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WEBINAR

THE ECONOMIC CASE FOR TACKLING CLIMATE CHANGE NOW

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David Wessel: Good morning. On behalf of the Hutchins Center on Fiscal and Monetary Policy at Brookings and the Center on Regulation and Markets at Brookings, I'd like to welcome you to today's event, Economic Case for Tackling Climate Change Now. I think in the last couple of years, concern about climate change has risen substantially and is no longer a subject of handwringing among a bunch of scientists and economists who are sophisticated readers of the literature but has become a much broader public concern. There is always the temptation to wait with a problem like this and fix it later. After all, why should we have to tighten our belts now for benefits in the future? That's sort of the theme of today's event, is to think about the economics of acting sooner rather than later.

I'm very pleased we have two presentations. The first one is about the benefits of an international agreement to phase out coal. The author, Tobias Adrian, will present for about 20 minutes and then Carolyn Fisher will respond and then we'll turn to the second paper. Tobias is the financial counselor and director of the Monetary and Capital Markets Department of the International Monetary Fund, a post he's held since January 2017. And he's had his hands full dealing with climate change, digital currencies and all the current issues with inflation and the residues of the COVID crisis. Prior to joining the IMF, Tobias was senior vice president of the Federal Reserve Bank of New York.

After his presentation, I'm very pleased that we'll have a response from Carolyn Fisher. She's the research manager at the Sustainability and Infrastructure Team at the World Bank. She joined the bank in July 2021 and is still affiliated with a couple of universities, the University of Ottawa and VU and Amsterdam. She spent many years at Resources for the Future, where she remains a nonresident senior fellow. Following the presentations, my colleague Sanjay Patnaik will lead a panel discussion with all of the authors and discussants. But for now, the floor is yours, Tobias.

Tobias Adrian: Thanks so much, David, for the kind introduction, and thanks for having me at this important event. I'm going to start sharing my screen now. All right. So you should be able to, to see my slides. So what I'm going to talk today is a paper that is joined with Patrick Bolton and Alissa Kleinnijenhuis. Patrick is at Columbia and Imperial and Alissa joined Imperial recently as well. So the paper is called the Great Carbon Arbitrage and it is a cost benefit analysis of phasing out coal, basically making the point that phasing out coal is actually the economically right thing to do.

So there's a great economic benefit from phasing out coal, and we are giving numbers to how big that economic benefit is. So let me dive right in. I'm going to explain how we do the calculation, then I'm going to give you the headline numbers and then I'm going to talk about policy, so how to implement the great carbon arbitrage or how to reap the gains from phasing out coal. So from an economic point of view, there are two approaches to internalizing negative externalities. The problem of climate change is one that everybody who has taken an introduction to economics class has learned, there's an externality. Everybody is better off when everybody takes the action of, say, phasing out coal or saving the planet. But of course, any one person might not have the right incentives. Collectively, we do, but as an individual we might not, as an individual firm, an individual person or an individual country.

This is externalities, and economics has two main ways of internalizing externalities. The first one is Pigou. This goes back to an article in 1920 and this is Pigouvian taxation. So basically you can phase in taxes, in this case carbon taxes to align the private cost of using carbon with the social cost of using carbon, i.e. with the cost for the world as a whole. And that is certainly the baseline policy approach that institutions such as the IMF and most other policy institutions have been recommending. And that remains the baseline policy approach, is to recommend carbon taxation to align internal incentives and global incentives.

What we are doing here is to explore an additional complementary approach, which is the Coasian approach. So the Coasian approach says, well, there are these externalities, they're gains to be made and in principle, through bargaining or through setting up institutional, institutional arrangements such as multilateral development banks, for example, we might be able to achieve the efficient social outcome. In my personal view, I think both approaches should be pursued in parallel, and that is because the politics of carbon taxation, you know, are challenging in some countries. They might work in some countries, but not in others. And so we need to also explore complementary approaches. And this is where the Pigouvian approach comes in. So that's the end of the presentation, I will talk more about the policy implications of thinking through such a Coasian approach.

So the punch line of the paper is the question how much would the world benefit by phasing out fossil fuels and replacing them with renewable energy? So we're focusing on coal here. Of course, it could do this for other sources of energy, such as gas, but coal is particularly damaging for the

environment. So this is like a first order. But of course one could make the calculation broader. And so we measure the gross social benefits using a familiar concept, which is the social cost of carbon. So that is basically the cost to the world of the emissions from coal.

So that is taking the global economic view here. And we compare this social cost, so by phasing out coal, you're, you're, you're earning the social cost. And so that's the benefit, right? So the benefit is by phasing out coal, you're earning the benefit of not destroying the planet. And so we compare that to the present value of costs, which is the investment costs to shift from traditional sources of energy to new sources of energy such as solar and wind. So let's take a look at some of those scenarios.

So these are scenarios from the NGFS, the network for greening the financial system. And so we are focusing particularly on two scenarios. So one is the current policy scenario in blue. The left shows that the coal production, the the right chart, the coal emissions. So it's just rescale, basically. And so under current policies, coal production continues to increase and hence coal emissions continue to increase. And we compare that to the net zero scenario. So this would be phasing out coal by 2050. That's the orange line. Of course, there's a more extreme scenario as well, which is the halt to coal production immediately. But that is, you know, difficult to achieve. So we, we use the net zero 2050 scenario and we basically want to compare what's, what's, what is the net benefit.

So what is the benefit to the global economy by comparing the net zero scenario from the current policy scenario? And so the key on the investment side are the investment costs and renewables and the cumulative installed capacity of renewables. So the left-hand chart shows you the investment costs and you can see particularly for solar, they have been falling very rapidly. But even for wind and onshore and offshore, they have also been falling pretty dramatically. And so I will explain how we calculate this going forward. And then you can see that the cumulative installed capacity is rising very rapidly, particularly for solar, but also for onshore wind.

So what is the great carbon arbitrage? So the carbon arbitrage is basically the cost benefit analysis. So it's the difference between the benefit of phasing out coal compared to the cost of phasing out coal. And we are comparing S1 and S2, so the benefit basically from going from the current policy scenario to the net zero 2050 scenario, S1 versus S2 and Sr refers to the replacement. So how do you replace the, the current sources of energy? And theta is the social cost of capital. So

we, we are focusing on the global arbitrage, but I will also give you a little bit of regional results later on.

So what are the benefits? Well, the benefits are basically reaped by summing up the phase out of coal at the company level. So what we're doing, we're using a huge dataset, which is a company level dataset. So for every call company in the world, we are summing up the phasing out of coal or the phasing out of the emissions, and we are valuing those emissions at the social cost of carbon or what, you know, you could, using a carbon tax, think of as the optimal tax from a global perspective. So the baseline average social cost of carbon that we are using is $80 per tonne, which is based on a survey by Pindyck. So Pindyck did the survey of many, many scientists, particularly environmental scientists, but also other scientists, about 2000 I think in the study and asked what is the average cost of, social cost of carbon? And the average was about 80. It's very close to the IMF estimate of $75. But of course there's a wide variety, and I'm going to show you some robustness relative to assumptions around the social cost of carbon.

