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MIKE LIVERMORE: Welcome to the *Free Range* podcast. I'm your host Mike Livermore. This episode is sponsored by the Program on Law, Communities, and the Environment at the University of Virginia School of Law. With me today is Jonathan Colmer, a professor in the economics department here at UVA. Jonathan is also director of the Environmental Inequality Lab, and his research touches on environmental economics, development economics, and the distributional impacts of environmental policy. Jonathan, thanks for joining me today.

JONATHAN COLMER: Thanks for having me.

MIKE LIVERMORE: So I thought we might start off the conversation with a paper that you published a couple of years ago with several colleagues that came out in one of the premiere journals in the world of science. And this paper was on inequities, or we could say the distributional characteristics, let's say, of air pollution in the United States, and how that kind of has changed or not changed as a consequence of environmental policy, things like the Clean Air Act and so on over the last several years.

So maybe we could just start off by talking a little bit about that paper. What led you to that project? A little bit on the methodology and the findings. And then I'm sure that will give us plenty of a runway to start the conversation.

JONATHAN COLMER: Yeah. That sounds great. So yeah, with this work, we wanted to really try and understand in a more systematic way the distribution of air pollution in the United States. There's been a huge amount of research over time in sociology, and in public health, and other fields, including economics, but a lot of it has tended to focus on more local case studies highlighting the disparities that we see in exposure to environmental risk.

It's well established that disadvantaged communities are disproportionately exposed to greater environmental risks like air pollution. But we didn't have as much of a systematic understanding of this for reasons of measurement and other considerations. And so we wanted to try and provide a broad understanding of what disparities in fine particulate matter, which is a particularly damaging form of air pollution, looked like in the United States across different neighborhoods. And also really to think about how this has evolved over time.

So the reason that we were really able to answer this question is the increased availability of new satellite data and other ways of measuring air pollution, which allowed us to get really high resolution information on exposures on the concentrations of fine particulate matter for many neighborhoods in the United States. We're talking over 60, 65,000 census tracts in total going back to the early 1980s.

And so this allowed us to look at how exposures to a particular matter have been distributed across space and across time. And what we find in terms of the core result was that while there have been substantive reductions in air pollution and fine particulate matter over the last four decades. Really the disparities that we saw back then and see today have really persisted.

So we see that in terms of the spatial distribution of pollution, the most polluted areas in 1981 are still the most polluted areas today. And the least polluted areas in 1981 are still the least polluted today.

MIKE LIVERMORE: Yeah, it's a really interesting-- as you said, the ability to track these issues both temporally and spatially is really, really interesting. Part of, I think, one of the things that strikes me about this is I think it raises the question about how to think about these disparities from a normative perspective. And I wonder if we might talk about that a little bit.

JONATHAN COLMER: Sure.

MIKE LIVERMORE: So if I could imagine kind of two arguments happening simultaneously, and I'm curious what you think about these. So on the one hand, I think, on its face we could say, look, this is a problem. We have disparities. That's bad. We think that people should have equal access to a clean environment, or that's a norm that we would like to have in society, and that's not happening here.

On the other hand, I could imagine an alternative reading, which is something along the lines of, well, what we're seeing here is this is a happy story, like we're improving air quality across the board. So it's not the case that the same areas that were polluted in the early 1980s are still as polluted as they were in the early '80s. They're getting cleaner.

The cleaner parts of the country are also getting cleaner and it's rising tide lifts all boats kind of story. We can imagine a similar story with health care, that if it was the case that people were living longer, and their health was improving, and so on. But some people still were healthier than others, that wouldn't be surprising in some sense. And it's part and parcel of the overall reality that we live in a society where there's inequality.

There's some people who have a lot of stuff and some people who have very little stuff. And the environment is just tracking that larger phenomenon. So I'm curious which one of those normative stories you find more compelling, or if there's an alternative take that you have.

JONATHAN COLMER: So I think there are a number of-- I think I agree with what you're saying. I mean, yes, pollution has fallen. That's great news, of course. But I think at the same time, ideas of fairness and equity and justice are inherently comparative. And we do care about who is advantaged and who is disadvantaged. And so what our results show is that those who are disadvantaged and those who are advantaged remains remarkably stable over time. And that's, I think, important to understand.

I think that there's also a sense in which we see that there are these reductions in pollution, which have been largely proportional. And as an economist, that raises questions for me about how these reductions have arisen as well because, I mean, if we think about the cost of reducing pollution and it's not zero, my prior at least would be that reducing that first unit of pollution is a lot cheaper than reducing the last unit of pollution, which would be incredibly infinitely costly.

And so the fact that we see these proportional reductions such that there's been a 70% decline in the most polluted places and the least polluted places, has implications in terms of the allocation of resources that we are expending in terms of trying to reduce pollution.

