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The Role of Economics in the Fight Against Climate Change

Introduction

Since 1800, the human population has ballooned. After taking all of human history to reach one billion people on Earth, the last two centuries have produced a more than seven-fold increase in humanity's population (Roser). As population growth snowballed and nations industrialized, demand for natural resources shot up as well. The pressure that a swelling population places on humanity's limited resources was famously studied by economist Thomas Malthus, who observed the fact that "while the number of mouths grows geometrically, the amount of cultivable land grows only arithmetically" (Heilbroner 42). In other words, humans can expand their population faster than the Earth can accommodate. Malthus' warnings about overpopulation may not have been borne out in the agriculture sector, but the ever-growing "material consumption" of humans has caused an "acceleration of threats to biodiversity" (Sher and Primack 4).

These threats to the natural world are both wide-ranging and closely related: habitat loss, pollution, climate change, invasive species, and overexploitation of natural resources. As conservation biologists remind us, "threats to biodiversity directly threaten human populations as well because people depend on the natural environment for raw materials, food, medicines, air, and the water they drink" (Sher and Primack 5). Economies around the world are deeply intertwined with the natural world and its products. For instance, timber and wood products are estimated to yield a value as high as $2.6 trillion per year to the global economy (Sher and Primack 69). Beyond the high economic value of natural resources, environmental economists must also contend with implicit values humans derive from ecosystems themselves, such as hurricane protection that bayous and seaside forests provide to coastal cities. Finally, there are benefits that are much more difficult to pin down. How would Adam Smith account for the enjoyment that people receive from a hike in the forest, or a fishing trip on a nearby lake? Does the lumberjack stop cutting trees for his business because everyone else's weekend campouts are more valuable? Incorporating the full value of the natural world into economic models and calculations is difficult because of the myriad ways that humanity interacts with and depends on the biosphere.

The challenges economists face when dealing with environmental problems are made more difficult because of the slow-moving disposition of the threats to the planet. Nowhere is this more evident than in the fight against climate change, whose full effects may take decades to appear. At this point, the evidence for climate change's existence is overwhelming. Analysis of air bubbles in Antarctic ice cores shows that, 1) Atmospheric levels of CO2 have increased proportionately to increases in human emissions, 2) In the 800,000 years for which ice core data can account for, Earth's atmospheric CO2 level has never been nearly as high as it is today, and 3) Increases in so-called "Greenhouse Gases" cause corresponding increases in global temperature (Sher and Primack 133).

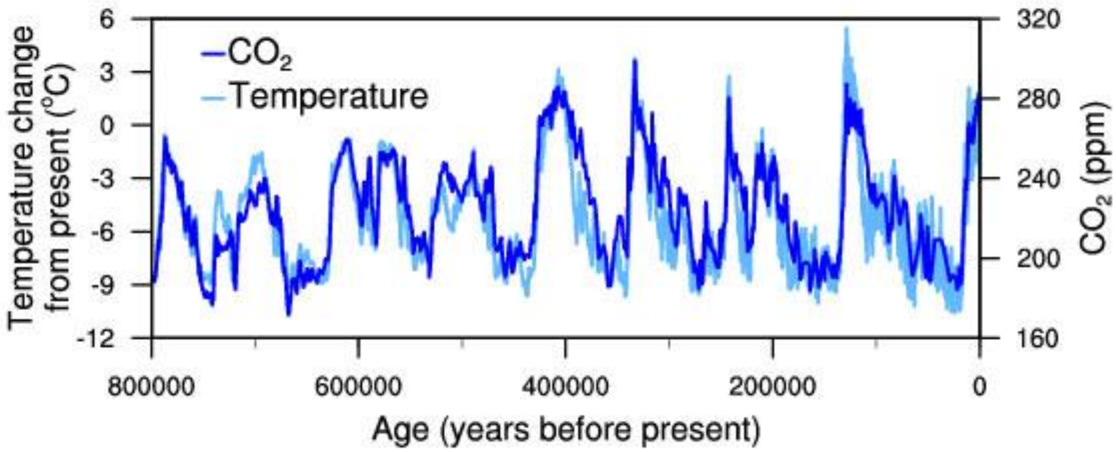

Figure 1 Global Mean Temperature tracks closely with atmospheric CO2. It is worth noting that this data for CO2 levels only goes up to 2008. Atmospheric CO2 is now over 400 ppm (NOAA).