And so the emissions reduction is just the difference in the emission between the baseline and the phase out scenario. And then we have to think about the cost of phasing out. So the cost of phasing out has two components, the opportunity cost of avoiding coal emissions, which is basically the present discounted future cash flow of no longer earning from those coal companies, and then of course, importantly, the investment cost of building new capacity. So O plus I. So let's take a closer look at that. So the present value of the opportunity cost of coal is basically the present value of future profits of coal companies, because you have to shut them off. So you somehow have to compensate those companies or the owners of those companies.

And of course, what we're not doing here, which could be done, is to think about broader opportunities costs of phasing out coal, so for, for example, local wages to workers might have to be replaced somehow or workers might have to move across regions and there might be retraining costs. So those are not costs we're currently taking into account. And future works should certainly focus more on those particular costs as well. And then importantly, there is the present value of investments, because, of course, you now have to replace all this coal capacity with new energy. And our baseline assumption here is that part of that is solar, wind shore and offshore, here are the fractions for the current capacity in those different sectors. Now, how do we estimate the cost of investment going forward? This is using Wright's law; this has been documented in the literature.

So the more capacity that's installed in terms of solar and wind, the lower tends to be the cost of investment. So the more you do, the lower the cheaper it gets, basically. So this is kind of like an exponential learning model. So we are using that. And so this is how it looks like on the left-hand chart here shows you the unit investment costs for wind and for solar. And the right-hand chart shows you our assumptions under the alternative scenario, under the net zero scenario, how the capacity would accumulate. So in particular, the baseline assumptions and you can vary all of those assumptions so when you look at our paper, there are lots of sort of robustness checks looking at how different assumptions are changing the results.

So the social cost of carbon is $80. Time arises 22 to 2001, 2021. The phasing out is the net zero 2050. So that's the alternative scenario relative to the baseline. And then the replacement is assumed to be 50 solar, 50% wind, which again is 50 onshore, 50 offshore, investment costs assumed to be 30 years. And the opportunity cost of coal is the median unit cost of coal of the top ten coal companies. And then there's a discount rate, which is 2.8% percent. Again, we have a lot of robustness checks around those assumptions. And so this is the main result of the paper. The present value of phasing out coal is $114 trillion. So this is through 2021. The present value of phasing out coal is $29 trillion. So $29 trillion is a huge number. But relative to the economic benefits, it is small, right? So the benefits are enormous.

And by the way, the costs can be broken down in terms of the opportunity cost of phasing out coal and then the investment cost. And it's mainly the investment cost that is weighing here. And so the net benefit, i.e. the great carbon arbitrage, is $85 trillion or in terms of annual GDP, about 1.3% annually of GDP. Okay, so you gain every year 1.3% by phasing out coal. So it's an enormous, enormous source of economic gain. And here are also the numbers in terms of how much coal production and how many emissions are being prevented and what is the impact on temperature rises, it's two degrees. So it's a massive amount.

So here is, for example, one illustration of robustness. So we use the $80 from Pindyck in our baseline and the earlier study, in the earlier version of the paper used 75, which is the IMF estimate. But of course, the literature has all kinds of estimates between, say, the $50 of the Biden administration and the upper estimates of [inaudible] of of of $170. Now we can look at the climate financing needs, right so these 29 trillion, those could be broken down by country or you know by geographical region. So here we are showing you the breakdown, for example, into the world

developed countries, developing countries and emerging market countries or by region, Asia, Africa, North America, etc. So you see there's quite a bit of dispersion across countries here in terms of financing needs.

Here is the time series, so because we have this 30-year cycle, there is somewhat, somewhat of a cyclical feature here. And you can see how over time, these financing needs would evolve. And so let me, to finish my presentation, talk about climate finance. So why is, is our approach a kind of Coasian approach? So it's a Coasian approach because we're thinking about some like coalitions of coal companies, investors and the public sector to come together, to come to mutually beneficial agreements that are moving the world towards reaping the benefits of this great carbon arbitrage. In particular, coal companies would have to be compensated to phase out of coal and to get into new sources of energy.

There are three recent deals in Indonesia, Vietnam and South Africa, which have been very invisible and that where sort of like arrangements along those lines. There's the public investment and here what we have in mind are structures similar to what the IFC— the IFC is, is one of the institutions of the World Bank— have an important deal already back in 2018 with Amundi, an investment management firm, to basically offer a structure where the, the MDBs, such as the IFC and EIB invested in the equity tranche and then the more senior tranches, were issued at investment grade levels to global investors of about 2 billion. And basically that allowed levering up of public funds. So this is, you know, one example of how investors and the public sector could come together in terms of scaling up public money.

So let me give you a sense of the country specific net benefit. So each dot here is a country and you can see that actually, perhaps surprisingly for the majority of countries, already the net benefits actually exceed the, so the benefits exceed the costs. So the net benefits are positive. So when you're about the 45, the green line here, that means that your benefits are higher than the costs. So for many countries individually, they already have the right incentives to phase out coal. But there are some countries where the benefits are lower than the costs from their perspective. And this is where global institutions such as the IMF or the World Bank and of course, COP, the Conference of Presidents of the U.N. come in importantly.

So the narrative, the frame of mind is one where the climate change is a global public good, and even if some countries bring down the carbon emissions, quickly climate change will proceed

apace unless all countries make a transition. So you have to come up with financing arrangements to get everybody on board. And again, this can be complementary to Pigouvian taxes. So we absolutely believe in Pigouvian taxes, we just realize that it might be difficult in some countries. And so climate finance can be a complimentary approach to Pigouvian taxation.

And so here is an illustration of how regional deals might work. So this is broken down by the regions. And you can see here if you had a regional deal, so, for example, public private partnerships in terms of investment funds at the regional level, you move up because you're internalizing some of those externalities, you can move up above to, to positive territory in terms of net benefits. Of course, a global deal would be, would be fully positive. So let me conclude with that. So our analysis makes a simple but powerful observation; phasing out coal and replacing it with renewables is not just a matter of urgent necessity to limit global warming, but it's a source of considerable economic gain, right. So the world is much better off phasing out coal. And so there's a great carbon arbitrage here.

And then from the policy point of view, the cause and perspective gives economic logic, or it is sound economic logic from a Coasian perspective to compensate losses incurred from phasing out coal and to account for capital expenditures to reap those social benefits, the world would realize a natural gain of about 1.3% of GDP every year. And so the quantitative, quantitative climate financing needs of about $29 trillion will be to these very, very large global gains. So let me stop here. And thanks again. Looking forward to Carolyn's remarks.