MIKE LIVERMORE: Right, yeah. That's a really interesting point. Just to maybe reiterate it is there's two things that we could be thinking about simultaneously here. One is the equity and distributional consequences of this. If one of the goals of laws like the Clean Air Act was to reduce disparities, it doesn't seem like it's being very effective in that sense. So that's one general set of concerns.

The other one that you just raised is an efficiency concern, kind of very traditional economic concern, is that wait a second, it should be the case that the cheapest, easiest places reductions to get are in places where the air is somewhat dirty. And that cleaning up the air in places where it's already quite clean should be expensive. And so why is it that it seems like we're spending more money than we need to per unit of reduction?

And that is quite interesting. I'm curious if you have any maybe have some hypotheses. Do you have any hypotheses for why we see the pollution reduction allocation the way that we see it?

JONATHAN COLMER: Yeah. I mean, so just to touch on the efficiency point as well, I mean, think even the efficiency point does come back to these ideas of equity and inequality as well because we distinguish between ideas of distributive justice in terms of outcomes. But it's almost a sense in which when we're thinking about the allocation of resources to reduce pollution, it's slightly differently to how we might normally think about it, but it comes under a more of a procedural justice concern as well in terms of the allocation of resources to deliver those outcomes.

In terms of hypothesis, I mean, at the highest level, we don't have-- I think, this is still an open area of research really in terms of understanding the causes of these disparities. But to me, it suggests that the reductions in pollution that we've seen have been more driven by broader aggregate patterns.

So one might think of technological change, and say federal policies like CAFE standards, and other transport-related policies, more so than more localized policies to the degree that localized or local policies are contributing to reductions in air pollution, which we have evidence that they are in terms of understanding the effects of nonattainment through the Clean Air Act and things like that.

But that signal is not coming through as strongly as these more aggregate patterns that we're seeing, I think, at least in terms of relative reductions. Now, it's not fair to say that the Clean Air Act hasn't reduced absolute disparities.

My long standing colleague and coauthor John Voorhis, who's a principal economist at the US Census Bureau, has a great paper that's just coming out in the *American Economic Review* with Janet Currie and Reed Walker that shows that the Clean Air Act has helped to reduce absolute disparities in terms of black white gaps in air pollution.

So there has been contributions of these policies to improving absolute disparities in terms of the gaps in exposure. At the same time, those gaps are inherently bounded at zero. And so those gaps are going to get smaller more measured mechanically as air pollution falls, which is why I think it's also important to understand relative disparities as well.

MIKE LIVERMORE: All right. And there's a story that an alternative world where disparities could have gotten worse and even absolute disparities could have gotten worse with air pollution control if the cleanest parts of the country got cleaner and the dirtier parts of the country didn't get cleaner at all, that in theory could have happened. And it's good that didn't happen at least.

JONATHAN COLMER: Yeah. I mean, and it's possible that there are concerns that those gaps in more recent years may have been getting worse, that there may have been a reversal. And I think this relates to our broader interest in environmental risk that stemmed beyond thinking about air pollution in a traditional sense that, for example, recent increases in wildfire activity really threaten to reverse some of the gains that we've seen in terms of reductions in air pollution.

And with climate change, these are expected to not get better anytime soon to say the least. And that's a problem, that is a harder problem to manage in terms of reducing the air pollution that is generated through those more natural events.

MIKE LIVERMORE: Yeah. No, I mean that's a whole these next generation questions, really pose all kinds of difficult challenges. Just in terms of the thinking through the causal and the normative story, as we're talking about it just gets more and more interesting, I think, in some ways because there's also increasing marginal harm too that we might think in the context of air pollution.

So other things being equal, actually putting aside even concerns about fairness, and disparities, and quality per se, and we just were focused entirely on harm reduction, it would make sense likely to address harms in places where you have the highest concentration. So those are both where you should get the cheapest reductions, and also where you get the most harm reduction benefit. So those really provide, I think, very compelling efficiency dilemma for the results that you guys see.

JONATHAN COLMER: Yeah. I mean, I think as with the objective of any good descriptive work is that it ultimately raises more questions than it answers. And that's one of the things I'm so excited about. The work that we're doing at the moment, which is we're getting a much at least broader understanding of what's going on as well as being able to raise new questions and dig into those more deeply to try and get at the causes of these disparities and their consequences.

MIKE LIVERMORE: Yeah. And one interesting coming from a legal perspective, one thought that comes to mind is that our policy instruments might be part of the story as well. The National Ambient Air Quality Standards, for example, in principle alone could reduce disparities because the idea with the NAAQS, as you know, is to set a minimum standard that every jurisdiction is supposed to meet.