However, the "cascading effects" of increased temperature are not yet apocalyptic. Over time, rising sea levels and greater frequency of catastrophic storms and weather events have the potential to cause billions of dollars in damage and create millions of climate refugees (Sher and Primack 134; Stern 122). In an ideal market, costs and risks this enormous should persuade rational decision-makers to reduce activities driving climate change. But this has not happened, at least not on a scale large enough to substantially reduce emissions or mitigate other forms of environmental damage. Climate scientists may be able to explain the dire situation of the planet in visually appealing graphs, but scientific data alone cannot address the human behaviors that are causing climate change. This is where policymakers can turn to economics to fully understand and, hopefully, solve this threat to the planet.

The Role of Economics in Climate Change

Like many other human crises, climate change has economic causes and effects of its own. Using economic analysis to determine why free markets have produced such a perilous situation for humanity in the first place is important to developing market-based solutions to climate change. Although economic tools have been used in environmental policy for decades, the economic elements of climate change were most famously summed up in the 2006 Stern Review, a 700-page report produced by Lord Nicholas Stern for the British government. Calling climate change "the greatest market failure the world has ever seen," Stern argued that the costs of allowing climate change to continue unchecked are so high that firms and governments have little choice but to immediately adapt aggressive policies to combat it (Stern 4).

Stern's landmark report was somewhat controversial among economists, although even many of his critics ultimately agreed with the Review's overall conclusion, noting that "mainstream economic models definitely find it economically beneficial to take steps today to slow warming" (Nordhaus 201). A 2008 review of the literature on climate change economics found that in "all these studies, efficient [emissions] abatement paths start relatively modestly and then increase over time" (Mendelsohn 46). Critics disagreed with Stern's assumptions of discount rates when weighing the short-term GDP costs of emissions reduction policies against the future damages of climate change. Those assumptions powered Stern's recommendation for "aggressive near-term mitigation" policies to cut emissions and halt climate change (Mendelsohn 58). The broader economic consensus on climate change may not endorse the high short-term costs of Stern's policies, but the literature agrees that climate change is a serious, long-term threat to humanity.

Furthermore, the disagreement over policy recommendations is one of degree. Economic analysis shows that stopping climate change means correcting the market failures that spawned it (Nordhaus). If deficiencies in the market have created conditions where firms are not properly disincentivized from damaging the environment, then Stern and his critics both propose policies that correct these market failures and push the economy towards a more sustainable future.

As Stern and others have pointed out, the "core" market failure driving climate change is the "greenhouse-gas externality" (Dietz et al.). On one hand, this is a fairly classic externality, where companies creating the emissions do not pay the full cost of the vapors they release into the atmosphere. In other words, the "adverse effects" of carbon emissions are "external to the market" (Dietz et al.). However, there are several aspects of climate change that make it more difficult to address than other externalities, including its global scope, its long-term consequences, the difficulty of estimating its economic impacts, and the "serious risk of major, irreversible change with non-marginal economic effects" (Stern 68). The sheer magnitude of the climate change externality makes it not only an unprecedented threat in an economic and existential sense, but even more difficult to slow down or reverse.

Beyond the externality associated with greenhouse gas emissions, there are several other market failures to consider. First, there is a sort of externality-within-an-externality problem when marshaling the international community to fight climate change. Stern writes that the impacts of climate change are not distributed equitably, meaning "poor countries…suffer the most, notwithstanding that the rich countries are responsible for the bulk of past emissions" (73). As seen in the United States, it can be difficult to raise political support to solve a problem whose consequences seem far-off and intangible. More industrialized countries may be reluctant to internalize the costs of their economies' emissions since they are not feeling the impacts as strongly as poor nations.