David Wessel: Thank you, Tobias. Carolyn.

Carolyn Fischer: Okay, great. Thank you so much. And thanks for a great presentation, Tobias. Let me just start out with the usual disclaimer that my statements here are not a reflection of the World Bank, my employer, but are my own opinions as a researcher. So it is, there we go. And so this paper is a perfect fit for this, for this webinar as it really does make the economic case for tackling climate change now. So, you know, they find that the present value of the benefits of phasing out coal are over $100 trillion, and the present value of costs are under 30 trillion. And so you get a big net benefit from phasing out of coal. And let me just say that there is always a lot of quibbling that one can do about parameters, what is sort of in and out of the costs and benefits of the equation. But fundamentally, it's going to be really hard to change the result that this is an order of magnitude difference between the benefits and the costs.

And I think the other thing I'd like to talk about a little bit is, you know, thinking about other aspects of the distributional impacts that can deserve a little more attention. So this sort of Pigou versus Coase, you know, it's important in this sort of world of nationally determined contributions because, you know, there's a lot of concern about carbon leakage. And so here, if you have, say, global supply of coal and you have demand from countries that aren't taking on demand side policies and then demand, global demand includes those that are, you know, if a sub-global coalition of countries, you know, prices coal out of the market reduces their demand, well we're going to move down along the coal supply curve, lower the price of coal, but that makes it cheaper for everyone else, and they tend to increase their consumption which gets leakage. So that's part of the, the issue with unilateral pricing policies.

And so the idea of this literature on the supply side, climate treaty as well, you get the, we get negative leakage if we get folks to commit to reducing the supply of coal because that drives up prices for everybody and reduces consumption by everybody. Now, of course, if we're going to actually phase out coal globally, then, then we're getting the global solution and doesn't matter so much if that's from the demand or the, the supply side anymore. But, you know, there are, I think there are sort of distributional things to think about. So, you know, it's this question of who should be compensated in the coal phaseout. And the paper focuses on sort of the first order effects, the coal mining firms compensating them for their lost profits. This is a little, this is a little tricky.

This is a, was an article in The New York Times a couple of years ago how one billionaire could keep three countries hooked on coal for decades. These are, you know, large multinational corporations or held by billionaires. You know, they, there are mining companies that may stand to benefit actually from the, the switch to renewables because they can use their capital and expertise to extract the rare earth elements and other things. So, so it's not clear that, that these are the folks necessarily that should be compensated. And you mentioned this, you know that, you know, countries are typically the owners of the resource, the ultimate owners of the resource, and they may sell rights to it, but they'll lose royalties, should we compensate them, should we compensate the miners for the lost jobs.

This is actually, you know, a big issue in the just transition deal certainly in South Africa. Do we compensate the coal fired power plant owners for the stranded assets from early decommissioning, or do we want to compensate these companies for their present value of their lost

profits, the plants they won't be able to build and operate? And then do we compensate consumers for higher electricity prices if they, if they do become higher. So, you know, there are a lot of folks in the supply chain that will be affected by this phase out. And whether you're looking on the consumption or production side that's, you know, there's a different set of players that you may be looking at. And of course, China and India are both big producers and consumers of coal that I think they're both net importers now. So if you're compensating the ultimate or the resource owners, it's a different set of, of countries, including several developed countries than the consumers.

Now, the other thing to think about is what are really the costs of, the investment costs for switching to renewables? Is this really all the new capacity that has to be built through that whole horizon and enough to make sure that coal is credibly and permanently crowded out and never wants to be mined again? Or is it, you know, what you need to replace the existing coal fired generation capacity that needs to be decommissioned so you're not buying coal? Or is it something in between? Is it like the incremental cost over what capacity would have been otherwise over the horizon? And so I think we need to realize that, yeah, we're going to have to build out a lot of renewables, but we're actually over that horizon. We're going to be saving a lot of money from all the coal fired power plants that we're not building. So thinking about what, it wasn't clear in the paper, you know, which costs are being accounted for here.

Now, on the benefit side. So they find that the avoided social cost of CO2 are, you know, 1.3% of annual GDP if you, you know, bring it back to that. And I'll just point out a recent report by my colleagues at the World Bank that, that highlights the costs of conventional air pollutants are really substantial and often, you know, much higher than the avoided cost of social, of CO2. So they find that the global annual cost of health damages associated with exposure to air pollution is little over 6% of global GDP. And this doesn't include, one of my team members is doing research on the productivity impacts of air pollution and finding that they shave off a couple points of GDP in some major developing and emerging economies. So, so these are important. And so, you know, this would really add to the benefits of the coal phase, the coal isn't responsible for all of these emissions, but it's a good, it's a good chunk. So you can certainly justify, justify it on that as well.

And finally, so I thought this was sort of interesting, an interesting graph that Tobias showed. And it's this question of who really needs financing and in terms of compensating the losses and, and

accounting for the investment expenditures. And it's really struck me because developing countries, the low-income countries, are getting very little.

So I'm wondering where that's coming from, because I thought, you know, energy demand is this expect, you know, if we expect them to grow and converge, their energy demand is going to be rising pretty rapidly. You know, emerging markets are, are a lot of this investment need. And you can argue whether developed countries that need, really need to be compensated in this, they should be taking action. So, so, you know, I encourage you to think a little bit more of, you know, the distributional implications and sort of the, you know, what are really the priorities for a just transition to phase out of coal and improve energy access and development in the developing world. Thanks.

David Wessel: Thank you. We'll give Tobias a chance to respond when we get to the panel afterwards. But we're going to turn now to a paper by my colleague Glenn Rudebusch on what he calls climate policy curves, which is an attempt to systematically link climate policy to climate outcomes so we can decide rationally if that's possible, given the political realities that Tobias spoke about, what, what choices we want to make now.

Glenn Rudebusch is a nonresident senior fellow in the Hutchins Center at Brookings, he's also a senior fellow at the NYU Stern School of Business, and he previously had a very long and distinguished career at the San Francisco Fed, where he was, among other things, executive vice president and senior policy adviser, and before that, the research director. After his presentation, I'm pleased that we'll have a response from Irene Monasterolo, who's a professor of climate finance at EDHEC Business School in Nice, where she's director of their program on the impact of finance on climate change mitigation and adaptation. So with that, Glenn, the floor is yours.

Glenn Rudebusch: Great. Let me share my screen here. How does that look. Thanks a lot, David. Again, this is a paper, this is a great session, a great event on the economic case for tackling climate change now. My discussion is going to be drawn from a new paper on climate policy curves with my co-authors Martin Hänsell, Michael Bauer, Moritz Drupp, and Gernot Wagner. The point of it is to try to impress on people that connecting policy instruments to outcomes is, is crucial. The genesis of this project is that understanding the linkage between policy instruments and desired outcomes is important for the design and calibration of any, any public policy actions. So for example, formulating good monetary policy requires understanding how changes in interest rates are going to affect the economy and inflation. Good fiscal policy requires, requires knowledge of how government

tax and spending is going to affect the economy, and for climate policy, quantifying the linkage between policy actions and subsequent climate outcomes is also crucial.

