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PAPER: ECONOMICS OF DEMAND-SIDE AND SUPPLY-SIDE CLIMATE POLICIES

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EBERLY: Okay, the last paper is being presented by Ryan Kellogg.

KELLOGG: Am I good? Yeah, no, exactly. You know, I could have gone with the traditional smokestack belching out gray stuff, but, yeah. This is somewhere in Switzerland. Which there's nothing ugly there, right?

EBERLY: Okay, let's let Ryan get started.

KELLOGG: Fabulous. Thank you. So this is gonna be another paper that has demand and supply in the title, and it's gonna be a big piece of it, but this time we're gonna be talking about climate and energy policy.

This paper is broadly motivated by the idea that there's sort of just the observation really, that if you look out into the world at what a bunch of different governments are doing on climate policy, the policies different countries and jurisdictions are using are really all over the map. I'm gonna classify COP policies into two bins, demand side and supply side.

By demand side, I'm gonna mean any type of policy that's really targeting the demand for fossil fuels or consumption or really emissions of carbon. There's a bunch of different flavors of this. I think the most prominent one, like as economists, we often think about Pigouvian policies that price carbon. Kind of the flagship here is really the EU emissions trading system. Like this is the sort of like the banner emissions pricing program. Prices have been high for many years, over sixty euros per ton of carbon much higher than really any serious carbon pricing program anywhere else in the world. Though there are plenty of those other ones, Catherine's gonna mention that as part of her discussion.

I think the other class of demand-side policies I'm also gonna spend some time thinking about in this paper are things that are non-Pigouvian, and in particular, policies that subsidize clean energy use or clean energy R&D. The US Biden-era Inflation Reduction Act was really almost entirely within this bin. Some of the other prominent things you're gonna wanna think about here is sort of everything that's China's doing really in the flavor of green industrial policy. Basically moving China to the point where if you're buying a solar PV panel, it was made in China. If you're buying a battery, it was probably made in China. If you're gonna buy an EV, as long as you're not in the US, that EV probably came from China. That's where China has driven it. So that's demand-side policy.

The flip side of this is supply-side policy that's gonna target the supply of fossil fuels or really fossil fuel extraction at the source. And the policies, when you look around, what are different countries doing that tend to really try to target fossil fuel infrastructure. So prohibitions on building a pipeline, prohibitions on an LNG export terminal. Biden administration did some of these. Different states in the US have done some of these. You even see some of this in Europe.

One thing I'll flag now and come back to later is that what you really don't see when you look around in the wild is a supply-side analog to the Pigouvian version of the supply-side policy. That is, we see a lot of pricing of emissions. You really don't see, like, pricing of extraction, or at least not at large scale. Maybe you see some subsets of that, like pricing extraction on federal lands, but you tend not to see it at scale.

So what do I wanna do here? I wanna sort of, kinda carefully wade into this debate between demand-side and supply-side policy, which at times has gotten a little bit sort of terse on the American left between sort of the abundance crowd that wants a lot of clean energy, and then the keep it in the ground crowd that is very supply-side focused on one hand.

What I want to do is try to just shed some light on some of the economic trade-offs here. A lot of this is going to be synthesis from a lot of work that's already out there that I'm going to try to unify while on the way trying to do some, to add some new data to this, as well as some new modeling and economics. The upshot of all of this is going to be there's actually some value in a policy portfolio when you think hard about the fact that there's a bunch of sort of imperfections in the market relative to what you would write down in a standard carbon pricing kind of model.

The big one I'm going to stress is, comes from just the observation that climate is a global problem. The climate does not care at all if when a ton of CO₂ goes up into the air, it comes from a smokestack in the US or a tailpipe in China or India or South Africa or anywhere else in the world. What that means is that if you are a domestic policymaker trying to do something on climate, you need to be thinking all the time about, how do my climate policies here at home affect emissions elsewhere in the world? And that's going to be the main theme through a lot of what I'm going to talk about.

I'm also going to spend some time, there's probably going to be more, there will be more in the paper than what I can do in my time here on sort of like imperfections in real world markets have a really important role to play. And then, of course, there's this, always the balance between efficiency and distributional goals that's going to be important that, you know, it's not my job to weigh in, but I'll try to shed some light on what the trade-offs are, and people can apply their values as they will.

On the global point: The first thing I want to sort of land on is thinking about the issue of emissions leakage. And this is the concern that if I do climate policy here at home, price carbon, whatever it is, that's gonna-- I'm international, I'm linked to everybody else through international trade, and that's gonna push up emissions up elsewhere up. The classic way, the vast majority of the policy conversation about leakage is really about leakage in trade and manufactured goods, carbon-intensive goods, steel, cement, aluminum, all of those kinds of things, where I put my own industries at a comparative disadvantage with emissions pricing.

The mechanism I want to focus on here is a little bit less that and more about leakage that just comes through trade and fossil fuel itself. It turns out that there's just an enormous amount of trade IN, like, literal coal, oil, and gas that's out there. What I'm doing in this chart, I haven't seen anything quite like this before, is basically I'm plotting out for each country, each dot is a country here. Horizontal axis is CO₂ net imports, literally how much oil, gas, coal are you importing converted into carbon. So importers on the right, exporters on the left. And then the vertical axis is your carbon balance in terms of embodied carbon in your trade and manufactured goods.

So for instance, here you're gonna see the USA on the left side. We're a carbon exporter now. This ties into the paper Diego presented yesterday. But we import manufactured, heavy-duty manufactured goods. Russia is the gas station to the world over here on the left. And then China and India are way over here on the right, where China imports just massive amounts of oil and gas. They turn it into manufactured goods, and then they export those

manufactured goods out to everybody else. India's kind of working its way down the same trade. So what all these data suggest is that if you're gonna worry about leakage, you should think about how might leakage come about through trading fossil fuels. And I'm gonna sort of build a model really building off a lot of work by David Weisbach and co-authors that, that tries to get at all this, also while incorporating the clean energy sector at the same time.

