ECONOMICS OF CLIMATE CHANGE – MACRO COSTS

Lesley has just outlined some pretty grim situations where climate change is causing all kinds of damage – whether from flood, fires or otherwise – resulting in significant costs that are unplanned, unmanageable, and regionally concentrated, affecting both the private and the public sectors in the US.

I have been charged with looking at the toll climate change might take on the global economy – and then using that information to look at how to perform cost-benefit analyses for mitigation investments, and how we might affect consumer behavior with policy measures such as a carbon tax or cap-and-trade.

THE ISSUE

So first off, we need to establish one thing: climate change is an ECONOMIC problem. (Remember, I've been saying all things come down to economics for years now, and once again…!) The reason it is an economic problem is that ENERGY (the creation of which leads to carbon emissions) DRIVES ECONOMIC GROWTH and economic growth leads to even more carbon emissions as people drive cars, fly in airplanes, heat and air condition houses, etc. Zero economic growth would greatly limit threats from warming. But this is tricky – who among us would like to give up her car, her HVAC system, her computer and phone? And who would deny people in developing countries the ability to achieve a higher standard of living? Yet if carbon emissions keep going as they are, what sort of standard of living will we have in the future?

In addition, economics is all about INCENTIVES and human behavior (remember it is a social science!) so in this case, how can we provide the right incentives to change human behavior and limit climate change?

You may recognize the name William Nordhaus – he just this fall won the Nobel Prize in economics for his climate modeling. Fortunately for me, my economist father-in-law had already sent me his book, Climate Casino, on which I will rely heavily for this presentation, both because of the Nobel and because his book made sense to me. The other economists I followed whose names you may want to know are

- Nicolas Stern, a British economist who prepared his seminal "Stern Review: The Economics of Climate Change," 600+ page report on climate change in 2007.
- Richard Tol, author of "Climate Economics," and
- Michael Greenstone and Gary Becker, both from the eponymous Becker-Friedman (as in Milton) economics research institute at the University of Chicago

So getting back to how economic growth and climate change are related. Virtually everything produced requires some amount of energy, most of which is currently derived from fossil fuels.

Nordhaus starts his book laying out the nature of the problem by relating economic growth and carbon emissions, which he calls the "**carbon intensity**" of the economy. He points out that the US economy has grown on average 3.4% annually over the past 80 years (wow). The good news is that during that time our carbon emissions per unit output of GDP has actually declined, by about 1.8% on average each year. This is the result of using less energy to produce most items, whether a t-shirt, milk or a phone call. Plus our economy has shifted to less carbon intensive products like electronics and technology, and our sources of energy are less reliant on high carbon fossil fuels like coal.

The bad news is that, though our “carbon intensity” has declined, it has not gone down fast enough to reduce total carbon emissions. In the US, emissions have grown on average 1.6% annually (3.4 - 1.8) over that same 80 year time period. For the world, global output has grown 3.7% annually while carbon emissions have become 1.1% more efficient each year – leaving a 2.6% annual growth rate in carbon emissions. In a nutshell, countries around the world are growing rapidly, and they are using carbon-based resources such as coal and oil as the main fuel for the economic growth. The efficiency of energy use has improved over time, but the rate of improvement is insufficient to total emissions from growing.

These carbon emissions are what economists call an EXTERNALITY. When we burn fossil fuels, we inadvertently emit CO_2 in the atmosphere, and this leads to potentially harmful impacts. It is called an **externality** because those who produce the emissions **do not pay** for that privilege, and those who are harmed **are not compensated**.

For example, when you buy a head of lettuce, you pay for the cost of producing it, and the farmers and retailers are compensated for their efforts. But when producing the lettuce require the combustion of fossil fuels – to pump the water that irrigated the lettuce field or fuel the truck that delivered the lettuce – the cost of the carbon emitted in the growing and transporting process is not covered. We’ll talk about that more later…

Economics teaches one major lesson about externalities: markets do not automatically solve the problems they generate. In the case of harmful externalities, *without regulation*, markets produce too much because there is no cost associated with the external damages from emissions. (e.g. sulfur dioxide/acid rain or the CFCs and the ozone)

And climate change is the mother of all externalities because it is (1) GLOBAL, caused by people around the world in their everyday lives, not just one company or industry that could be targeted with regulation, AND (2) its effects will not be truly known for a very LONG, LONG TIME. Global externalities are particularly tricky because there is no economic or political mechanism to deal with them.