But I think this connection has been difficult to perceive given the complexity of the relevant socioeconomic and physical climate responses. So this is a paper that tries to focus, tries to emphasize that it's policy choices that are going to affect, that are going to determine climate change. Here's an overview of the complexity I've talked about. This is just the DICE model, which is a very simple model in this, in this area. The blue area is the economy, a higher carbon price leads to less fossil fuel spending, production, financing, investment over time. The reduced flow of emissions, subsequent reduced flow of emissions then leads to a smaller stock, it's the atmospheric stock of emissions that's important working through a carbon cycle and in climate system.

We're going to simplify this to the essentials. We're going to focus on future climate change as a policy choice. And the key policy question then: what climate outcomes will result from a given policy setting? And to better communicate the efficacy of climate policy, we introduce climate policy curves, or CPCs, sorry, and these CPCs then quantify the relationship between the effective price of carbon dioxide and the future level of global, global temperatures. They've got these two important linkages, one from CO2 prices to emissions and then also the link from emissions to global temperatures. They provide a simple, reductive framing device for thinking about the climate policy transmission mechanism.

So we often talk about the monetary policy transmission mechanism in macro, there's also a climate policy transmission mechanism that I think gets lost in some of the discussion. There are two important elements of both sides of this climate policy curve that should be taken into account. First, the effective CO2 price can serve as a summary statistic for a wide range of possible energy and climate policies. Carbon and fuel, taxes, emissions trading programs, green subsidies and so forth. Just like, you know, there were studies of the Inflation Reduction Act, large model-based studies that translated the many policy, many of the policies of the Inflation Reduction Act into temperature, similarly, you can take those and back out an effective carbon price that would give you the same temperature response. And so that's how we think of the effective carbon price. It really is a summary statistic for a wide range of potential policy, climate policies.

For example, a methane emissions fee that leads to a temperature effect can be reproduced with, with the CO2 price path. Similarly, in terms of temperature, we're using average, global average

surface temperature as a summary measure to encompass a whole host of other environmental shifts, including sea level rises, weather extremes, other climate hazards. So using the CPC relationship simplifies the complex policy challenge and focuses on the key policy choices. You can also represent this mathematically, but if you don't like math, you can ignore this slide. But it's just saying that temperature, the amount of, of additional global warming for a given increase in emissions is denoted by that delta T over delta P, essentially the, the effect, the Earth's climate policy sensitivity.

So this is the basic climate policy curve. It's just temperature on carbon price again, to, to stress that that's the relevant policy consideration and transmission for, for climate policy. And then we're going to estimate these CPCs. So this is what they look like estimated, the particular model uses is an updated DICE model. And to calculate the CPCs, we're just projecting emissions, CO2 concentrations, temperature trajectories under alternative exogenous paths for the climate policy. Previous work has focused on individual CO2 paths, that is sort of a point on this curve, but we're going to graph the whole curve. The horizontal axis measures the carbon price in 2025 in constant dollars per tonne of CO2, that's the initial policy choice. The vertical axis measures climate outcomes, that's summary, summarized as the average global peak in temperature relative to 1850 to 1900 average. The shaded regions are uncertainty bands that I'll talk about later.

The initial level of the effective CO2 price and its effect of future growth rate are the fundamental climate policy choices that determine future emissions and global temperatures. We construct these assuming constant future growth rates. So here we've got 2%, 4% and 6% for the red, green and blue curves. Of course, you could imagine, you know, any, any, any possible, you can construct these for any possible trajectory. And importantly, for those who read the paper, I'm using, I'm using the peak temperature, not the, we've also done this with the temperature in 2100. These are what the temperature trajectories look like for different initial carbon prices in 2025, all of these assume a 4% annual future price growth rate. The highest trajectory there at the top has an initial price of more than $200. The lowest trajectory has initial price of, of less than $2. So you can see where the peak temperatures are occurring.

What path are we on? Well, currently the current state of global climate policy is still spotty. This, this map shows explicit carbon pricing, varying coverage across countries, regions, industries. Non carbon price climate policies are similarly heterogeneous. And all in all, at a global level, climate policies can likely be approximated with an effective CO2 price of of less than $10. On the estimated

CPC curves, the yellow arrow approximates that current effective carbon price, and it's intersecting the green line here at around three and a half degrees Celsius of warming. And that's what the model indicates is consistent with current, current policies. That is, the current low carbon price leads to a peak global temperature that exceeds the, the Paris climate target of two degrees Celsius shown by the upper dash line.

So clearly climate policy needs to be more ambitious to attain the U.N. climate target. What policies are consistent? Well, for the Green Arrow here, about $60 together with a 4% real carbon price future growth rate is consistent with 2%. But there's a range of, of possible climate trajectories that is here, they're also intersecting the 2% dashed line at higher and lower initial carbon prices. And this gets us to the key tradeoff that is the subject of this event: act now or wait. This figure shows two ways to get to two degrees Celsius. The red arrow is an act now or act soon climate policy with a high initial carbon price of over $100 a ton. The act late carbon price, the blue arrow imposes a low initial price, less than $50 per ton, but that requires rapid carbon price increases in the future to achieve 2%.

So kicking the can down the road, postponing ambitious climate policy just increases the need to do more later, increases policy uncertainty, transition and physical risk, and makes solving climate change even more painful and difficult. Let me take two slides to talk about two extensions of the analysis. One is we, again, we generated the CPC using a particular model. Here we as a check on our CPCs, we also examined the 100 or so different model simulations from the IPCC's sixth assessment report, these are plotted as gray dots. So each initial carbon price and temp, and temperature, in carbon price and temperature space and the black line fits a curve to these data and that provides sort of an implicit CPC from the AR6. And that summarizes a variety of models and carbon price paths.

At moderate initial carbon prices, the AR6 black line matches our own CPCs with carbon growth rates of 4 to 6%. That's the green and blue lines. So in some sense, we can serve as a, as a useful summary metric for model evaluation and comparison, as well as stressing the importance of, of climate policy implications. Uncertainty is also, of course, a central issue for the design and assessment of climate, climate policy and substantial uncertainty about key climate economy interactions persists. Earlier on, I had the shaded regions, that represented uncertainty about the equilibrium climate sensitivity, which measures the sensitivity of global temperatures to carbon prices. And we varied this ECS within the likely range of two and a half degrees to four degrees Celsius.