What does that look like? Well, I'm gonna do the model through pictures. Could start very simply with a closed economy just to fix just to fix ideas. This is like principles of micro with an externality here. This is a model of fossil energy supply and demand, so we're gonna have some supply curve, some demand curve for fossil energy, which is really the net of my demand for energy and what I'm gonna get from clean supply $S_{sub c}$ here. Standard result, again, this is like EC1, is that what you wanna do? You wanna do some Pigouvian pricing. Standard incidence rules apply in a carbon economy. It doesn't matter whether I use an emissions tax or an extraction tax. The economic incidence is the same. I get on with my life and sort of implicitly when people teach this, certainly when I've taught this before writing the paper, I just think emissions tax and go on.

It turns out that distinction really matters, though, when we think about an open economy where we have trade and fossil energy. Assume for now that we don't have trade and goods, just to keep this clear. And let's just go really simple, where we're gonna have a home jurisdiction that's doing policy, rest of the world that's not, and just keep this super simple by saying, let's say rest of the world is just a duplicate of home, maybe scaled up or something like that, such that supply-demand meet in the same place, and there's some global price of energy P .

That is, there could be trade, but in principle, you don't actually need it in this simple world. This turns out to be really helpful in clarifying in-intuition. What happens if we do the standard thing at home and price emissions? We're gonna have some tax on the use of carbon to you. In a world where we're j-- not thinking about trade, and let's say the global price of energy doesn't move, well, that's not gonna work in equilibrium.

We're gonna have some excess supply that comes out of that 'cause demand, home demand's gonna be based off the tax. Home supply is gonna be based off the global price. In order to re-equilibrate what has to happen, the global price of energy has to fall. And this is what's gonna generate leakage from the emissions tax even before we've considered any trade in goods.

The global price falls of energy, that leads to an increase in consumption elsewhere in the world, and that consumption's gonna come from exports from home. So we have this export-import shift. How do you deal with that? You deal with that by combining the emissions tax or the use tax T_U with an extraction tax T_E .

What's the extraction tax do? It reduces domestic quantity supplied. That's gonna push up the global price of fuel. And in this very simple example, it's kind of pretty, you actually do a little bit of both, more on the use tax in this example because demand's e- inelastic, and you actually just keep the global price of energy unchanged so that you don't affect ROW at all, and you've actually reduced emissions at home, in this case with absolutely zero leakage.

So you're looking for a balance between these two instruments that's gonna be governed by the elasticities. Then the total tax actually sums up to the social cost of carbon. So that's the

idea in the nutshell, very tightly related to the work by David Weisbach and co-authors. I'm gonna sort of do a toy calibration of this, thinking about two cases of home, the US and the EU.

These are very different cases. The US is a net energy net energy exporter, particularly for fossil energy. The EU is the opposite of that. They only produce about half the energy that they consume in the EU. This is in part because Norway's not in. Very little of that energy is actually fossil.

They're just in a completely different place. I'm gonna need a bunch of energy demand and supply elasticities. I'm not gonna say much about here. There's more in the paper. I will only say that we know remarkably little from the literature about what these elasticities are. There's-- we can imagine a ton of sensitivity analyses here.

The other thing I'm gonna do in the full model is allow leakage for trade and energy-intensive goods. This is gonna provide some efficiency justification for clean energy subsidies. And I think Andrés is gonna talk more about sort of that piece of the calibration. What do you get out of this is that when you think about what are the sort of surplus-maximizing instruments, both for the US and the EU, at least with these elasticities, the extraction tax actually winds up carrying a lot of the weight in the efficient policy package.

That is, sort of, this is the tax that you don't actually see in the real world, but it turns out to be a big, turns out to be a big deal here. Clean energy subsidies much less so. In terms of emissions reductions, you can imagine sort of taking instruments away, get rid of the extraction tax, get rid of the use tax. Losing the extraction tax in the US is a really big deal in terms of the emissions reductions you get. You basically lose more than half of your reductions. This is because the US is a big fossil fuel producer. The emissions, the extraction tax is a much less big deal for the EU, just they don't produce a lot of fossil fuels, so it matters a lot less.

So I want to return now to the point that I made at the very beginning. The extraction tax is a supply-side climate policy, has some value in combining it with the standard emissions tax to deal with leakage, but it is not the supply-side policy that we see in the wild. The thing we actually see in the field are things that target very specific pieces of fossil fuel infrastructure.

So to make a specific example from some of my own past work, this is a map of the Dakota Access Pipeline. This is a crude pipeline that moves half a million barrels a day from North Dakota to the Gulf Coast for refining and export. It got stalled for years. It finally got completed in 2017.

What my co-author and I do in this paper is think about what would have happened had that pipeline been blocked. Does the carbon stay in the ground? And the answer turns out to be no, because producers and transport, transporters substitute. More than eighty percent of that oil would have gone out and gotten produced anyway, and it would have gone by train, which is particularly bad because trains have locomotives. In the US, those locomotives have big diesel exhausts, and that stuff is nasty, and they go straight through the middle of cities, including Chicago, like, literally just a few miles from my office which is, like, the last thing you want. So there's a big difference here between sort of, like, the Pigouvian flavor of supply-side policy versus what supply-side policy actually looks like, which, you know, I think we can talk about this more in the discussion.

That there's a-- I think it's really fascinating why supply-side policy looks like that, whereas when you think about demand-side climate policy, you actually do see a lot of emissions pricing going on in the world. The other thing I'll mention in terms of demand side policy that I think is really important is when we think about the efficacy of doing things to try to green the grid, whether it's clean e- clean electricity subsidies or taxes on emissions from fossil power plants, a big barrier to doing that and really sort of getting demand to be more elastic is lack of transmission.

Like, a lot of the wind and solar resources, particularly in the US, are in the middle of the country where the population centers are not. You need transmission to get that power out, and we are already in a situation where we've had this big wind and solar build-out, much less so on, on transmission, which means that we have a bunch of wind turbines that are getting curtailed. Which basically means that they're producing more power than the grid can take, and the grid operator has to say, "Sorry, we need-- you need to shut down." So we're just basically feathering the turbines.