But we've chosen in the US to augment that National Uniform Ambient Standards with other overlays including the prevention of significant deterioration program, which requires cleaner parts of the country to remain clean, and makes it more difficult for them to-- where the idea is that it stops them from polluting up to the level of NAAQS in most circumstances. And then we have other parts of the country that are just-- we essentially allow for them to be in what's called nonattainment where they go for decades not coming into compliance with the National Uniform Standards. And so there likely is a story there, too, as well, as opposed to alternative approaches like a cap-and-trade system or some other mechanism where getting-- there would be much more of an incentive to get the cheapest reductions first, whereas that's really not how our system is set up.

JONATHAN COLMER: Yeah, I mean I think in understanding the contribution of policy and different types of policies to the more distributional outcomes is incredibly difficult to get at. One of the people who are doing very interesting work on this is Deni Hernandez Cortez, Arizona State University. She has a great paper with Kyle Meng that looks at the-- trying to understand the cap-and-trade system in California and understanding how the reductions in pollution that you see as a consequence of that program. How those were distributed, and understanding how-- one of the most complicated things about thinking through the distribution of pollution is that it's not necessarily to do with proximity to the facilities themselves because that pollution gets transported.

And so whether depending on how you look at that, how you measure the pollution exposure, whether you're looking at people who live just around the facilities, or if you're looking at the transportation of that pollution through a chemical transport models, which are thinking about how that pollution is carried by the wind, you can get very different answers. And I think one of the real contributions is to show that the careful measurement of how this pollution is transported is really important in understanding these considerations. And I think that plays a role in terms of thinking about National Ambient Air Quality Standards as well because we're measuring pollution in a particular location. But then you have other factors that are potentially contributing to pollution in that area that were not sourced from that location either through again wildfires or from pollution in neighboring counties or states.

And so it's an incredibly complicated causal chain to disentangle, to really even measure the distribution of exposure. In terms of getting at the causes, it's straightforward to take images from satellites to understand in a given location and time what it's exposure. But it's a completely different kettle of fish to understand the source of that exposure.

MIKE LIVERMORE: Yeah, it's incredibly difficult. And it's an irony of the Clean Air Act that it took decades before the federal government really used the Clean Air Act to address interstate air pollution as basically something that sat on the shelf for many presidential administrations. And it wasn't really until the George W. Bush administration that-- the Clinton administration to some degree. I mean, of course, you can-- there's always a prehistory. But the point is it took several decades to really get serious about air interstate air pollution.

Another factor, too, that's interesting in the reality as you were is you're noting that on-the-ground reality of exposure is that people move. And so it's an interesting finding that you have that we can probably assume that there are some persistence in human habitation and land over time. But what you're really finding is that it's like particular places that remain relatively more polluted than others, physical places. And presumably, there's some flow of people through those places. So I don't if it's odd or if it's expected at some level that what we would the finding is that-- or what your findings are is that it's linked, it's geographically linked rather than perhaps linked to specific individuals.

JONATHAN COLMER: Yeah, I mean, so one of the major limitations are all the science papers that we're not measuring individual exposure. We're measuring place. And that started really-- it was the starting point for our thinking that resulted in the environmental inequality lab coming into reality, which was that in all of this, when we're thinking about communities, communities of people. And so we want to understand. We want to move from a place based understanding of environmental inequality to a person-based understanding.

Because just as there are differences in exposure, there's differences in mobility and differences in income. And almost all of the literature to date-- thinking about environmental inequality within economics, at least-- using it in terms of quantitative research, has tended to use place-based measures using Census tract or county-level characteristics, such as the share of the population that is in a disadvantaged community or the share of the population that is non-Hispanic Black or non-Hispanic white or Hispanic, or what is the median income.

But in all of that, it's very difficult to think about what those considerations mean and how that actually maps, then, from place to people. And really, the goal of the Environmental Inequality lab going forwards-- and what we've been doing for the last few years, really, has been trying to move from a place-based to a person-based understanding. And that's been the result of the research partnerships that John Voorhees and I have been forming. As I said, John is one of the principal economists at the US Census Bureau.

And so, for the last few years, we've been building a data infrastructure, which, in effect, provides really detailed information on the distribution of exposure to many environmental hazards. We'd be looking at air pollution-- obviously, building on our earlier work, but we're also interested in exposure to extreme heat and flood risk and sea level rise, the effects of hurricanes, wildfires and wildfire smoke, as well as an area thinking about energy security and the clean energy transition as well, and other measures of environmental policy and regulation.

The data that the US Census Bureau has allows us to effectively follow, at the individual level, almost everyone-- almost every legal resident in the United States for the past two decades. So we've been building this data infrastructure. And it's an ongoing process, but it's all anonymized, of course, and highly confidential. It requires lots of federal background checks to even be able to get access to the data in the first place, but we've effectively managed to and to construct residential histories, so the addresses where people live over time.