Next, there is a general failure of imperfect information when it comes to climate policy in the market. Firms simply may not be aware of the options they have to reduce their carbon footprint or incentives for innovating more efficient technology (Dietz et al.). Finally, because of the fact that curbing emissions requires change in a number of diverse, interconnected industries, any one of these smaller markets may suffer from market failures of its own. Stern specifically covers the aviation, energy, manufacturing, agriculture, and transportation sectors in his report (383-387). All this amounts to a predictable conclusion: that climate change as an economic problem is vast and extraordinarily difficult issue for policymakers to untangle. A whole paper could be written about the complex nature of climate change's associated market failures and their impacts; Lord Stern wrote 700 pages. However, this report will focus the remainder of its attention on the solutions that economics can produce for solving climate change.

Solutions to Climate Change

Based on the scientific data, the key to stopping climate change is lowering emissions. Policies that aim to achieve this goal have several criteria to consider:

Criteria One: A policy should address the Greenhouse gas externality or other market failures by providing incentives for firms to reduce emissions, whether that be through carrot or stick.

Criteria Two: A policy should spur the economy toward innovation of "clean" technologies to boost sustainability and output over the long run.

Criteria Three: A policy should not impose such high short-term costs that it creates broader problems for the economy or precludes the political support necessary to enact the policy in the first place.

The next few sections of this paper will address several policy prescriptions for reducing emissions, and evaluate their pros and cons based on the above qualifications. Over the past few decades, different policy tools have been enacted with varying degrees of success. No single program could solve the various environmental challenges facing governments today, so understanding the specific situations in which each type of policy would be optimal is a useful starting point for policymakers.

Command and Control

Command and control ("C&C") policies, also known as the traditional regulatory approach, are the historical standard for governments dealing with environmental problems. C&C programs simply set a quantifiable standard for a pollutant that firms are legally required to meet. Although not as trendy as market-based solutions, a C&C approach can be useful when dealing with a narrow, urgent issue, such as the EPA's bans on chlorofluorocarbons or DDT pesticide ("Economic Incentives"). C&C policies automatically pass Criteria One because they remove the need to "incentivize" firms to do anything; firms either reduce their pollution to meet the standard or face legal penalties. However, the heavy-handed nature of traditional regulations makes a strictly C&C approach to climate change unrealistic, given that it would likely be politically unpopular in the U.S. Furthermore, as observed in other economies or sectors where a centrally planned approach is used, the economic losses are higher when a C&C method is used instead of a market-based policy (Moran 74). Economists generally agree that market failures are responsible for climate change, but studies have still shown that "even where externalities are dominant, market approaches may allow the lowest cost means of reaching the desired solution" (Moran 74). This means it is more efficient to introduce a market-based policy instrument that "internalizes" the costs of an externality rather than cripple all companies that pollute with strict regulations.

The inefficiency of large-scale C&C policies means they are often too unpopular to pass Criteria Three, but proponents of market-based environmental solutions can still use well-designed, narrow C&C programs to aid the transition to a greener economy. Specifically, market-based policies are vulnerable in sectors where there is a large technological gap between "carbon-intensive" – also called "dirty" – options, and their "clean," lower emissions alternative (Lamperti et al. 10). If firms cannot easily substitute between dirty and clean production methods, a market-based solution may not succeed, because firms can maintain higher profits by paying whatever tax is put on pollution and reaping the higher productivity associated with the carbon-intensive operations. The further the gap between dirty and clean technologies when a market-based policy is instituted, the harder the transition to a sustainable economy, and the shorter the window of time policymakers have to act (Lamperti et al. 17). Put differently, market-based programs may struggle to fulfill Criteria Two in carbon-intensive industries where more research and development (R&D) is needed to make environmentally friendly options viable substitutes to their CO2-emitting counterparts. While C&C measures are unable to carry the load of reversing the market forces driving climate change by themselves, these traditional regulatory approaches can be used as bridge measures in industries with specific technological challenges.