A lot has been written, I flashed the abundance book earlier, about permitting challenges being a huge thing here. The point I want to make is that permitting's important, but it is not the only thing here. And in fact, if you just look at what's happening with transmission investment, we have been massively increasing the amount of transmission in terms of dollars spent that's actually going into the-- that's been happening in the US across a whole variety of parts of the grid, like a three X increase just since 2010.

Now this is dollars, not megawatts of capacity but still. The problem is that the transmission that gets built tend to be very local, regional, local reliability projects and projects and not the long-distance transmission that's really needed for a green transition or even to support things like the AI build-out in a very, very serious way.

Part of that is permitting. Part of it is really a problem of planning and incentives on the behalf of the utilities that have the responsibility of actually putting this stuff in the ground and building it. There is no entity that's responsible for any cross-regional transmission planning in the US. Nor do markets work well for this, in part because the utilities who are on the buy side of any transmission project are rate of return regulated and don't really have the incentives to be buying power from anyone.

And sort of a great problem, classic, the problem is really nicely laid out by a couple papers. Katie Hausman has this amazing paper in the AER from last year that basically points out we can sort of-- we have horrible congestion right now between the Midwest, where there's a ton of cheap wind and further south, okay, Oklahoma, Arkansas, and Louisiana, could build transition and save a bunch of cost, but that's going to come at the cost to a bunch of incumbents because their power plants aren't going to be worth as much anymore and their revenues are going to go down.

These incumbents are going to be vertically integrated utilities. These are the same utilities that have a direct input in the transmission planning process. You see where this is going. So, like, there is a fundamental incentive problem that goes above and beyond the permitting problem that seems to be taking up a lot of the policy conversation here.

So I really wanted to flag that, and I see that I'm running out of time. I will make one more point and this will sort of bridge into Catherine's comments as well. I think it's really important

when we think about domestic climate policy that, you know, we're not just trying to minimize leakage of emissions to other jurisdictions. We're actually gonna try to-- we really need to bend the curve for what other countries are doing as well, particularly growing low and middle income countries, 'cause that's where the emissions growth is really going to come.

Particularly when you couple that fact with the other fact that who's gonna get hurt by climate change, it's gonna be the middle income, the low and middle income countries. Like, that's where the damages are. They're already hot, and they can't adapt because their income, because their incomes are too low. You know, I think there are many ways to think about how do you do local policy that influences what other countries are doing. Part of that is going to be international climate negotiations. Catherine is going to talk about that. I think the other big lever is really all about clean energy research and development some of which is, like, literally the sorts of things that DOE has been doing for years in terms of basic R&D.

And then I think the other lever is to really think hard about what China's been doing on green industrial policy. Like, at least for the past five years, the big thing that's been bending the curve is the fact that it is now way cheaper to buy PV, EVs, and batteries than it was ten years ago. And that is basically almost entirely because of what China is doing. And I think there are really big questions about, like, if you're sitting in the US or the EU, how do you think about that?

So I will stop there. I can say a few things about distributional impacts as part of the discussion. But just really quickly summarizing, you know, I think I came into this not really sure where I was gonna wind up. Like, there's a big role for supply-side pricing here as contrasts with the supply-side policy we actually see in practice. Really thinking hard, getting away from the blackboard model and thinking about the imperfections of real world markets turns out to be really important.

And of course, I didn't talk about this, but we can do it later. The distributional considerations really do weigh in here too on sort of which are you going on demand and supply side. So thank you. I will stop.

EBERLY: Thank you.

The first discussant is Andrés Rodríguez-Clare

RODRÍGUEZ-CLARE: Thanks for inviting me to discuss this paper. I've learned a lot. I think it's a really nice paper. Has a lot of breadth and yet remains integrated in its approach to different topics. So I enjoyed it and learned a lot. I'm going to make four comments, mostly related to the relationship between the model used here and the calibration and trade. And then finish with a couple of remarks about the--

Okay. So the first is about the relationship between the clean energy subsidy and the carbon border adjustment mechanism that is implemented in the EU in particular. So this is part of a table that the paper has on with the US as home being the one that is implementing this unilateral policy with a use tax, an extraction tax, the combination that Ryan was emphasizing, and then a small clean energy subsidy there because of leakage. So the, because of leakage, the sum of TU and TE is not as high as the social cost of carbon, so there's still role for an additional policy, and in this case it's going to be the the clean energy subsidy.

And then there's a discussion that Ryan didn't get to in his presentation about what Ryan calls the ideal border tariff adjustment or tax adjustment where you basically are able to remove leakage, and that leads to no longer having the clean energy subsidy, right? So you get, that's a formula in the paper, and then the clean energy subsidy goes to zero with the ideal BTA.

My first comment is going to be this ideal BTA imposes full rebate on the exports on the carbon taxes paid on exports. If you move to the optimal BTA, which doesn't necessarily have that full rebate now you have leakage, but the clean energy subsidy remains at zero. And yet, once you move to the actual carbon border adjustment mechanism, you bring it back. So I'll show you how.

So, to think about this, it's useful to separate three different margins. There's the carbon tax on the emissions abroad for goods consumed in home. There's the emissions in home for goods consumed in home. And then there is the emissions in home for goods consumed abroad, right? So those are three different bases.

Let's think about a tax for each of the bases. The baseline, which is a production tax that Ryan calls a use tax is going to be the one where you equalize the tax on the domestic base and the export base, right? So everything that happens domestically, regardless of the final destination, is taxed at T_U , and then there's no tax on the foreign emissions for goods that are consumed domestically. That's called the production tax. The ideal BTA then says we're going to now extend the tax to foreign emissions for domestic consumption. That's the T_M . So let's call, so now it's gonna be a T_M equal T_D . Let's call that T_A . And then there is a full rebate on the taxes paid on the emissions domestically when you export the goods. So that's now a consumption tax. All the emissions generated by domestic consumption are going to be taxed at the same rate, T_A . But optimality doesn't necessarily imply full rebate of those taxes. Optimality allows the tax, the tax on exports to be positive. And in fact, the Gortum and Weisbach find that the optimal policy is gonna have a tax that is positive, still less than the absorption tax or that consumption tax because of leakage, but it's still gonna be there, so there is leakage.