This is where we get into the game theory issues that Cindy raised – and the prospects of FREE RIDER problems. Where we are best off doing nothing and letting everyone else adjust their carbon emissions (translation: lower standard of living) but if every country takes that view, then we all lose. If each and every country participates, then we are all better off.

ECONOMIC EFFECTS

So what effects will this externality (carbon emissions) have on the economy in the future? Recapping what we know about climate change, there are of course all the weather-related disasters that have to be cleaned up as Lesley just told us – floods and fires cause billions in damages, displace people, and ruin natural habitats. Droughts and floods can disrupt food supplies. In addition, excess heat reduces labor productivity, as people are unable to work as hard or as long in extreme heat. Heat can also produce adverse health effects with dehydration and death as well as increased incidents of tropical diseases (and Mary will tell us more about that in our next meeting). All of these things will affect economic output in the future.

Given all this, what sector of the economy would you expect to be hit the hardest?

Correct – agriculture, along with fishing and forestry. Does anyone know how much these industries contribute to the overall US economy? Would you believe only 1.2%? Other sectors that might be considered “moderately impacted” by climate change include transportation, construction, utilities and coastal real estate, which together account for another 9.0% of the total US GDP. That means that about 90% of the US economy would be only slightly if at all impacted by climate change.

The economies in developing countries are much more reliant on the contributions of agriculture to their GDP. Check out this graph from the Nicolas Stern’s major climate study in 2007, which relates per capita GDP to percentage contribution of agriculture. You see on the left developing countries, mostly in Africa, and on the right, developed ones. Clearly, the developing nations will be hit doubly hard by climate change as more of their economies are tied up in agriculture AND they have fewer resources to deal with climate problems.

But the good news is, that like the US (which has seen the share of farming, fishing and forestry plunge from 9% in 1948 to 1% now), even developing countries are reducing their dependence on these industries. Farming is becoming more efficient and more and more people are moving to cities and entering industry and service businesses. From 1970 until 2010, the share of agriculture in low- and middle-income countries fell from 25% to 10%. Of the 166 countries for which the World Bank provides data, only 4 of them show a rising trend over the past 40 years (Zambia, the Congo, Sierra Leone, and Central African Republic).

ECONOMIC CLIMATE MODELS

Climate economists take all of this sector information into account when constructing the INTEGRATED ASSESSMENT MODELS used to predict how climate change could affect the world economy. The models take different scenarios for economic growth, the emissions that would create, the climate change that would result and its impact on the economy.

These models have actually been hugely controversial. The biggest reasons being (1) the COMPLEXITY associated with projecting so many sectors in so many countries, and (2) mountain of UNCERTAINTY associated with looking so far out into the future. I used to model company projections for work to look at how different events might affect their ability to repay debt. The only thing I knew when I was done is that the projections were wrong – and that was only one company for a 5-10 year period. And of course economists are trying to forecast effects climate change in 2100, 80 years from now. How can we possibly know what external shocks (like a financial collapse) may be felt along the way, or what technologies might be influencing the economy, and when all these things might happen? Besides which, we do not know how humans may adapt to the challenges of climate change. Many of those changes are likely to occur in a very different world when you consider the pace of change in technology.

Not only that, but when modeling the economy, we can only account for the conventional marketplace, that is, the goods and services that make up the GDP. Yet, the most damaging effects of climate change will be in what economists call UNMANAGED and UNMANAGABLE SYSTEMS – in particular, things like sea-level rise, hurricane intensity, ocean acidification and loss of biodiversity, all of which are hard to put numbers on. Add to this, potential tipping points like melting glaciers and reversing ocean currents. How can these non-monetary effects be factored into economic models? These impacts are hard to quantify in economic terms, and hard to manage from an economic or engineering perspective…

Another criticism of the models is that, we really can't even produce a realistic base case off to compare mitigating scenarios to see how much we save.