In this figure, we're showing six other sources of parameter uncertainty that affect the slope and shape of, of, of CPCs. The top three panels consider shifts that could be managed relatively quickly by appropriate policy choices. This includes the availability of negative emissions technologies that is direct air capture at scale. That's in the upper left. Most IPC scenarios assume the availability and scale of these technologies around 2050, and we adopted that timing for our baseline estimate.

As an alternative, we also estimated assuming the later, a later adoption, later availability and you can see that shifts the CPC up substantially. I think this highlights the importance of climate policies that can incentivize the timely uptake of, of these types of technologies. We also examine a backstop technology that is the cost of carbon abatement technologies and emissions from greenhouse gases other than CO2. The bottom three panels look more at, at economic and social uncertainties. That is growth rates of population, growth rates of industrial decarbonization and growth rates in total factor productivity.

To summarize, CPCs provide a simple framing device for the climate policy transmission curve. It focuses on the essential mapping from climate policy to climate outcomes. CPCs underscore that delaying climate policy actions comes at the cost of much more mitigation burden for future generations. So attaining the U.N. climate targets will require setting in place sizable carbon prices or their regulatory or fiscal equivalents in the near future. CPCs can help frame and navigate the difficult choices between near-term ambition and procrastination. Let me stop there. Thanks, David.

David Wessel: Thank you. Irene.

Irene Monasterolo: Thank you so much. So I will try to share my screen now. And hope it works. Can you confirm that you see, and—.

David Wessel: We do. We do.

Irene Monasterolo: Okay, great. So, first of all, thank you so much for inviting me today and for inviting me to discuss this very interesting paper. The paper is extremely clear and well written. So thank you so much, because I think it's really, it clarifies one of the major points and it connects well to the paper presented by Tobias Adrian. So the key message is that acting now is better than waiting in terms of sort of costs and impacts and makes really the case with the analytical work to opt for early climate policies even in the form just of a carbon tax. And this is still extremely, extremely relevant, particularly given the latest developments in, in the world. So this is a very important message.

So the paper develops climate policy curves, so introduces the concept and applies them to quantify the relationship between the effect price of CO2 emissions and the future increase in global temperature. Why this so? Well, because this is important to inform the design and calibration of optimal policy, produces policy that would allow us to stay within the Paris Agreement temperature target, so to increase the global temperature and above pre-industrial times, not more than two degrees, and we are already at plus 1.1 global, but in several places, we already are above two degrees. So this is very important also to act now. Testing for different type of policies. So not only carbon tax but the green subsidies, so the paper is very rich. So it builds on an updated version of the DICE model, and which fits into the tradition of cost benefit analysis of climate policies.

So I really like the paper and I have some suggestions for improvement. The first one is about the richness of the policies that you consider. The part is that climate policies, however, the ones that you can see, the more in general, they differ with regards to the transmission channels to agents and sectors in the economy and finance. And the differences can be very substantial when it comes to affecting the quantity and price of capital available to different types of technologies, particular renewable or high carbon and fossil fuel energy. And these in turn could affect the policy impact on the transition.

We published, we analyze this point and find out these results in a paper coauthored with colleagues from the World Bank with which we publish a Theory of Change about the green, role of green financial sector initiatives. I think that this would enrich the paper given that the faculty already have the bases. So there is an assumption of annual growth rate for future CO2 prices, but I find it a bit struggling to understand how does it captures, does it capture the co-benefits, since in the model connected to the DICE model you have only one sector, so no differentiation, high carbon and low carbon.

There is a claim of essential mapping from climate policies to climate outcomes, I think that strengthening this message would benefit from a consideration of frictions and challenges in implementation. First, that I could think of, and which is quite the news also highlighted by the ECB, is the fact that firms could pass on the cost of the tax on consumers. And the last point is about complexity and uncertainty and certainty treatments.

On this point, I have more concerns, and these concerns mostly relate to the modeling choice that you use for analyzing the climate economic spots. The DICE model has some advantages, so it's

rather simple, as you mentioned, and it's also open access, so on GitHub, you can go and download and run it. However, there are some limitations in the [inaudible] that could affect our understanding on when to invest, how much to invest, and in particular how to assess the risk and opportunities of different investments and adjust as the cost of capital and net present value.

Some of them are, most debated in the literature are the aggregate damage function. Why we know that there is wide heterogeneity of impacts when you consider assets that could be exposed to climate risk and or not even within the same area. And what we found in a recent paper is that neglecting heterogeneity could lead to an underestimation of losses of even up to 90% on investor's portfolio and 85% at the firm level. So that's why it's important to use disaggregated damage functions.

The other point is the positive discount rate here. I mean, there is huge literature including Dasguptha, Arrow et al and Weitzman. And I think, however, that you could play with this in your approach and test for different sensitivities to declining discount rates, so the paper by Arrow et al would be a very interesting point to connect to the treatment of uncertainty that you do in the policies because they actually consider declining discount rates, right, to take into account uncertainty. But the, my major concern is about the regional and sectoral aggregation, which actually doesn't provide inputs for financial risk assessment and investment decision because we know that the transition is all about structural change in the economy.

So switching from high carbon and fossil to low carbon renewables. So with one sector in few regions actually you cannot analyze the policy, which kind of policy design can better lead to adjustment in expectations, in risk assessment and thus cost of capital and NPVs, which in turn affect the feasibility of the trajectories. And another point is about the sector and the region, about the sectoral regional aggregation is that in some areas we already like, for even wealthy countries like Switzerland, we already over two, the two degrees temperature increase, so this is another point that maybe you might want to to consider, I don't have that solution for to or suggestion for this now.

Also there is, to tackle this last point, the IPCC and the Network for Greening the Financial System collaborated with another type of integrated assessment models which are much more refined and detailed in terms of sectoral and technological disaggregation, and these are called process based integrated assessment models. Based on the, you can see some examples or what you obtain with these models, which have a kind of agriculture, land use, transport, water, of course, climate and

economy module, and which are connected all together. And they work in a very different way. So it's not, the approach is not based on social cost of carbon and optimal climate policy, but it's a risk management approach.

So given if we want to stay within a 1.5 net zero or a two-degree target, how much emissions we can still introduce in the atmosphere so that concept of carbon budget and how does should the economy, from a technological point of view and sectoral composition, should readjust in every country and through time in order to get there? And with this, with these scenarios, the NGFS developed narratives of the transition, which could be orderly, disorderly, and at the, sorry, hot house world, and in particular with this disaggregated approach, we can actually adjust the future cash flows of firms and thus translate it into adjustment in credit risk and in the value of the securities.

This is also another in particular we can also better understand a major driver, almost certainty which emerges from the interplay between climate policy uncertainty and investment decisions via expectations. This is a paper that we published in Science in 2021 where we showed actually how to connect process based integrated assessment models with financial risk models based on the climate stress test we published in Nature Climate Change in 2017 to embed the interplay between investors' expectations and policy credibility in the making or failing of the transition scenarios being orderly and disorderly.