And so the question is, does this bring back the clean energy subsidy? And the answer is no. And the answer is no because regardless of the T_x , of the tax on exports, the optimum has that nice Pigouvian flavor. The wedges the different wedges on the fossil fuel extraction and use is equal to the social cost of carbon. With either the ideal BTA, which sets T_x equals zero, or T_x -free in the optimal BTA, the increase in the absorption tax does not affect the export tax. And so because of that, there is no leakage that matters for the clean energy subsidy to come in. You get the T_a plus T_e equals to social cost of carbon and the clean energy subsidy can be zero.

With the actual carbon border adjustment mechanism, for example, in the EU, the carbon tax on exports remains the same as the overall carbon tax. There is no rebate on exports. And so when you're increasing T_A , this drags T_x , and that generates leakage. And because of that, you're going to have the sum of T_A and T_E less than the social cost of carbon.

And then you plug that into the formula above, you see that the clean energy subsidy is now going to be positive. So the fact that the actual CBAM doesn't have a full rebate on the exports or doesn't have a rebate at all implies that there's still a role for the clean energy subsidy in this case.

Now, the second comment is to think about the leakage for associated with the movement of goods because of taxation in one place and not the other. And the calibration that Ryan does for this based on some previous literature and what we can get for this number based on a trade model.

So I wanted to show you what I've done here. So basically, think about a simple trade model where you are using oil and labor to produce goods. Goods are differentiated by origin, consumed with a CES utility function and elasticity σ . There's an outside good that pins down the wage. And then we're gonna hold the price of carbon fixed at P , so that we're gonna focus on the relocation channel, right?

The channel where you're taxing in one location. The carbon-intensive goods in that location become more expensive, and then you switch to buying goods from places that, that don't have a carbon tax. So split emissions by destination so that in the first part of that summation, you have the domestic emissions in home for consumption in home in sector R .

And then the second one is the, the corresponding one for the the goods that are going to consume abroad. Let this ϕ_H be the pass-through of the price, the increase in the price of carbon into the prices of the goods that are being produced and traded. And then that ρ_H is the difference in the carbon intensity of home versus foreign.

So then you get this formula, which basically says that an increase in the price of carbon is affecting the price of the goods that are traded with an elasticity σ minus one that's going to be affecting the allocation of expenditure. The expenditure that is exposed is that big ψ_H defined here.

And then what this formula is saying is then the numerator is the emissions that are going to be generated abroad because of the shift in the, the in expenditure from home to foreign goods. And then in the denominator, you have the decline in emissions in home, which is coming from a purely intensive margin, just more abatement because of the higher tax.

And then the, the other part, which is the emissions that are falling in home because of relocation. So that's the formula you get. I'm not gonna have as much time to go through some details here. There's basically, the calibration here is following Gortemaker and Weisbach, and it's consistent with what Ryan did. So σ minus one of five a pass-through of point fifteen from Gortemaker and Weisbach. And then just to simplify here, let's just assume that whatever is saved in emissions in home is going to be the same that the same carbon intensity abroad. So that ρ_H is equal to one. Then from some OECD greenhouse gas footprints data, we can then implement that formula, and we get that focus on the second column. You get a zero point seventeen for the US and a zero point twenty-four for the EU. Which compares to what Ryan did-- used in his paper of 0.1 and 0.2. They're kind of in the ballpark. I was relieved and very happy for-- about this. Not sure if it's from the perspective of quantitative models that now look better or that quantitative models are saying that the calibration looks better. But in any case, both look like having numbers that are in the same ballpark and that can be reconciled with the empirical areas and with the structural models that, that we use for this.

Okay. Third comment is going back to what I said before, if we have an actual CBAM that doesn't fully rebate exports, then we need to think about the leakage that remains, which is going to determine the size of the clean energy subsidy. That leakage is not the leakage that

we were talking about before, which is the full leakage on both the imports and the exports. The leakage that is going to matter here is the leakage specifically on the export side. You impose the carbon tax, you are extending it to imports through the CBAM, but you're not rebating it on export.

Because of that, now your exports of carbon-intensive goods are going to fall. And that's going to now happen in the rest of the world. That's the leakage you care about. So it's a -- you need to look at the exposure only on the export side. And once you do that, these numbers fall quite significantly. So extending the tax to imports removes about sixty percent of US leakage and about half of the EU's. So that implies that the clean energy subsidy in the baseline is gonna be falling by around a half in, in both places, but not to zero. Okay.

And the final comment I have is about other gaps that are not necessarily leakage. So, these are, the first one is something that Ryan talks about in his paper that I found very interesting, which is about the, the retail markup. So if you have a retail markup, then consumers are gonna pay the price of carbon plus the use tax, plus the margin, plus the markup which is going to imply that the optimal use tax is going to be the difference between the social cost of carbon and this other wedge that is there kind of already doing part of the job of what you would want a carbon tax to do.

But you also have a wedge between clean and dirty energy that must be equal to the social cost of carbon that one, the dirty one, the dirty energy has and the clean one does not. So you also have the TU star plus the sum of those two wedges has to be equal to the social cost of carbon. Now, in this paper that Ryan cites what they are saying is that the markup in many areas of the US is actually higher than the social cost of carbon.

And if you take that into account and you say the carbon tax cannot be negative, you cannot have a subsidy, then what that means is you set it at zero at the corner, and now the social cost of carbon is going to be the full social cost of -- sorry, the clean energy subsidy is going to be equal to the full social cost of carbon.

So we go from the numbers before, like two to 50, if we use a social cost of carbon of 50, like, like Ryan does. So that would imply a big clean energy subsidy. And the one the, the last one is, of course, political constraints. If you have some constraint that implies that the use tax cannot be above some level, then all the remaining way of internalizing this externality is gonna fall on the on the clean energy subsidy, which would imply that's gonna be ϕ minus TU bar.