And so we can see where they move, and we combine this with the economic characteristics. So we have measures of income from tax return data, and we have information on employment and education and those considerations.

But then what's really interesting is we also have the detailed information on demographics on race and ethnicity. And so this really-- before we even get into the environmental inequality dimensions of it-- the IRS has tax return data, of course, and what the national income distribution is. But by combining this with the information that the Census has, we're able to understand what income distributions look like by race.

And so this then helps us to get a lot deeper in terms of our understanding of environmental inequality because we can look at individuals who are exposed to these same environmental risks and understand differences in the consequences of those risks. So what is the difference in economic outcomes for low-income individuals versus high-income individuals when that area is exposed to a hurricane, or non-Hispanic Black individuals versus non-Hispanic white individuals?

And we can even go as far as say, what is the difference between-- in consequences for low-income non-Hispanic Black versus low-income non-Hispanic white individuals? And so that really just opens up a huge opportunity for us to get into mechanisms a little bit more and understand the causes of these disparities, as well as avoiding some of what we might refer to as "aggregation bias" that arises from looking at things at the place level as opposed to the person level because, when we're looking at county-level characteristics or Census tract characteristics, we don't know whether it's-- these things are all correlated.

And so, when we see that there is gaps in exposure, is this driven by income? Is this driven by race? And one is able to disentangle those things at the place-based level. But when you get to the individual level, you are able to see how those things are actually-- what's going on at the individual level instead.

MIKE LIVERMORE: Yeah, it's really amazing. It's an incredible data set. And there's just so many possible questions that you could imagine getting at. It's vast.

And again, at the individual level, once you start to link all this together, the one thing that just immediately strikes me-- and I'm just curious if this is something that you guys have in the pipeline-- is-- there's a lot of exogenous shocks that are happening that you can identify, like hurricanes, for example, wildfires, even siting, as well. The siting of a new facility is, in some sense, a exogenous shock.

And so is that one-- one line of your research, is to look at the downstream consequences? Presumably, if you have health data, you could look at that. But at the very least, if you have income data, education data, those kinds of bits of information, then you could really get at least some of the economic effects of these, and it's a really clean setup for identifying causal relationships.

JONATHAN COLMER: Yeah, so we broadly split our work up into a couple of areas. We we're building, first, on the-- what I would describe as systematic facts, the descriptive work that we first published with our science paper, but moving from a place-based to a person-based understanding. So that's, again, just trying to understand the degree to which these papers that have historically used place-based measures and place-based characteristics.

Through those results, number one, can we provide more systematic evidence on those results than previously? But also, how do the inferences that have been drawn from that earlier literature hold when one moves from a place-based to a person-based understanding?

So that's this idea of the ecological fallacy. Inferences are made about individuals using place-based data. And when we move to the individual level, do those inferences still hold? So that's the first thing we're doing, and where we have research looking at the distribution of flood risk and sea level rise. We have work on extreme heat, which is being led by a really fantastic graduate student at Harvard, Tridevi Chakma, who's been working with us to look at individual-level exposure to heat disparities.

We're doing work on wildfires, so wildfires themselves, which are-- exposure to wildfires is-- themselves-- is obviously a pretty rare event and only really tends to affect a relatively small number of individuals directly. But because of the scope of our data, we can really get into understanding exposure rates and differences at the individual level that one wouldn't be able to do as much with more aggregate data, but then also thinking about the distribution of wildfire smoke.

So wildfires have much broader consequences than just the fires themselves. I think, the last couple of days, San Francisco has been having the highest particulate matter concentrations all year-- that it's had all year as a consequence of the wildfires that are going on. And of course, no fires are actually happening in San Francisco themselves.

And I remember, last year, Charlottesville had-- had a real spike in particulate matter that ended up being, I think, something like two times above the World Health Organization's standard during the peak wildfire period. And of course, no wildfires are going on anywhere around Charlottesville, but I remember looking out the window and seeing that the air was very hazy. I was looking at the monitors and thinking, wow, that is a huge spike relative to what air pollution is normally like in Charlottesville, which is usually pretty low, and seeing-- going onto the satellites and seeing these huge plumes of smoke that were coming out of the West and being transported to the East Coast, which was just-- So understanding the distributions of those exposures at the individual level, as well, is great.

And I think, particularly in the context of wildfires, it really allows us to dig into our understanding of disparities for Native American populations because, normally, these populations tend to get missed in survey data or in aggregate geographic data because they're a much smaller share of the population. But with wildfires, they're a population that are, actually, pretty disproportionately exposed. And so, with the individual level data, we have the statistical power to really provide more comprehensive information on that. But yeah, so we do that descriptive stuff-- sorry.