And why this matters? Because we know that investors allocate capital based on risk assessment and expectations about climate risk matter to steer or hinder the policies and investment decision, which in turn can make the transition happen or not. So the concept of endogeneity or climate risk. And in this way adopting this approach with disaggregated trajectories by output, we could have this richer consideration and analysis of policies, and in particular studying the interplay between orderly and disorderly policy introduction and enabling or hampering the role of finance based on expectations.

And what I would like to point out is that the difference that we obtain when we feed, when we apply this feedback loop between climate economics and climate financial risk models, which are the dotted lines that you see here of course, the green one are for renewables and the brown one are for fossil fuels. And what we see, for instance, is that even if we believe we are in a context of immediate climate policy, so orderly transition it should be fine, if the financial sector doesn't adjust these expectations because doesn't trust the climate policy anymore, then we see that the trajectories which

are these dotted ones would be those more alike to a disorderly transition, so a delayed one with larger asset price volatility both for low carbon and high carbon. And the worst case would be even when we do the transition late and in a disorderly way and expectations don't align. So that's what we would, an insight from adjust, from what we can do with the other approach or to use the climate scenarios for climate finance. Thank you.

David Wessel: Thank you very much, Irene. That was very comprehensive. So I want to turn the virtual stage over to my colleague, Sanjay Patnaik, who, as I said, is director of our Center on Regulations and Markets, where much of the climate work within economic studies is going. Sanjay joined us a few years ago from George Washington University, and he's going to lead the conversation for the next half hour or so. So, Sanjay.

Sanjay Patnaik: Thank you so much, David, a really interesting session today. And I think one key aspect of, of today's papers is really that climate change is an economic issue. And I think we cannot emphasize that enough. Oftentimes when you look at the climate debate, it is very ideological. But when we think of it as an economic issue, we really have much more tools and new policy approaches that we can look at to, to mitigate this. So I want to go back to the presenters and give them a little bit of time to respond to the discussions. Tobias, why don't you take a couple of minutes just to respond to some of Carolyn's comments before we turn over to Glenn, and then I have a couple of questions for you both.

Tobias Adrian: Thanks so much, Sanjay. And thanks, Caroline, for the, for the thoughtful comments. Let me make three quick points. So the first one, the first question you raised is about who to compensate, right. And, and so compensating workers, we do actually have a back of the envelope calculation in the paper. So the baseline opportunity cost is about 50 billion to compensate the core companies. If you also compensate workers, it does rise to about $331 billion. That's our estimate. But of course, that's still in the billions, it's not in the trillions, which is where the gains are. So I do think it makes the net benefits somewhat lower. But in terms of trillions, it's after the commas, so to say.

In terms of price increases, so in our assessment is that the, the alternative sources of power would be large enough, you know, because we, we, we, we assume that there's this investment in wind and solar and that, that would roughly offset the price changes. You know, this might not be true in every country or in every region, but on average, that's probably a pretty good approximation. Now,

when we do think about the opportunity cost of compensating coal companies, we do take into account the whole of future profits. And so in principle, that would also be sufficient to compensate the coal that hasn't been taken out of the ground yet.

Finally, in terms of the health benefits, I fully agree that the health benefits make the benefits even bigger. And you gave a very, very big number there. And you know that that is an additional argument for why the kind of economic arbitrage, as Sanjay referred to, is so big. The final point before turning back to Sanjay, would be on climate finance. So the idea that we really push is that it's a, it's a kind of conditional climate finance. So you get climate finance, conditional on phasing out. And that is really what would be limiting carbon leakage. That's another, another point that that Carolyn raised. So in some sense, the conditionality of the climate finance is so like the equivalent to a border tax adjustment in the, in the carbon tax thinking, right? Because you get, you know, finance conditionally on not, no longer using coal. Let me stop here.

Sanjay Patnaik: Thank you so much. Glenn, over to you. Can you respond to some of the comments of the discussion, that would be great.

Glenn Rudebusch: Thanks, Sanjay. And thanks to Irene for, for a very interesting discussion. And I think it highlights, you know, her, her point of there are a lot of challenges in modeling, modeling climate; the regional and sectoral disaggregation, the importance of finance, accounting for finances is, of course, key. And so in what we're doing, we're trying to introduce a simple concept, a simple transmission mechanism for policy. We implement this with a, again, a fairly simple DICE model where we quantify and estimate the climate policy curves. But of course, it could be done with a much more complicated model, one that takes into account co-benefits and regional and sectoral differences.

So I completely agree that, that these are all important aspects of doing, of doing climate policy, thinking about climate policy. But as Sanjay said, stressing the economics of this is what we're trying to, we're trying to do, stressing the economics and really how it's climate policy. So finances, accounting for finances is a critical thing, but it's all going to be driven by climate policy. It's not banks, it's not financiers, it's not technology. Those are all driven in an environment of incentives and taxes and policy interventions that really will, you know, again, determine the kind of climate change we're going to see going forward.

So trying to get this link between policy levers and climate outcomes, this transmission mechanism in, but I agree with you that, you know, there are a lot of potential frictions and, and complications and challenges in modeling this, but getting that basic idea out, connecting, connecting policy instruments to climate outcomes I think is, is, is still our, you know, that's our message we're trying to, trying to convey.

Sanjay Patnaik: Great. Thank you so much. So let me turn to Adrian and to Tobias. A couple of questions related to the feasibility of what you suggest there, and I think you really impressively show what the benefits could be if we started phasing out coal. But one aspect I think of coal that is not really mentioned in the paper is that coal fired power plants are often used for baseload power generation, right across the world.

And so then the question is, in many of these instances you probably will not be able to replace them with renewables at that rate because renewables don't, are not very good for baseload, at least most of them, unless we look at hydropower or some other options that are still in its infancy. So can you talk a little bit about that, kind of like what is the feasibility of actually starting to phase out all the coal that we have and replacing it with renewables or other alternatives.

Tobias Adrian: Yeah. Thanks so much for, for the question. So, you know, one of the advantages of our approach and, you know, really complementing, complementing the kind of integrated assessment models that that Glenn was talking about is that we are starting with planned level of data, right? So this is a geolocation-based data of all the coal power plants in the world. And you know, that can be, can be then looked at together with, say, the financial performance from stock and bond markets. So it's a, it's an extremely rich approach, cross-sectionally.

Now, you know, when you are looking at our calculations, you know, the phaseout is somewhat gradual, right? It is not an immediate phase out. And, you know, that is a part of the answer to your question. So it is going to take time to, to phase out coal. And you really have to look at the plant-by-plant level to understand to what extent renewables can, at what time horizon sort of like replace that capacity. So it's not, it's not something that is extremely easy. And I fully agree with your concerns that not in every case can you, can you replace what is currently there with wind and solar for, for exactly what you mentioned.