If TU bar is low, then again, that's going to be a reason to have high clean energy subsidies. So I'll finish there. So basically the, there is, there is-- there are reasons to think that clean energy subsidies may be larger than the initial calibration suggests. Thank you.

EBERLY: Thanks very much.

The second discussant is Catherine Wolfram

WOLFRAM: Great. So, Jan told me that she wanted me to try to end on an optimistic note and I will try to deliver in a climate session. This is a really wonderful paper. Ryan's done a masterful job synthesizing a bunch of pretty complicated papers, and I will definitely be assigning this when I teach next semester.

What I want to do, Andrés had four points. I have basically one point, which is to talk about how Ryan is modeling the rest of the world. And I want to talk about this from two different perspectives, both the dynamic perspective and his model. Policymakers don't respond to what the home country is doing, so I want to talk about that. But I don't really have a suggestion there. I think it would be a whole different paper.

I want to talk about that as a way to set up my second point, which I do have a suggestion around, and this is the assumption that there is no existing climate policies in the rest of the world. And then I have a grab bag of other comments, and we'll see if we have time to get to those.

So, in Ryan's formulation and in the work that he summarizes, you know, this has been the standard assumption. People model markets, and people model consumers and firms and how, you know, oil markets will respond to the policies. But what they don't model is how other policymakers might respond to the policies.

Ryan is very upfront about this. He has a whole paragraph on page three that acknowledges this. But I do think that the most important climate policy that we have going is a clear violation of this assumption. So Andrés brought up the, the CBAM. I teach MBAs. I have a nice little picture that describes the CBAM. It's the European Union's Carbon Border Adjustment Mechanism. And so basically as we all probably know, the European Union has a price on carbon through its emissions trading system. In my diagram, it's seventy-five euros per ton. And so starting January first of this year, for these industries, steel, aluminum, fertilizer, cement, when you export to the European Union, you have to pay at the border as though you face the ETS price. But, and this is a very crucial but, if you've already paid a price, a carbon price domestically, you get credit for that And so I think that this has been just tremendously effective at encouraging other policymakers, other countries to adopt carbon pricing.

So this is a graph from the International Energy Agency that is looking at global all industry emissions and the share covered by a carbon price. You know, look what happens the year before the CBAM comes into effect. A lot more of industry is covered by a carbon price. In 2026, beyond this graph, India introduced a cap and trade system, Vietnam, Japan, Brazil has one, Turkey. You know, there are a bunch of countries that are adopting carbon pricing.

I have a paper that I published with like twenty plus co-authors, including Kim in Science recently, and one of the things we do is we zero in on the CBAM sectors, the aluminum, steel, cement, fertilizer, and point out that eighty-two percent of the emissions are covered by carbon pricing systems. And so, you know, to me, I trace this back to CBAM.

There, there is some some empirical work that kind of tries to differentiate countries by how exposed they are to CBAM and suggest that the countries that are more exposed have a seventeen percent higher likelihood of implementing a carbon price. I'm not sure I hundred percent believe their identification strategy, but I do think that in this context, the, the examples are very powerful.

And so Turkey is a country that exports fifty percent of its manufacturing to the European Union. Turkey very explicitly has said, "We don't want to be sending money to Brussels. We want to keep it home." And so they are implementing, as I showed you previously, a carbon price.

In climate circles, having China as an example is very important. China is a third of global emissions. So China in March of 2025 expanded its carbon pricing system to cover three of the four CBAM sectors. Now, the Chinese government does not admit that they did that because of the EU in public, but in private, I have heard people say they did not want to be sending money to the European Union. They were planning to do this. They accelerated it because of the, the CBAM So, Bill Nordhaus has this idea of a climate club. I think of the CBAM as kind of the original climate club. The Nordhaus idea is that you have a carbon price if you're in the club, and you have a punitive tariff for countries that remain out of the club.

And so what I've done with a bunch of co-authors, again in-including Kim, is to think about kind of how you get from where we are now, where we have this profusion of carbon pricing, to something like an, a Nordhaus style climate club. And so we put out a report last September where we recommended starting with the CBAM sectors, starting with the heavy industry, and then we recommend a couple of other things, like maybe you want entry into the club to be a function of the country's GDP per capita, so you could have lower carbon prices expected of lower income countries.

And very happily, the Brazilians loved this idea and really ran with it. They introduced a declaration at COP30. They got eighteen, seventeen countries plus the European Union to endorse the declaration. So the EU was there, China was there. In March of this year, Brazil the EU and China formally launched what's now called the Open Coalition on Compliance Carbon Markets. Brazil is the lead and the EU and China are co-leads. So the China Daily was very excited about that. Ursula von der Leyen was very excited about that. The declaration at COP was a leader level declaration.

So right now the members of the Open Coalition on Compliance Carbon Markets represent about forty-two percent of global emissions because you've got the EU in there, 'cause you've got China in there. I think very importantly it also includes middle income countries. Brazil is the lead. Turkey is a member. And there are some low-income countries that have joined as observers. And we also know that there are other middle income countries that are potentially in, in process of joining the Open Coalition.

So you know, something like the Nordhaus style climate club seems to be bubbling up with all the enthusiasm around carbon pricing. So here are- The map, here are a bunch of other countries that could become members. The ones in blue are the ones that have emissions trading systems implemented. Brazil has an emissions trading system that, that's planned, but not yet implemented.

So I think that this assumption that countries, you know, the rest of the world doesn't have a carbon price is not representative, is especially not gonna be representative, hopefully in 2029 when the US actually might have a chance of being able to implement carbon pricing or, sorry, climate policy. Let's not get too enthusiastic.

So I think it, it would be useful to think about what happens in his model when you have binding caps in the rest of the world. And so, like, my armchair theorizing here is that you don't get emissions leakage because they're binding caps in the rest of the world. It's important just from a practical perspective, some of the things that are listed as ETSSs don't actually have binding caps now. China has an intensity-based standard, but they do plan to introduce by 2030 a, a binding, a hard cap. So I think, you know, especially by 2029, we might be there.

