exercise.

Joe: It feels like this work you and your colleagues did and your predecessors did owes a lot to what Marty Weitzman-

Gernot: Oh, absolutely.

Joe: ... seminal contribution, and it would be good to hear a little bit about what it owes to Professor Weitzman.

Gernot: Well, frankly the very sort of idea, at least not to speak about my coauthors now, who sort of came from this from a different angle, from sort of the financial economic side, applying those tools to climate. And an important new, for them, for financial economics, risk management problem. Just speaking for

myself now, yes, Marty Weitzman taught me most everything I know about climate economics initially. And yes, this is very much trying to do justice to some of those fundamental Weitzman insights into how one conceptualizes the risks inherent in, he liked to call, the world's perfect problem. More long-term, more global, more uncertain, more irreversible than every other public policy problem out there. Or at least unique in the combination of the four.

Gernot: So just to be clear, there are other problems out there. All out nuclear war? Yeah, that's global. It is certainly irreversible. It's also uncertain up to a point, maybe not all that much. Now it turns out, it's not very long-term. Person pushes button. 15 minutes later, world disappears, or at least world as we know it disappears. So the consequences are immediate. Which one way of looking at this is to say, "Wait, that's even worse because there's very little you can do in those 15 minutes." On the other hand, it makes it so obvious how big a problem it truly is, that from a political perspective, from a policy perspective, it's relatively speaking easier to try to do something about that problem than about climate change where the full affects, and yes, we feel plenty of them today already, but the long-term effects are by definiton very long-term. They are hundreds of years out, millenniums out, where what we do today, what we do in the coming decades, affects life on earth, on this planet, for centuries to come potentially.

Gernot: And yes, it's this long-term nature that makes it so difficult to try to do something about the problem today, from a very sort of real political perspective. So it's some of those insights that either sort of tangentially underline why this is an important problem in the first place, or for that matter, that feed directly into the way the model is structured to incorporate some of these tail risks, some of these tipping points, from the very beginning into our analysis. And basically, take the calibration of those tipping points extremely seriously from the get-go.

Joe: I can't let you go, Gernot, without getting you to talk about one of my favorite passages in the book Climate Shock. It was a passage in which you and Professor Weitzman urged your fellow economists not to get stuck on endless elaborations of the perfect solution, or perfect policy designs, but actually to figure out constructive ways, I think what you and he referred to as, "Second, third, fourth and maybe even fifth best policy designs for dealing with pollution and climate change." In which I think you acknowledged that it was okay for economists to acknowledge the potential value of commanding control of technology-based standards, and similar policy instruments.

Joe: So since it's such a favorite, I was wondering if I could get you to talk about it a little bit before we go.

Gernot: I will try. So I assume you are referring to somewhere in the introduction. In the first chapter, we basically talk about economists had known about the solution forever. We as a profession have known about the solution to climate change, known in quotation marks, since before there was a problem. It was Arthur Pigou who basically said, "Well, let's just tax the problem way." Now, just to be clear, he died a long time ago, Arthur Pigou did. So long before it was universally acknowledged that climate change was the problem, Pigou introduced this idea of what is now known as Pigovian taxation, worrying about rabbits overrunning a meadow. But the principle is the same. There is a difference between what the private individual faces as the cost, and the social cost of one's actions.

Gernot: And in order to right the wrong, in order to internalize the externality, the solution is very simple. You internalize that externality by taxing it, by making sure that I as the individual boarding a flight, fly across the Atlantic and emitting one ton of CO2, I don't just have the privilege of boarding the plane and enjoying the view, and enjoying the trip, but I also pay for the pollution. I pay for the full cost that that one ton of CO2 emitted will have caused over its lifetime.

Gernot: And that's what often leads economists to then say, "Well, here is the first best solution. It's a carbon tax." And now there are epic debates whether it should really be a carbon tax, or a cap and trade system. Both basically are first best approaches. Carbon tax or carbon cap. These first best approaches to the problem. I would sort of say that's econ 101, an econ 101 view of the world. And yeah, that principle is correct. There's one law in economics, and so we often pretend to be like physicists and of course we are not. Humans don't behave like atoms in a vacuum. We have emotions and feelings and all that sort of stuff.

Gernot: But there is one law in economics. It's called the law of demand, so the law of compensative demand technically, which means price goes up, quantity demanded goes down. Works every single time, or at least a couple instances we know where it doesn't work. Carbon isn't one of them.

Gernot: Now, that basically leads to economists jumping up and down, shouting carbon tax all day, or maybe cap and trade. Now of course, the real world is messy. And well, this is sort of earnest academic meets reality. There are, I would say, lots and lots of esteemed colleagues, economists, who basically never go beyond shouting carbon tax, or basically saying, "Well, here is the solution." Right? "We know the problem. Here is the solution." And actually, there's some Marty Weitzman papers where he basically says, "Well, let's assume a world climate assembly where every country comes together and negotiates the ideal carbon price, or maybe even every citizen comes together." Seven billion of us in a room and we negotiate the right carbon price. If and when that's possible, here is the solution.

Gernot: Well, turns out, that's not really very practical. Let's start with that. And of course, even the 180 or so countries meeting, well, we've had that. We've had that for more than a couple decades by now happening, and that too of course, butts head with reality and isn't a very practical solution, to say that that sort of top-down thinking will lead to the perfect solution.

Gernot: So fast forward a bit and sooner rather than later, you are left with what you just called a second, third, fourth and fifth best world where in many ways, economists would have to hold their noses and would have to sort of be allowed to remind everyone that in the ideal world, we would prefer a carbon tax. But well, we are not in the ideal world so fine, let's go with something else. And I guess what this sort of section of the book is trying to do is sort of say that that's okay. And more importantly, say that, "Well, in an imperfect world it's not just okay. Maybe there are in fact other imperfections that in fact demand other policies."

Gernot: While econ 101 might tell us it's a carbon tax or a cap and trade system that is the solution, well, econ 102 might point to the fact that there are positive learning by doing spill overs. That the kind of deployment of new technologies like solar photovoltaic, for example, in fact deserves subsidies, deserves additional support in order to right a wrong here. Another wrong which is that when an inventor sits in his or her garage trying to figure out how much to invest in this new technology, well, he or she does not incorporate the full social spill overs, the positive spill overs in this case, in that decision. That person might only be concerned with his own profits and innovate accordingly. Meanwhile, there are positive spill overs. Society benefits from new technologies, typically. So we may want to subsidize those technologies.

Gernot: So you move from econ 101 to 102 and you realize that, "Wait, picking winners, subsidies, picking particular technologies may actually be a good thing, just looking at standard economics alone." And actually, last year- so unfortunately, Marty Weitzman didn't share the Nobel Prize with Bill Nordhaus last year. Turns out someone else did, Paul Roma. He's actually an NYU economist who shared the Nobel Prize with Bill Nordhaus for basically drawing attention to just this question, to what's called often endogenous technological change, basically inducing new innovation. And yes, a policy response there is to subsidize the clean, green, lean, mean, new technology. That's econ 102 admittedly, it's not 101. But it certainly ought to be part of the solution as well.

Joe: Well, Gernot, I think a lot of people know that you are a highly accomplished, indeed at this point, mere economist, but what they may not know is that you are also an award-winning teacher. And you certainly put those teaching skills on display during this interview, so I want to thank you very, very much for

giving us all this time and for your great work, and your great lucidity in explaining it.

Gernot: Thank you.

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