All that said, the long-term nature of the problem is not likely to *ever* give us enough *current* information to make decisions before it is too late to prevent the effects we predict, so people continue to model the economic effects of climate change to at least provide a launching point for policy discussions.

For example, you may have noticed that, the day after Thanksgiving, the US National Climate Assessment report came out – just in time for me to have figure out what it said! ☺ There was great fanfare and headlines, even in the WSJ, that 100s of billions of economic losses will result from climate change. This is true – the model did predict this, but many of the articles didn't put that result in context so let me do that for you.

In the worst case scenario of 8.5˚F (4˚C) warming, the Assessment expects damages in all aspects of the economy to total just over $500B by 2090 – yes, hundreds of billions of dollars, which at face value sounds huge. It includes assessments for things difficult to monetize like loss of biodiversity

AND the context should be looking at what the economy will look like in 2090 and then assessing the projected damages against that. The US GDP in 2017 was $19.4 Trillion (with a T). Assuming 2% average annual growth through 2090 (compared with 3.5% for the past 40 years), the US GDP would be about $82T, or about 4x what it is today. $507B is only 0.6% of that size economy, and that is without any adaptation or mitigation that would likely reduce the scope of damages.

Nordhaus similarly concludes that the climate-related damages to the economy are only about 1% many years into the future. (The Nordhaus model is called the DICE model, which stands for Dynamic Integrated model of Climate and the Economy. I tell you that only because you may see it in your readings since he just won the Nobel…) He includes some information from other economists' models and they are similar, ranging from 1-5% over the span of decades.

What this means is that, the costs of climate change are actually projected to be negligible, from a purely MARKET ECONOMIC perspective. In fact, according to the IPCC report, the first 1 degree of warming may even have a positive effect on the world economy as crop yields increase with "carbon fertilization" (until drier conditions start in with lower snow pack melt and longer warm spells).

From Steve Koonin, undersecretary of energy for science during Obama's first term:

> Human induced climate change isn't an existential threat to the overall US economy through the end of this century – or even a significant one. Changes in tax policy, regulation, trade and technology will have far greater consequences for Americans' economic well-being. There are many reasons to be concerned about climate change, including disparate impact across industries and regions. But national economic catastrophe isn't one of them.

Similarly, WSJ columnist Holman Jenkins says:

> A sizable portion of human economic activity since hunter-gatherer times has been devoted to mitigating climate risk, from the creation of clothing, shelter and fire, to the invention of sea walls, storm drains and insurance. With the arrival of the theory of man-made warming came the opportunity and perhaps imperative to consider applying these costs to altering climate directly. But you would have to know which steps are worth taking.

ASSESSING MITIGATION INVESTMENTS / COST OF KEEPING TEMPS LOWER

Since there are still lots of reasons to address climate change, how do we evaluate various mitigating investments? We need to do a **cost-benefit analysis,** to compare the cost of the investment and the cost of the damages that would have been incurred without the investment in the future.

Any consideration of the cost of meeting climate change objectives requires confronting one of the thorniest issues in all of climate-change economics: How should we compare present costs and future benefits? If we are told a given investment today will provide a $100M benefit 50 years in the future, how much would we be willing to pay for that today? The answer lies in the use of **discount rates**. The basic premise is that money today is worth more than money tomorrow, so I have to DISCOUNT tomorrow's benefit to make it into an equivalent amount today.

Let's take an example. Suppose I could spend $10M today to build a wind farm that would save $100M in climate change damages in 50 years. Would it be worth it? Using a 4% discount rate, $100M in 50 years would be worth $14.1M today – more value than the $10M investment so yes, it would be worth it. But if the discount rate were 7%, the present value of that future benefit would only be worth $3.3M, far less than the $10M investment required. You can see why the choice the discount rate can have profound implications.