All right. Let me do a little bit of a diversion on why I think modeling this binding cap might be interesting. So go back to this map. You can look at it and note that seventeen of the twenty G20 jurisdictions have a carbon price, at least planned, if you include Brazil. And the three that don't are Russia, Saudi Arabia and the US. And so it kinda suggests that the US is you know, in the company of petro states And so I have some ongoing work with Mara Reguant looking at-- and I think this is something that this group has seen. I think it's also important to note that this was happening kind of over the time period that the literature that Ryan is summarizing was written.

So what's happened, the US has gone, like, more than doubled our oil and gas production. We are now the largest oil and gas producer in the world. Over that same time period, we have increased by a factor of six our expenditures on campaigns. And even with that sixfold increase, the oil and gas fossil fuel share of those contributions has gone up. So these are all, you know, relative to the index of 100 in, in 2004. This is a total diversion, just a fun fact. The US spends about \$40 per registered voter on our campaigns. That's, like, almost an order of magnitude more than the second highest G7 country. The US fossil fuel industry spends more on our campaigns than anyone in France, like, all of France spends on campaigns.

Okay. So, you know, how does this relate to the, the frame for US climate policy when we might have a chance in, in 2029? I guess my hope is that we enter the discussions about climate policy, we as the US, from a kind of do no harm and, like, recognize the progress that the rest of the world has been making without us at the table. Recognize the fact that our political constraints are different because of our role as the world's largest oil and gas producer.

And I do think that, like, this is where Ryan's model is useful and helps us think about, like, what if we were to put on an extraction tax? What would the implications be? I have some work again with Kim. This is a theme here, also with Jim Stock John Biceline and Neil Marocha. So we modeled-- this is a paper we wrote in 2024. We were kinda optimistic that it might be actually useful. But about a potential, like, options for climate policy. We modeled a very modest carbon price. I think it started at, like, fifteen dollars a ton. But one thing we did is we noted that if you don't rebate exports, you collect, like, six hundred million over the budget window... Sorry, six hundred billion. But if you do, sorry, if you don't rebate exports, you, like, more than double your, so basically, if it's an extraction tax base versus a consumption tax, you more than double your fiscal revenue. So I think that's an important consideration.

But then again I think if you have binding caps elsewhere, again, like my armchair theorizing, is that basically, if we raise fossil fuel prices globally subject to these binding caps, we're just gonna make their caps clear at a lower price. And so, like, we're gonna be taking in fiscal revenues to the extent that other countries were auctioning off their permits. They're gonna be taking in less fiscal revenue, so it's just like a transfer from the rest of the world who's been pretty assertive and aggressive on climate policy while we weren't at the table to us. And so that to me seems geopolitically costly.

So, I would encourage Ryan to add this to his paper. I think it'll be an, an interesting hopefully, you know, at some point in the US interesting contribution. Okay maybe I won't go, I won't give Haowen a, I won't go through my grab bag, but we can talk about these things.

Let me do one of them. So, like, and I was-- because Andrés brought up the clean energy subsidies, I think it's important to recognize there are other ways to reduce energy prices and we don't only have to rely on clean energy subsidies. So we have some ongoing work thinking about using carbon pricing revenues, flowing it back to residential ratepayers. Like, just literally give them money to reduce their energy prices. All right. Thank you.

EBERLY: Thank you, catherine. So we have some tags up. We wanna start with Jim Stock

STOCK: Okay. This is really interesting. I'm really glad we're talking about this. I'd like to step back thinking about the main theme of, the main framing of Ryan's paper and make some make an intellectual case. What is the historic intellectual case for supply side policies? And it's really not these trade considerations that are going on here. These are issues that Ryan knows extremely well. The overarching case comes from historically comes from the theory of exhaustible resources. Hotelling basically, if you've got this exhaustible resource, you're gonna want to use it all. Hotelling tells you how to price that. Prices are gonna be going up at the rate of interest.

That is kind of a doomsday, really hard to avoid situation because you've got this oil in the ground and you're gonna, you're gonna use it. So what can you do about that? In the old days, we didn't really have any choice. We could wear a sweater or something like that, but all that wearing a sweater, or we could have a carbon tax, but all that's going to do is kick it down the road. Now it's gonna kick it down the road in some optimal way if you have a carbon tax, and that's what's in the DICE model. But, you know, it depends on your discount rate, and some people like Laura Stern would say that your discount rate should be really close to zero and that we owe it to future generations to deal with the problem now.

So, you know, it's a kick-it-down-the-road solution. Today, things are just different because we have what technically might be called a backstop technology. That is to say, when the oil price gets above a certain amount, it's just that you don't use your car. You just, you could get, you get an EV instead. And so there's gonna be backstop technologies that can be used and that really changes a lot of the hotelling framing and so forth.

But in the first framing, how do you-- if you've got this inevitable use of your oil, how do you stop that? The only tool you have is to shift the supply curve. So you say, "I'm sorry, we're not gonna be able to use some of that." So that's the keep-it-in-the-ground logic. I think that logic is arguably less relevant today, but it was-- but I think that's where most of this came from. So, and the logic today, if you've got this backstop technologies, you still wanna use all of the oil. And if you sort of combine that with the fact that we're a net exporter, as we talked about yesterday, I think that explains a lot of US policies as Catherine alluded to.

Second comment, I would take issue with the statement that carbon, that's optimal supply side pricing is really not, I don't know. I will - it's not in the conversation. That actually has been very seriously considered. So the notion here is how can you implement a carbon extraction price? I mean, going back to work that was done in the Obama administration between the Council of Economic Advisors and the Department of the Interior, there was a lot of work on reform of the federal coal leasing program that ended up in a draft PEIS that was relieved in - released in January 2017, sort of a nice document. And that that the lead reform there was actually not to, like, scale back quantitatively, but actually it was to add a royalty adjustment that was based on the carbon externality. Since we, most of our coal comes from federal lands, that actually didn't have a huge amount of leakage, and it was really really an upstream an upstream carbon extraction pricing.