MIKE LIVERMORE: Actually, why don't we-- we can go to the causal stuff in a second. But I thought it might be worth-- for folks who aren't as familiar with this stuff, to actually just get into the ecological fallacy for a moment, to just emphasize the importance of the work here, and how it is that drawing inferences from a population can lead you astray with respect to individuals. If there's an example or something in particular that you're looking at right now where you're hopeful, in some sense, that you can find that your new data and your new methods are going to help fine-tune or even improve or even disprove some earlier thoughts, some earlier findings.

JONATHAN COLMER: So one of the things that I can talk about, in terms of results-- a lot of our results-- a lot of our work is ongoing. And with this confidential data, there's many more results that I'd like to discuss than I'm able to because they haven't gone through the disclosure process.

But one example-- building on the work that we did in our 2020 science paper on air pollution-- is we wanted to understand things at the individual level in that context, too. And so one of the things that-- and you mentioned this earlier, in terms of the fact that people move.

And this gets into hypotheses about the causes of disparities. And we've talked about the fact that low-income individuals measured based on geographic information. So Census tracts that have lower median income tend to be exposed to higher levels of air pollution, and Census tracts with a higher population share that is non-Hispanic Black also tends to be exposed to high levels of air pollution.

Now, the question, in terms of the causes of those disparities, in a sort of Econ 101, very simple logic is, is it income, or is it racial discrimination or other considerations that are contributing to those disparities? And that question is pretty first order important because it has big implications for policy, of course, because, in all of this, we want more than good-- more than good intentions. We want to make sure we're allocating resources to actually address the fundamental problems that exist.

And if the disparities are income-- if the reason for the disparities are income-oriented-- i.e. the reason that disadvantaged communities are exposed to more pollution is because those communities are poorer and, therefore, they're sorting and selecting neighborhoods to live in which are cheaper to live in, in that world or that model of the world, environmental inequality is income inequality, and the way that you address it, then, is to target income.

But in the world that disparities are due to-- these disparities that are the result of more systemic institutional factors, like zoning and segregation and historical policies that have exacerbated broader racial disparities in the United States that we know and understand, then interpreting these disparities as being driven, simply, as low income is not going to address anything. And you can't get at that with geographic data because they're just inextricably linked. You don't have enough variation in the data to be able to separate these things out. But moving from a place-based to a person-based understanding, we can get closer.

And so one of the things that we see, in terms of this idea of understanding an ecological fallacy-- this aggregation bias-- is that, if you look at the relationship between, say, county-level or Census tract-level income and pollution exposure, you see almost a U-shaped relationship. So higher income areas tend to be more polluted-- the New Yorks and Los Angeles of the United States. And then lower income communities are also exposed to more pollution, and then there's lower average exposure in the middle.

But when you move to an individual level, the relationship is almost flat, almost flat. It's much less curved than at the aggregate level.

MIKE LIVERMORE: So which is to say there isn't a relationship.

JONATHAN COLMER: Which is to say that, in terms of the correlation between income and pollution, it's much weaker than would be inferred at the aggregate-- the geographic level. And the reason being is that it's really that these disparities in exposure or these differences in exposure are-- when we aggregate the information up, we're confounding low income and race. And it's really-- when you get to the individual level, it's the-- what's left is that there are these very large racial disparities in exposure, but not so much in terms of income.

MIKE LIVERMORE: And that;s a huge finding.

JONATHAN COLMER: We're still digging into this to better understand what's going on. And it's, again, still descriptive. But it's really fascinating to see that how sharply that relationship changes when you move from a place-based to a person-based understanding of these disparities.

MIKE LIVERMORE: Yeah, when that's all ready to go and goes out into the world as final work, that could really be huge in terms of the effect on the discourse broadly, and then within policy circles. But also, as you noted, the policy interventions that we would contemplate are just entirely different if what's, quote unquote, "really happening," if what's-- now, we're not saying causally, I guess, but you can start to try to draw-- you can add your descriptive-- these descriptive findings with a causal model of the world to think about-- well, if income and pollution exposure is just essentially flat, if there isn't a relationship there, then it's pretty clear that what is likely not happening is just income sorting into cleaner or dirtier places based on preferences and budgets

JONATHAN COLMER: Yeah, exactly. And one of the nice things with the data is that we're able to see people move, of course. And even just descriptive-- a really nice paper that Nathaniel Hendren and coauthors released a few weeks ago from the Opportunity Insights group at Harvard, who also use this type of data to engage in broader questions about economic opportunity and inequality, and consistent with some of the things that we see in the data-- people are very immobile. They don't move very much. I can't remember the exact number that the Hendren paper gives, but it's somewhere in the ballpark of-- I think the kids end up-- 80% of kids living in the same county as their parents when the kids are grown up.