So what is the appropriate discount rate? There are two schools of thought. (1) One is the simple concept that capital is a scarce resource and can be employed in many different ways, and that climate investments should compete with investments in other areas. (2) The other school of thought, espoused by Nicolas Stern, is that it is unethical to discount the welfare of future generations and therefore a discount rate of only 1% would be appropriate.

Looking at our chart, we can see that with such a low discount rate, future dollars are worth almost as much today as they would be years into the future so any investment today is well worth it for the future benefits.

Nordhaus differentiates between discounting *goods,* which applies to things like houses or energy spending, and discounting *welfare,* which applies to the treatment of people of different generations. When evaluating investments to mitigate climate change, he argues that we should discount future benefits based on the rate of return that could be earned on alternative investments. Nordhaus believes 4% is right for the US, with a slightly higher rate for the rest of the world.

Societies have a vast array of productive investments from which to choose to help combat or cope with climate change, including new low-carbon technologies, technologies to help low-income countries, health care research to combat tropical diseases and education to prepare the workforce. All of these will help coming generations but will have to be evaluated based on today's cost versus a future estimated benefit. This is the process by which all of the investments (like different power sources and green building) that will be outlined later in our program should be evaluated.

Taking the one-investment-at-a-time analysis and aggregating it, Nordhaus uses his DICE model to assess what fraction of the world economy would need to be devoted to investments mitigating climate change in order to reach certain emissions-related goals. He concludes that the cost of keeping average temps from increasing more than 2˚ would be 1.5% of the world economy – and that assumes UNIVERSAL PARTICIPATION, 100% of all carbon emitters, and EFFICIENT REGULATIONS rather than some hodgepodge of special interest carve-outs. Both seem like difficult requirements to be met at this point.

SOCIAL COST OF CARBON

So what economic policies are actually in place to combat climate change at this point? Putting a PRICE ON CARBON EMISSIONS has been the primary economic tool that governments have been able to implement to date. In this way, they are accounting for that EXTERNALITY in the price of carbon-intensive goods. (Remember that the producer does not pay to for the polluting privilege and those affected to do receive compensation.) In order to put a price on carbon, which economists try to calculate an estimate of the economic damages caused by an additional ton of carbon emissions, in a given year. This is called the **"social cost of carbon."** It is the present value of future damages in agricultural productivity, human health, property damages from increased flood risk, the value of ecosystem diversity, and other impacts caused by a changing climate. Estimates of SCC range widely.

In an editorial, Cass Sunstein commented that estimating the social cost of carbon was a “laborious and highly technical process” and I have to say, I read, or tried to read, articles discussing how different prices were reached and why there was so much disparity, etc. so I could explain it here but… nope. I decided that I would just hone in on the upshot, which is that when evaluating the benefits of damage avoidance in the future, the price of carbon needs to be high enough to provide an INCENTIVE to polluters to switch to less carbon-intensive forms of energy. In 2017, a group of leading economists known as the High Commission on Carbon Prices concluded that carbon prices would have to be between $40-80 per ton by 2020, increasing over time, in order to achieve the emissions cuts called for by the Paris Climate Accord.

Interestingly, the Obama administration used $36 – 45 per ton (depending on the time frame) as the official social cost of carbon when evaluating various regulations, subsidies, etc to combat climate change. The Trump administration uses $1 - 6 per ton. How can they be so different? First off, the Trump administration considers only the damage to the US while Obama used global damages. It is actually standard for the US government to use national effects in cost-benefit analyses. But, arguably, it makes more sense to use the global number here because carbon emission impacts are global, unlike other pollutants that have almost entirely domestic consequences. The other big difference is the discount rate used. Where Obama used 1, 3, and 5% rates, Trump uses 3 and 7%, and you can see in our chart that the higher the discount rate, the more difficult it is to justify investing today to save 80+ years from now. So, the Trump administration has used the lower present value of savings from mitigating climate change to justify cancelling programs under the Clean Power Act as no longer cost-effective.