So there are certainly hurdles. So we are trying to account for that in terms of the speed of adjustment. But you could certainly look at much more detail at the plant level, you know, and you

know, so like at the at the at the geolocation data to what extent you can use one or the other. So this is, this is certainly a work in progress. You know, that is, that is much more granular. Now, of course, we are looking primarily at wind and solar, but there are also other alternative sources of energy that could also address some of the concerns.

Sanjay Patnaik: Great. Thank you very much. I actually had also an audience question that is a bit related to this. And so someone asked that phasing out coal makes sense for developed countries like the US or Europe. But for instance, in India, they're considering promoting coal for cooking instead of using firewood in order to develop healthy rural and forest landscapes and ecosystems. Can you talk a little bit about that, which are kind of like the tradeoffs with other environmental factors? In this case it would be deforestation or like the health of kind of like indoor air health. So how do you think about that?

Tobias Adrian: There are many tradeoffs, many tradeoffs. So, you know, you're mentioning India or other sort of like emerging markets. And so what our findings clearly show is that, you know, the biggest net benefits, you know, many of those are in emerging markets. And, of course, some of the biggest coal emissions, as Carolyn mentioned, is in the emerging markets. Of course, you know, these are, you know, the kind of calculations we are doing are big picture calculations. So, you know, there are, there are many policy tradeoffs, such as, you know, coal might be on the margin better than wood once you look at the environmental impact. But of course, there are things that are better than coal. So how you phase one to the other, you know, really depends on, on, on the very specific region or even within a country.

But I think the past and the future is very clear, right? I mean, we do have to get to the combination in order to, to keep the productive capacity of the planet alive. I think that is the first, first order, it's the economic argument for phasing out coal is overwhelming, right, it is just massive. And so the policy tool here is climate finance that we are proposing. So basically giving finance to phase out and this would include, for example, replacing say, wood fire with alternative sources over time, in due time, of course, in order to get to a conditions where coal is left in the, in the ground. And of course, nature is preserved as well. I mean, there's a whole other debate about the value of nature and what it takes to preserve nature. It is implicit in this concept, the social cost of carbon. But of course, there's a lot of work ongoing to have better assessment of the benefits of, of, of nature in and of itself.

Sanjay Patnaik: Okay, great, thank you, you know, this is, this is very helpful. I think it really shows kind of that that climate is, is a very nuanced topic, right. And there are so many tradeoffs to be made, but there are opportunities, I agree with you where you maybe can leapfrog some of those dirty technologies with coal and go directly from wood to something else. And I think that's key here—.

Tobias Adrian: Let me just make one more point, right, which is normally we think about this global deal, right, COP has to come together to have one global deal that solves everything. And of course, it is, it is a hard thing to do, all right. But what we are pointing to is that regional deals can also be extremely, extremely helpful. And this is where the Vietnam, Indonesia, South Africa examples are coming in, right. These are conditional financing tools, right. And they can be very powerful even if they are not at the global level, at the, at the, at the regional level.

Finally, let me also mention energy storage. So that's a whole other topic that is very important that that we do discuss in the paper. You know, how much would it cost to really get energy storage up to the levels that we need? And this is where the baseload issue can also be addressed to some degree.

Sanjay Patnaik: I think that's a really important point, especially on the regional aspect, because I completely agree with you. Even when we look at carbon pricing, we have seen that a global agreement is very difficult. But you have these regional programs or kind of like country programs that link with each other, which is much easier to implement politically. Carolyn, you had a question related to this or a comment before I turn over to Glenn.

Carolyn Fischer: Yes. So, you know, I think you are still likely to see, you know, coal producing countries looking for ways to, you know, to keep, to keep coal, keep using coal in some ways. I don't think, you know, for, for cooking coal is not a particularly clean cooking fuel. And so I think most efforts there are going to like propane or LPG or you know, solar renewables.

But I think that the one question is, you know, to what extent folks will look at carbon capture and sequestration with coal fired power plants. I'm guessing that, you know, given the trajectory of renewable energy costs, you know, renewables are just going to be cheaper, at least if you can solve the storage problem. But that, that is another option, I don't think I saw addressed in that, in the paper.

Sanjay Patnaik: No, Carolyn, I think you're bringing up a really good point. And I saw Tobias had some assumptions in there on kind of like carbon capture and storage and the costs. But I do think there is a lot of movement in that space. And I've seen we had a fireside chat like one and a half

years ago, kind of like with one of an expert in this, and they believe they can get through carbon capture and storage to about $70 per ton of CO2 within the next two or three years. So I think if we can bring down the cost significantly, that is definitely something that can help at least in that transition period. Irene, you had your hand up, before we turn over to Glenn.

Irene Monasterolo: Oh yeah. Well, your question was very relevant, I think also because how can we ask, the question should be, okay, how could we ask low-income emerging countries to stop using coal when we have started to reinvest in coal, even in several EU member states? So the issue here of this makes the, both papers even more relevant right now and also highlights the importance of policy coherence in order to get to a global carbon tax, which is however beyond both papers and the ideal way to get to where we should go.

Sanjay Patnaik: Now, I think you raise a really important point, again, like highlighting these tradeoffs, right? I mean, in Europe, again, like the tradeoff now is between national security and energy security. And so then countries have started using it again, not to use the Russian gas. Glenn, I want to turn to you. I have a couple of questions from the audience and also from myself. Let's start with an audience question. They were a bit more interested in kind of like the specifics.

Can you talk a little bit about kind of like is there a minimum necessary price on carbon that we can start putting on now in order for us to succeed going forward in decarbonizing? And you really lay out very beautifully in the CPCs kind of like the different paths and maybe you can talk a bit more specifics for our audience, and also kind of talk about some of the trajectories in terms of growth rates and where we think the carbon price should end up in a couple of years.

Glenn Rudebusch: Yeah. The carbon price again right now is, you know, just a few dollars, the effective carbon price. And again, I'm using carbon price as a summary measure, you know, as a unit of account, almost, a summary measure to take into account a whole host of climate policies. But it has to be a lot more stringent. I mean, the, the requirements for climate policy need to be much stricter, much more ambitious.

And then we've got a path rate, a growth rate going forward, a trajectory going forward where it pushes the climate policy, climate, the effect of climate price. So we're talking something on the order of $50 a ton in 2025, but that's going to have to go up to on the order of 150 by the end of the century. And again, we're looking at quite long-time horizons here, but as is typical for these models,

but the important thing is to, you know, a lot of climate policy needs to be implemented and it's better if you implement it earlier rather than rather than later.

Sanjay Patnaik: That's actually super helpful. And another question that came up is kind of when you think about the, the CPCs that you develop and oftentimes as we see around the world and even more so in the United States, climate policy is often tricky politically. And to implement certain tools, especially like carbon pricing. Do you think or have you found in your conversations with policymakers that using this concept of CPC, which I think is really fantastic, can help inform policymakers in a better way and help them understand the topic better and maybe facilitate action?