I think, within academia, there's almost-- there's a cognitive dissonance with this as well because we're all pretty mobile. Yeah. Listeners may recognize my accent as being British. We move around.

Our priors, as to mobility-- this is-- it really gets at the importance of having the data in a systematic way to get at this stuff because the people doing this work are an inherently mobile group of people. And so it also highlights the importance of combining this quantitative work with research that's being done outside of economics, by sociologists and anthropologists, the qualitative work-- the people who are interviewing individuals on the grounds and trying to understand their lived experience of all of this. I think the complementarities between the broader descriptive facts that we're able to generate as well as the causal stuff that we can do more about-- but combining that with people's lived experiences and trying to reconcile those is incredibly important.

MIKE LIVERMORE: Right. Absolutely. And I think-- thinking about the quantitative, qualitative point here, something we've talked a little bit about in past episodes of the podcast is-- data is always going to be reductionist, right? There's only so many features that you're going to be able to pick up.

The issue that you're addressing-- we always get better data. So moving from aggregated Census tract-level down to individual level's a huge improvement in granularity and variation and everything else. But of course, data on-- data on income isn't everything. And even if you got data on health, that wouldn't be everything. And so there's always more richness that could be added, one way or the other.

JONATHAN COLMER: Definitely.

MIKE LIVERMORE: So yeah, just moving on to the causal stuff-- yeah, so that's-- so one bucket of research is in this descriptive area, and, in particular, using the individual-- the wonderful individual data level-- individual-level data that you have to examine some of these questions. So what does the causal bucket look like?

JONATHAN COLMER: Yeah, so if we stick with pollution for a little bit-- just because we're on a theme, in light of these disparities that we see in exposure, both aggregate and relative disparity, one of the cool questions that John and I were particularly interested in understanding was-- well, we see that there huge racial disparities in environmental exposure and exposure to pollution. There are huge racial disparities in terms of economic opportunity and inequality. How much of the environmental disparities do we think could possibly contribute to those broader patterns of economic opportunity and inequality?

And so this is an incredibly hard question to answer. But it is like-- it's a really important causal question. The causal question is, how much does environmental inequality contribute to income inequality, effectively? And so how one answers that question is very challenging because you need to know the causal effect of pollution on-- on economic opportunity and income outcomes, and so that's tricky.

But we have a paper that we released-- a working paper a while back and have been presenting it at various workshops and conferences this summer-- that starts by-- starts with the descriptors and just says, look, in the raw data, we see that there's a really strong correlation between the amount of pollution you're exposed to and your economic mobility in the United States. So if you are exposed to high levels of pollution, you're less likely to rise up where you are in the income distribution relative to your parents. And again, that's just descriptive. That's a correlational.

The big question, of course, is that-- well, as we know, areas that are more polluted tend to be lower income, tend to be more disadvantaged in a variety of ways. And so is it really the air pollution that's doing this, or is it other factors that are correlated with air pollution? And so what we do is we try and get closer to the causal effect of air pollution on income and economic mobility by taking advantage of the reductions in pollution that came about as a consequence of the Clean Air Act and, in particular, looking at areas that-- when the 1990 Clean Air Act amendments came into effect, came into nonattainment immediately because they had air pollution that was too high. So the 1990 amendments reduced the cap, as we've been-- the National Ambient Air Quality Standards for PM10 and NOx, which is an important precursor to fine particulate matter.

And so the day before the 1990 Clean Air Act amendments came into effect, these places were in compliance. And then the bar fell. And the next day, the law comes into effect, and now they've got to-- the pollution is too high, and they've got to, now, reduce pollution to come into compliance.

And so what we do is we compare individuals that were exposed to the reductions in air pollution in utero during that prenatal period, because we know the date of birth and locations of birth, so we can see people who are born just before versus just after the National Ambient Air Quality standard, and that gives us what we think of as this almost-- well, more, exogenous. It's a jargon word but--

MIKE LIVERMORE: External, right.

JONATHAN COLMER: Had set them outside of the model. We get this reduction in pollution, which is induced by the regulation, as opposed to the other more endogenous factors-- again, jargon-- sorry, but model-based factors. And comparing the kids that were born in these nonattainment areas to the attainment areas allows us to get these reductions in pollution and allows us to then look at how those-- so the kids who were born just after-- they basically experienced this very acute reduction because the kids born just before benefit from the reductions in late-- in childhood, but they didn't benefit from those reductions during the prenatal period. And so we have this extra year of Clean Air for the kids who are born just-- born after versus those who are born before.

And so what we see is that this additional year of Clean Air has really large effects on later life earnings-- age 30-- and economic mobility, the upward mobility measure I said-- where you end up in the income distribution compared to where your parents were. And so this gives us something which is a lot closer to the causal effects of pollution because we've got this-- if we do all of the variation in pollution that's going on, and lots of it's very nonrandom, we're trying to identify this slice of the pollution pie which is more random. And in doing so, that gives us more confidence that the effects of pollution on later life earnings that are coming from this slice of the pie are causal as opposed to correlational. Yeah, so we find these really large effects.