This low number is also the cost that the market, so far, has given to the social cost of carbon. This is seen in how emissions permits trade around the world. According to Stanford professor Jeffrey Ball in a FA article, of the global emissions now subject to a carbon price, just 1% are priced at or about the $40/ton floor recommended by the Commission, and ¾ are priced below $10/ton. As a result, well under 1% of world emissions are subject to a carbon price that can make an environmental difference.

POLICIES

How are carbon prices used to influence policy? Nordhaus reminds us that economics is all about creating INCENTIVES to influence human behavior.

He notes that there are 3 primary drivers of carbon emission growth:

- Increasing population;
- Improving standards of living; and
- The carbon intensity of the economy.

It seems highly unlikely that any policies could be enacted on a universal basis to limit population growth or stop improving worldwide standards of living. Targeting the carbon-intensity of the economy is the most common sense area to look at policy improvements.

There are two primary policy choices that both involve putting a price on carbon emissions in order to account for the cost of the carbon: a "cap-and-trade" approach and a tax on carbon. According to the World Bank, 42 countries and 25 subnational jurisdictions have imposed or are pursing a price on carbon through one of these means (but representing only 15 of global emissions because only certain sectors covered).

Under the CAP AND TRADE approach, a regulatory body puts a cap on the overall amount of carbon emissions allowable and issues permits to polluters, ideally for some amount less than they are currently polluting. Companies are given a certain number of allowances to cover their emissions, which they can sell if they find they don't need them all. And, if they need more allowances because they emit more than their allocation, they can buy them in the open market. The "cap" on the overall emissions falls over time, encouraging members to switch to cleaner fuels and cut emissions. Cap-and-trade therefore provides financial incentives for companies and/or industries to

- invest in cleaner technologies and sell their extra permits to heavier polluters OR
- they will have to purchase more permits in the market OR
- they are subjected to heavy fines for excess pollution.

Several economists, including Nordhaus, believe that a straightforward CARBON TAX is a more straightforward way to provide humans and corporations with the incentives to reduce carbon emissions.

For most people, science is not going to change the way that we live our lives – what cars we drive, how we heat and cool our homes, the food we eat, etc. BUT economic incentives certainly may. Think back on the cost of long-distance calls – how many of us waited until the evening to make phone calls in the "off" hours saving 35%, or even 60% if we waited until after 11pm. I know I did! A carbon tax could work the same way, making carbon-intensive power more expensive (covering the cost of the externality) so that people and manufacturers will be less inclined to use it. Similarly, with carbon-intensive energy more expensive, there will be market incentives for inventors and investors to develop new low-carbon technologies and bring them to market.

Remembering that the two most important factors in having a chance to reach climate goals around limiting warming were <u>efficient policies</u> and <u>universal participation</u>. The imposition of a WORLD-WIDE carbon tax is one way to make sure that policies are implemented efficiently and not with the hodgepodge of special interest carve-outs that inevitably result when negotiating laws. To get to the free rider problem in prisoners' dilemma, Nordhaus suggests that import tariffs could be imposed on the products and services of nonparticipants – again, providing economic incentives to encourage participation to achieve the end goal of slowing climate change.

There is some discussion as to whether that tax should be assessed at the point of purchase, like at the gas station for each gallon of gas, which would drive home the point to consumers, but make administration more challenging – OR – assessing the producers at the point of manufacture, like at the power plants, to greatly narrow the number of entities from which collections must be made.

Politically, there is much talk about making a carbon tax "revenue neutral" so that all revenues collected reduce the tax burden from sales or income taxes, or go directly back to consumers in the form of a tax refund. This makes the imposition of the tax more digestible to those that want to make sure it is not just another way of growing the government budget and/or those who do not want the government "picking winners" by subsidizing certain industries like electric vehicles or wind and solar power.

What are the advantages and disadvantages of each of these policies?