Glenn Rudebusch: I think so. It's important, as I mentioned, you know, often the discussion becomes, are you a techno optimist or a techno pessimist in terms of climate? I don't think that's the right question. Technologies, innovation, invention are always a response to incentives, and it's really the policymakers who have the tools. So they've got to, they've got to keep in mind that the solution is going to be driven by policy and that they're, you know, essentially the ones responsible, they're the actors, they have that, they have that ability to, to make climate change, to lessen climate change going forward.

And so I think that's an important message for, for policymakers. Much like you'd want, you know, when we talk about— not to go back to monetary policy too much— but central bankers goes inflation sometimes you'd say, oh, inflation is just out of our control, it's, it's something that's being pushed on us. But there's always a transmission mechanism and monetary policy to inflation, understanding that that you know, that central banks are responsible inflate, for inflation in the long run is important. I think that's also true for climate policy, that it's climate policymakers that are responsible.

Sanjay Patnaik: I really love that analogy. And I think this is really important to frame that new thinking and new approach to that. I wanted to talk a little bit about the, about kind of like the way you calculate the carbon price, because you imagine, obviously, as we all agree, as economists, the most direct way would be you put a carbon price on, and that's the most efficient way to actually get like the negative externality internalized. But you also incorporate in your CPCs kind of like tools that might not be a carbon price but might be the opposite, like subsidies or other things and indirectly back out a carbon price through them.

And so I think that is a very interesting angle, and I'd love to hear from you a little bit of what are the difficulties of dealing with that and also modeling it, of trying to use these different tools in backing out a carbon price indirectly. And one reason why I'm asking that is that in the US, as you know, there is a discussion about potentially introducing a carbon border adjustment mechanism, but we don't have a domestic carbon price except for California. And so then the question would really be like, how are we going to calculate that on a credible basis? I'm curious to hear from you about, about those efforts and how you went about backing out that indirect carbon price.

Glenn Rudebusch: Yeah. And so that requires a really detailed model. And the analogy, the example I gave is the Inflation Reduction Act. And there were three private consortiums that that calculated sort of the emissions response and the temperature response from passage. And there's a lot of uncertainty what kind of take up you're going to get on, on these demand side subsidies, you know, the Climate Bank, the Green bank, you know, what kind of take up you're going to get on that. But there is, you know, a central tendency, a mean sort of temperature response.

And so then you can, you can invert that to think about what the appropriate carbon price, the effective carbon price would be. So that requires a more in-depth modeling than just the simple, the simple, you know, global one sector DICE model. But that's the that's the conceptual that's the conceptual framework. Again, it's these you know, we're not saying everything, of course we're not saying everything has to be a carbon price, but it's just a unit of account, a way to, to, to, to normalize, to think about all the other important and important possible carbon, non-carbon price climate policies out there.

Sanjay Patnaik: And I think it's actually super helpful to kind of like standardize it because it allows you to compare different policies and really think in economic terms throughout because I think oftentimes, they're the opposite, like, you know, subsidies and other things are sometimes hard to grasp and see like what the effect actually is. Carolyn, you wanted to comment on that, please come in.

Carolyn Fischer: Yes. I'm just, you know, so I believe some of Tobias' colleagues at the IMF are working on estimating carbon pricing equivalent. So the idea is can you calculate what carbon price you would need if that was your primary instrument to get the same reductions as this mishmash of policies? You know, it's, it's tough, though, because, you know, you are relying on model-based

estimates of some, you know, climate policy effort, which is, you know, a little tricky because it's, it's not directly observable.

But the other, the other point that I thought was great and I think, you know, deserves great emphasis is, you know, thinking more holistically about what are the price incentives out there that policymakers, you know, have control over and should think about. Because, you know, so the OECD has done a lot of work to calculate sort of effective carbon rates. And we at the World Bank are working on something simple, similar.

And, you know, so what, you know, the explicit or direct carbon pricing that we see out there covers maybe a quarter of emissions now is still relatively small compared to all of the indirect price incentives that you get from fuel excise taxes, especially in the transportation sector and also the fossil fuel subsidies that are still out there. So there are a lot of opportunities, even before going to a carbon, direct carbon explicit carbon pricing to better align our prices with the, you know, the social costs of fossil fuels.

Sanjay Patnaik: Very interesting. I totally agree. Irene, please.

Irene Monasterolo: Yeah, maybe to complement is also the way in which estimating what could be an optimal carbon price or most efficient carbon price is for sure very important. But also actually designing the implementation in a way that doesn't make taxpayers paying for stranded assets, that would be even more important because otherwise the way in which most likely it could be implemented and that might be implemented through firms would be a socialization of cost. And either they go to tax, taxpayers or consumers or governments. This will not be very effective, in particular, governments that have very little fiscal space to, to manage both.

Sanjay Patnaik: I think you raise a really important point, and this is not only in kind of kind of like the measures that we take to mitigate climate change, right, but the, the damages and the losses that we will incur even in developed countries, someone would have to pay for those. And oftentimes, even when we look at the United States, the flood insurance program is very outdated, a lot of other programs as well.

And so oftentimes the losses then get attributed to the taxpayer, to the government. And that's something that I think doesn't get the attention it should, because we have to plan it, right. And so if we invest now in mitigating climate change, as Tobias has really shown quite powerfully, we could actually have a much lower cost than we if we didn't do anything, and at the end of the day, we

will have costs to bear, and especially with extreme weather events and, and lost harvests and things like that.

Irene Monasterolo: And we need the citizens support otherwise and look what happened, for instance, here in France a few years ago.

Sanjay Patnaik: Yeah, yeah. I mean, that's, I think that's, that's one thing that we, we don't have too much time to dive into. But I think it is this key because climate change is not only an economic issue, but unfortunately, also a political issue, right, on how to implement those things. But I think looking across both papers, if we can make that strong economic case, I think that gives us more information and more data to help with a political piece.

And I think emphasizing those can really be a game changer, especially when we start looking at, when people start being impacted by it, right, and start being impacted by extreme weather events, and then they see the tradeoffs, right, of whether, maybe I'm I'm happy to pay a bit more of my taxpayer money to mitigate climate change rather than having really sky high insurance premiums or having a hurricane hit my area like every two years instead of every ten years. So I think we're unfortunately out of time. Even though I would love to continue this conversation, I think we could probably talk the entire day about this.

But I want to thank both of, both presenters for these really interesting papers, and both discussants, super important and I would really encourage our audience as well to read the papers if you can haven't, they provide really novel insights that I think can really influence and shape the current debate on climate change. Thanks to everyone and thanks to David for co-branding that event today. Thank you.