The analysis behind that is in a paper that came out a couple years ago with Todd Jerrard and Spencer Reeder in AEJ Economic Policy. And then in, and then that's actually carried on in, like, a first week EEO in the Biden administration. There was a, a mandate to look at oil and gas royalty and the oil and gas federal leasing program. And you know, the, one of the, I think the first item that was listed was incorporating a royalty adjustment for carbon pricing in in, in that reform. Brian Prest and I looked at that in, in a paper that was published a couple years ago. That too, I mean, politics happens, so the, neither of those actually transpired. But there were very serious attempts within the federal government to do that.

EBERLY: Diego Känzig and then Brian Prest.

KÄNZIG: Fascinating paper. I really enjoyed the presentation and the discussions. I wanted to ask a bit about the relation to some recent work by Kochin and Maji, and also O&K. So they basically make the case that in the presence of leakage, this improves the efficiency of subsidies. So if you look at an open economy, the optimal climate policy is usually a combination of the two instruments.

Now, if I understood correctly, what you show is if you have the extraction tax, that basically through the impact on energy prices, reduces leakage and thus the role of subsidies. But as Jim like alluded to, the extraction tax is very hard to implement probably politically.

And one other thing that I found fascinating is your point on like subsidies for clean R&D. And there're just like, if you think about the progress the US, China, and also part of Europe have made on solar panels and batteries, like, and if we allow these technologies to diffuse, this can have huge impacts on like energy savings throughout the world.

So I was just wondering if you allow for this diffusion of these new technologies that are maybe accelerated by clean R&D subsidies, how could that tilt the balance between these instruments?

EBERLY: Brian.

PREST: Thanks, Ryan. Yes, so, a great paper. I'm glad that you're bringing attention to supply side policies, given the focus has really been demand side by the profession and policy world, and how they interact is really important. I wanna second Catherine's point about the role of binding caps in other parts of the world. That seems like it'd be really important to understanding the actual net effect of leakage.

I have just three comments. So, first, it looked like from your table that your results actually showed more role for supply side policy, supply side pricing than demand side pricing. That was actually a little bit of a surprise to me. So I'm a little, I'm curious how you, how that squares with, and, you know, correct me if I'm wrong, but I got a sense that your discussion was kind of poo-pooing the supply side policies, but maybe that's wrong. But also more generally, the lack of kind of attention to them in the, the policy world given that your results are suggesting that we should actually be focusing more on them than the use side.

Diego's point is right that maybe they're more politically difficult to sell and that's why we have much more focus on carbon pricing on the use end, such as in cap and trade programs in California, New England and so on. But I will point out that many states do have severance taxes on oil. For example, North Dakota has a 5% severance tax on oil. That's

about \$5 per barrel today, which is what about nine or \$10 per ton of CO2 equivalent. We don't have a federal severance tax, but maybe that's something we should be thinking about, and also be thinking about what we might wanna use that for.

We've had a bad experience with the transition in coal country historically because of lack of planning and saving. Hopefully we can do better in oil country and a maybe a sovereign wealth fund funded by a federal severance tax could be one potential use of that.

Just two technical points. The elasticity used both on fossil supply and demand seemed larger than I would have expected, recognizing that they're supposed to be long run values. The paper I alluded to when we were chatting earlier has smaller values than on the oil side for the US alone. I would imagine the global would be even smaller than the US numbers. I'm happy to talk offline about that. The .61 demand elasticity also seemed large, but that's less my area of work, so I'll defer to you.

And then lastly, the abstract mentions that supply-side policies are inefficient because they don't tax extraction directly, they go after infrastructure. I first didn't get the transportation versus upstream distinction in infrastructure in the abstract that I understood better once I got into the introduction. So maybe just add the word transportation to the abstract. But it, you know, blocking transportation does create a shadow price. The paper mentions the difference, the delta in transportation pricing from the Bakken is what's like \$10 per barrel by rail versus \$6 by pipe. So that's, you know, a \$4 difference. That's, that's a shadow price. You know, obviously it's not the same as an extraction tax, but yeah. I'll leave it there. Thanks.

EBERLY: Thanks. Samantha Gross and then Elaine Buckberg

GROSS: And so I'm gonna step out of the world of math and into the world of molecules and electrons for a moment. Really appreciate the paper. It's super interesting and love to hear the comments on it as well. But my question is, when we think about oil markets, they tend to behave like a Econ 101 market, supply curves, demand curves, efficient markets.

However, when you look at the market for electricity generation fuels, they don't behave that way at all. Global natural and gas markets are bifurcated into pipeline gas and LNG. Never the two shall meet. The prices are wildly different, and they're very infrastructure constrained, both markets, but in different ways.

Coal also is not really a global market because its value is kinda low compared to its transportation price. So those tend to be local markets. How do these constraints and the differences among those affect your results given that oil behaves the way you want it to do, but oil is not used in electricity generation, which tends to be where the rubber meets the road on these policies? Thanks.

BUCKBERG: So Ryan did a lot of analysis and measurement around difficult to do things, but he also raised this really tantalizing idea that you then dropped, said it was really difficult, which is more interregional electricity transmission so that you know, renewable supply with essentially zero marginal cost isn't being curtailed and wasted.

And you pointed to the really different, difficult internal politics of these in wholesale re-different regional wholesale grids, which all have weirdly different governance with, but that

seems so important and I'd love to hear more or I think that deserves more work. It definitely deserves the, a, a grab bag treatment. Seems like a really important problem.

EBERLY: Okay I think we got everybody, so let's go back to Ryan.

KELLOGG: Amazing. This is, this has been great. So maybe I'll start with the discussants. Thank you both very much. And I think this sort of really important point about sort of like CBAM broadly speaking, and how do we think about policy in a world where you have policy interactions across a bunch of different parts of countries.