Carbon taxes would be better because:

- Carbon taxes are likely easier to administer because every country uses taxes, has the institutions in place to collect, etc.
- Carbon taxes mean real revenue for the government to pass along to consumers, reduce debt or pay for programs. Cap and trade could also produce revenues if the permits are auctioned off, but in many cases they are given to the polluters for free in order to placate them for their political buy-in.
- Cap and trade can lead to significant volatility in prices, so the intended effect of making carbon expensive may not result, as Prof Ball pointed out.

BUT the benefits of cap-and-trade would include

- A real cap on emissions. With a carbon tax, there is no cap on emissions so the quantity is uncertain. You may not get the benefit you seek.
- Cap and trade may be more politically appealing and more durable. Environmental laws tend to have staying power. Taxes are difficult to enact and easy to cut so could be more subject to the political winds of the day.

CARBON PRICING IN ACTION

Where are carbon prices used today? The EU, China, California and the NE US have all used a form of cap-and-trade. The EU was first and started their "Emissions Trading Scheme" (ETS) in 2005. It is the largest market and the one on which 45 other systems around the world are patterned. The ETS covers about half of the EU's total carbon emissions.

Unfortunately, the system has not worked out as envisioned though changes were made earlier this year, which should make the system more effective. What happened was that too many permits were issued in the early years, all for free, and then the financial crisis hit and output declined so companies did not need all of their permits. This left a glut of near valueless permits in the market. At the end of 2016 there was a 1.7 billion ton surplus of allowances on the market – the equivalent of a whole year's worth of emissions covered by the scheme – & allowances were trading at < 5 euros/ton.

Earlier this year though, they agreed to cancel a portion of the excess reserves every year beginning in 2019. This will significantly reduce the supply of permits – by an estimated 3 billion tons of emissions, or about 2 years worth in 5 years – and put further pressure on the industries covered to reduce emissions. Prices have risen from less than 5 euros per ton to more than 18 already.

China recently launched a national carbon market to cover emissions from power plants, 65% of which are coal-fired, which generate 3.5 billion tons of carbon emissions each year (2x the EU market and 10x california's but only about 1/3 of China's total emissions). China has done pilot programs in 5 cities and 2 provinces to help policy makers work out allowance allocation, emissions monitoring and verification issues. (Carbon there has traded between $3-10 per ton.)

How effective has cap-and-trade been at reducing emissions? The Environmental Defense Fund, which helps various jurisdictions set up cap-and-trade programs (and therefore has a vested interest in their success), says that EU "emissions from stationary structures" are down 26% since their program started. They also claim that, after CA began it's cap-and-trade program in 2013, emissions from the companies covered declined 8% in the first few years. But an article I read said that this is largely because of increased use of alternative energy sources mandated by the state. CA's carbon price was only about $15 per ton because of the extra permits that resulted.

On the carbon tax front, in Nov, Washington state voters overwhelmingly rejected a carbon tax initiative on the ballot and no state yet has one. A number of countries in the EU instituted carbon taxes after feeling like the cap and trade system wasn't effective enough at reducing emissions.

British Columbia instituted a truly revenue neutral carbon tax in 2008 – fuel taxes were instituted but income taxes were reduced to offset the additional costs, and a portion of the tax revenues went to offset heating costs for low-income families. Emissions declined 17% during the first 5 years but it is hard to say how much of that related to the tax and how much was the recession. Regardless, Canada thinks it a success and is now discussing carbon taxes in all of its provinces.

CONCLUSION

Is carbon pricing working? In his FA article, Jeffrey Ball basically bashed carbon pricing as ineffective for the reasons mentioned – too many permits, not priced high enough, not covering enough polluters, etc. On the plus side, carbon pricing has gotten some governments and companies used to the idea that they will have to incorporate decarbonization into their economic decision making. But, on the other hand, he says that carbon pricing has yet to cut emissions any meaningful amount, while at the same time, it is giving the major players, and maybe us, the illusion that we are dealing with climate change. Instead, he believes we need a whole host of regulations like phasing out coal, developing carbon capture technology, maintaining nuclear energy, raising fuel prices, etc. in order to have meaningful impact on emissions. We look forward to exploring these options this spring as laid out by the program committee!