And then the rest of the project is really about-- OK, well, in light of having that estimate, we see that there are large disparities in racial exposure to pollution. At the individual level, if we look at disparities at birth for each cohort in terms of Black exposure to pollution in utero and white exposure to pollution in utero and then combine that with our understanding of the causal effects of in-utero exposure to later life earnings, how much of the Black-white gap in earnings at age 30 can be accounted for in just a simple descriptive sense by our understanding of the causal effects of pollution on earnings?

And we find it-- very large effects-- almost 20%, 25% of the Black-white earnings gap could be accounted for by Black-white disparities in pollution at birth, and that's a very big effect. And there are lots of simplifying assumptions that go into the back-of-the-envelope calculation. But even if we're off by an order of magnitude, these effects are meaningful. We're not suggesting that you take 25% seriously to three decimal places, but it just highlights that these disparities in pollution, given our understanding of the physiological effects that pollution has on child development and other considerations-- that this exposure really does have-- can account for a nontrivial amount of the economic disparities that we see.

MIKE LIVERMORE: That's a fascinating-- fascinating paper, fascinating work. Yeah, just to get back to some of our terms. I think, ultimately, you got at it and, you said what I always-- how I always explain this stuff to folks is, essentially, it's a quasi-random thing. So you're trying to delink the exposure from other of plausible things that are happening to simulate, in some sense, a randomized controlled trial.

So here's a question for you. I'm sure you've answered versions of this. I'm curious what you think about it.

So what's happening here is we've got two kinds of air quality districts-- ones that go into nonattainment as a consequence of the Clean Air Act and, therefore, where there will be pollution reductions. And then you're controlling, with the-- with the air quality districts that are-- stay in attainment, where the new law doesn't affect-- they don't have to make any additional investment.

JONATHAN COLMER: So the kids born before and after in attainment areas-- they're in compliance. Their air pollution isn't changing. So those kids are exposed-- there's no difference in exposure for the kids born before or after the 1990 Clean Air Act comes into effect in the attainment districts.

MIKE LIVERMORE: Got it. So you've got a 2 by 2. You've got born before the act in areas that were in attainment and stay in attainment, versus before that were in attainment and then move into nonattainment, basically, right? Yeah it's really interesting. Just curious your thoughts on this as a-- because 25% does sound like a huge--

JONATHAN COLMER: Oh, yeah. As I say, that's assuming that we're extrapolating linearly in terms of our understanding of these effects. And it's out of sample.

There's a lot of assumptions that-- the paper goes into it in a lot more depth. But it's a thought exercise. It's not like, this number is the truth, so let's start making bets on it. We take a lot of care to get at what we-- and identify the causal effects of prenatal exposure to pollution. But then we want to use that number to get a broader understanding of its potential contribution to these broader patterns of disparities that we see.

MIKE LIVERMORE: Yeah, it's really interesting. Just curious what you think about this, as a possible pathway or-- supplemental pathway, because we normally think of negative economic consequences for environmental policies, putting aside the positive environmental benefits. So it's costly to invest in pollution control.

And so, one-- assuming people don't move, which is a little bit of-- as you know-- putting that issue to the side for a second, we might think that-- as between areas that were kicked into nonattainment versus attainment, that there would actually be less economic opportunity in the places that were kicked into nonattainment because they had to make these investments in pollution control technology, which, then, some would argue is going to be a drag on their local economy.

And so I think there's a extra interesting finding here, which-- that doesn't seem to be the case. What you're actually finding is that-- or at least, with respect to this one population, that non-- that getting kicked into nonattainment is actually good from the perspective of, at least, reducing economic inequality or improving-- actually, improving economic mobility because you're looking at people moving out of their parents' income decile or whatever, right? So that's interesting.

One other thought that just comes to mind is-- it's a little bit down the road. Maybe it's possible that, when you kick an area into nonattainment, that actually creates jobs for the local economy, and there would be a difference in pollution exposure over time. But also, what's going on is there's some economic opportunity happening as a consequence of investment in air quality control.

JONATHAN COLMER: Yeah, so I think there are a couple of things to touch on here. Number one is that what we're identifying in terms of the effects of prenatal exposure to nonattainment is going to be the net effect of those competing channels. So if mom and dad lose their job because the factory gets closed down, that's a bad shock, but the reductions in pollution are a good thing.

Now, for the most part, our understanding of the effects of nonattainment-- in terms of the economic consequences of nonattainment-- Reed Walker's work comes to mind. I mentioned Reed as a coauthor of John and-- earlier. He's done great work to try and understand the economic costs of the Clean Air Act.