I think one, at a high level I think sort of the piece I talk about in the paper that gets at this is this notion of sort of like using clean technology, whether it's R&D or industrial policy or some combination of both, to drive down clean energy costs so that other countries are willing to decarbonize on their own, even if they're not gonna actually do policy.

I think Catherine did, I think did a really nice job of highlighting sort of the other prong of attack, which is actually really trying to think hard about international agreements and international tools and policy levers like this notion of climate clubs to actually get countries to do policy. And I think these two approaches are actually quite complementary, particularly when you think about the political economy of the problem. When you think about like really trying to get low and middle income countries, the Indias of the world that are, you know, desperately trying to grow their economies, extremely coal-based at the moment, probably not terribly willing to sacrifice a lot in the way of economic growth for the sake of the climate, given where they are in the world. It would be fabulous if they were will- it's, you know, to... And you know, they're beginning to start making commitments and starting to put together a carbon market.

I think where the rubber's gonna meet the road is like, are they gonna be willing to go all the way to, say, like an EU ETS level price of 70 euros a ton, which is that's pretty chunky. Having accessible clean energy is something they could substitute to, to lessen the cost of doing that just becomes really paramount. Like I tend to think like a lot of the reason getting traction on carbon pricing is hard is because it's actually really costly to impose that on your economy, even when you are collecting revenues and trying to rebate them the best you can. The political economy of that just gets hard. Like even in Canada with, you know, Carney as PM, they've walked back on a bunch of their carbon pricing relative to where they were. These things are hard, and I think complementing these two things I think is a really useful way forward.

Yeah, and on the specific comment about like how do we think about carbon policy in one country when I know that other countries are doing some kind of cap and trade with a binding cap, I think is really useful. I tend to think of cap and trade... Like my model is very much in the flavor of applying price policies. I think sort of Catherine is thinking about the world in sort of the EU ETS version, where we have, you know, caps and the prices are flexible. I think in practice a lot of carbon policies are hybrids of those two things, where you have a cap, but it's kind of soft because you have a full price floor and a price ceiling, and you kind of wind up with some hybrid.

You know, I think one thing that is interesting is like if, say, we do wind up in 2029 with an administration that wants to get serious about climate, the US is gonna be in a place where you have all these other countries now that are doing emissions pricing and a bunch of

countries that are not. Like the arguments for doing extraction pricing become even stronger in that world because the fossil fuel price has been so depressed by what other, by what all these other countries are doing.

Again, you know, I'm not gonna have the page space to get onto into that in the paper I'm gonna, you know, finish and publish here, but like that seems like it's sort of a really interesting line of attack for somebody to take on. It's like Jim and Brian sort of parallel, so it's very closely related comments.

I think like Brian, the sort of the comment about severance taxes, about like what states do, I think that is like the model for what a federal extraction tax would be. It would be a severance tax on extraction. You know, historic states are not applying severance taxes for any, for reasons that have anything to do with climate. It's about revenue raising and trying to rein back some of the rents the, the extractors take. But that, that's exactly the, that's exactly the lever to pull.

And I think the really big piece of it is going to have to be, especially for oil and gas, and I think Jim, you're right, it's less true for coal. But oil and gas, somewhere 80 to 90% of US oil and gas extraction onshore anyway, is private, privately owned resources, not the federal oil and gas. So, you know, federal royalty reform, it's gonna have traction on coal. It's not really gonna get you very far on oil and gas. Like, think that's where like the really broad piece of this really needs to come from.

Yeah, and sort of like on the point about hotelling yeah, I think when I look at the supply side literature, there's definitely, like they got Bard Harstad's work, for instance. A lot of that is coming out of the hotelling style of model. And I do broadly agree, and I think this is something I'm gonna write about next, that like despite the fact that I've written a lot of hotelling papers and I've taught hotelling to PhD students, like the model of resource extraction for like 10 years now, I've kind of convinced myself over the past couple years that it's just not the right model anymore.

That these resources are just super abundant. We are not going to run out anytime soon, or at least not on any timeframe that any of us or even any of our children actually care about. And we should think about policy in that light. Like just to pick on oil, which is the scarcest of the three big resources, like you look at reserve estimates, the reserves to production ratio has been 50 for the past 30 years because we keep finding new things, and the shale revolution is just the latest iteration of that.

I don't know, James, you seem, it seems like you wanted to jump in, Jim, or no.

EBERLY: You need to wrap up.

KELLOGG: All right. We'll wrap up. Diego, just on on your comment on sort of the O&K and Kachin and Maggie papers. I think the difference in those papers is sort of what instruments you allow. Once you have the extraction tax and a use tax as separate instruments unless you're worried about leakage through trade and goods, you don't need the clean subsidy anymore as a leakage mitigation mechanism.

And I think what this leaves is your last comment, which is when I think about like what's useful about clean energy subsidies it is this point about decarbonizing the world and

lowering costs. Like, like that is the case for subsidizing clean energy, plus some, plus the mispricing comments that Andrés brought up in his discussion.

And yeah, I think, yeah, Samantha, your point is absolutely well taken. Like the model works well for oil. I think in the long run it works pretty well for gas once LNG gets built out. Coal, I think is like less so because of, I think, yeah, for exactly the reasons you stated. Yeah.

And Elaine, you gave me one more, one last chance to pound the chew on the table about transmission reform. Like, my worry is that like there might be some momentum to actually do something on permitting reform, but if it doesn't get at the fundamental governance problems of like who controls what transmission we build, you can get rid of the permitting, but you're not actually-- that's not on its own gonna be sufficient to get the long distance transmission built. Like somebody needs to say, "Yes, I wanna buy this power." And the utilities really don't have terribly strong incentives to do that.

EBERLY: Thank you very much.

All right. I want to thank all the authors and discussants for stimulating such an interesting series of conversations over the last two days. Especially thanks to Haowen Chen and Meghan Waring. And the authors and discussants all know this, so without them nothing happens. So we really appreciate all of their work.

And there are box lunches outside, and we'll meet again next spring, March 25th and 26th. We hope to see you there. Thank you.