And for those in industries that were directly affected, it is costly. People do lose their jobs. There is displacement. They find new jobs. It's not a permanent shock. But there is an economic cost to that. But the share of the population that are directly affected is very small, like less than 0.7% I think is the number, whereas the reductions in pollution benefit everyone in the community.

And of course, what we were showing in the paper is, really, the benefits to those in-- who had not been born yet-- really, the people in gestation. But we see that there are benefits to people in early-- to kids in early childhood as well. And then those effects dissipate as you get older.

But really, the benefits of nonattainment have to be, obviously, compared to the costs. Economists have tended to historically overestimate or overstate the costs and underestimate and understate the benefits. And I think our understanding of the science over time, in terms of the effects of pollution, as well as the more recent work that we've been able to do, have highlighted the economic benefits of pollution reduction as well as the health benefits.

Touching on what you were saying about jobs being created within the economy, we don't have results on this, but people are healthier. They are earning more because they're more productive. And so the reductions in pollution benefits the local economy because workers are being more productive, and that means that people are earning more and that firms are earning more.

Indirectly, for the firms and the sectors that aren't directly affected as a consequence of nonattainment, there are larger benefits, I think. And there hasn't been a lot of work to accurately and precisely quantify this stuff. The suggestive-- the health benefits and the earnings benefits points to the fact that the benefits to the local economy as a whole I think far outweigh the costs to the facilities that are directly affected by the Clean Air Act.

MIKE LIVERMORE: Yeah, that's very interesting, and your comments there put me in mind of another distributional element of environmental policy, especially air pollution policy in the United States that is just probably under emphasized, which is-- and including within the economics field, so I'm curious your thoughts about this. But for decades, essentially, what we focused as the primary benefit of air quality improvements is reduction in mortality risk. And the reason that we do that, in part, is because we have some good data on it, and air quality investments are very well-justified, purely-- especially from the status quo-- purely on the basis of this mortality risk reduction.

But there's a very important distributional element to this, which is-- when you reduce mortality risk, you're saving lives. But the number of lives saved, actually, which is still large, but it's a relatively small group compared to the total population-- you might be reducing our risk for a very large number of people. But if it's a 1 in 10,000 risk or 1 in 100,000 risk, the actual people that you're helping are the folks who would have that risk be realized, who would die as a consequence of the air pollution.

And so we've been focusing our estimation of the benefits of pollution control on a category of effects that are inherently very concentrated. They're very extreme, but they're very concentrated. They're not widely shared, in some important sense, whereas the work that you're doing is really focusing on effects that are much more widely shared, even if, for any individual, a small change in your income is much less important than dying or not dying, obviously, but it's spread over a much larger population.

JONATHAN COLMER: Yeah. So mortality has traditionally been a relatively easy thing to measure. I think, more recently, people are doing been doing work on morbidity as well, so less extreme measures of health. But the mortality effects are hugely important, even by themselves.

In terms of work that the EPA has done in terms of cost-benefit analysis of the Clean Air Act, the benefits in terms of mortality are very large. The infant mortality effects are large, the effects on older populations as well, although I think there's a lot of scope to do-- again, more nuanced and refined work in this space, to build on the existing work.

But yeah, the-- I think the takehome in recent years is that the effects of pollution have, just, far broader effects than health alone, and income isn't everything, as we've discussed. Our measures of income don't, for example, get at the reductions in health spending that people benefit from. They can spend their money on other things as a consequence of being healthier.

But I think the fact that we see these broader patterns as well just go further to effectively add to the benefits column when we're thinking about the gains from improving environmental quality. Yeah, as you say, the main motivation behind a lot of the Clean Air Act was not just mortality, but also just recreation and amenities. People don't like looking at smoky, dirty factories and don't like dirty water.

So yeah, the earnings effects, the productivity effects have largely been beyond the look. That does have a real implication for this inherent trade-off, which is pushed, the environmental regulation kills jobs kind of narrative, where it's industry versus people. But it's not really the case because very many workers benefit and many firms consequently benefit hugely from reductions in air pollution because workers are more productive. They're healthier. So I would go as far as to say that, certainly, on average, I would think that the environmental regulation saves firms money more than it costs.

MIKE LIVERMORE: Especially when-- if you think of worker productivity and all of that, absolutely, a healthier, more productive workforce is never a bad thing.

JONATHAN COLMER: No, absolutely not.

MIKE LIVERMORE: Well, Jonathan, I really appreciate you taking the time to chat with me today. It's just incredibly interesting and important work, and I appreciate you-- you doing it and sharing it with us today.

JONATHAN COLMER: Thanks for having me. It's been great talking to you.

[MUSIC PLAYING]