Information Disclosure

Many market-based policy instruments could be described as "supply-side" oriented. They directly regulate firms to encourage them to curb emissions and develop more sustainable technology. Information disclosure programs, however, aim to target consumers and boost demand for green technology, thus providing incentives for firms to innovate products that are more energy-efficient ("Economic Incentives"). Rather than directly targeting firms' emissions, information disclosure initiatives help to solve the market failure associated with imperfect information, where consumers struggle to accurately identify which firms or products are more environmentally friendly. While some information disclosure systems simply have firms report their performance on some environmental parameter, the most effective examples of this policy have to do with labeling schemes, such as the USDA "Certified Organic" tags that can be found on food items ("Economic Incentives"). These labels are easy to spot while consumers are shopping and greatly reduce search costs.

For instance, studies on the EPA's "EnergyStar" label on refrigerators showed that consumers were willing to pay a premium for energy-efficient products bearing the label (Ward). This increase in demand was "motivated by both private (energy cost savings) and public (environmental) benefits," although consumer interest in the public benefits of reduced emissions varied across demographics (Ward). Interestingly, willingness to pay decreased when customers were offered a rebate along with the labeled refrigerators because the rebate "appeared to lower a buyer's perception of the product's quality" (Clark 5). Overall, the body of research on information disclosure programs suggests that market demand is sensitive to increased information about the environmental impacts of products. Firms that earn these labels by creating efficient and sustainable products are incentivized by higher revenues. While they do not stop emissions at the source, these labeling schemes address the incentive problems and market failures in Criteria One, reward innovation under Criteria Two, and meet Criteria Three by being low-cost.

Marketable Permit Systems

The policy tools addressed up to this point have generally limited scopes of application. Information disclosure programs may be helpful, but no experts are arguing that climate change can be solved through EnergyStar stickers alone. The next two policy instruments stand out in the sense that they are – if designed properly – capable of capturing and reducing nearly all of an economy's emissions. The first of these policy tools is marketable permit systems, more commonly known as Cap and Trade.

Cap and trade systems, as the name suggests, consist of two parts. First, the government sets an overall cap on the amount of emissions permitted in the market. On its own, this is not much different than a C&C approach that puts a hard ceiling on how much greenhouse gas a firm can emit. However, the second part of the system allows firms to trade emissions credits with each other, adding flexibility to the economy. This concept of a system where firms can buy and sell the rights to an externality was envisioned by Ronald Coase in his 1960 paper, "The Problem of Social Cost." The Coase Theorem argues that, "Through a trading of rights, externalities become 'internalised', and thus market failure need not happen" (Lai and Lange 43). A cap and trade system designed along Coase's ideas can, in theory, keep output higher than it would be under a C&C regime and still incentivize firms to reduce emissions ("Economic Incentives"). The appeal of the emissions trading regime is its potential to correct an externality with minimal government interference in the market.

The worldwide popularity of cap and trade programs, between political parties and across industry and environmental groups, sets them apart from many other environmental policies. In a 2009 article in the Stanford Environmental Law Journal, Reuven Avi-Yonah and David Uhlmann point out that cap and trade can offer "something for everyone," which contributes to its popularity (5). As Avi-Yonah and Uhlmann observe:

> "For environmentalists, cap and trade promises a declining cap on the carbon dioxide emissions that are the principal cause of global warming. For industry groups, cap and trade offers the possibility of a new market in carbon allowances and therefore the potential for significant income for companies who can inexpensively reduce their carbon

> dioxide emissions…For politicians, cap and trade offers the opportunity to take action to combat global warming without implementation of a complex regulatory permitting scheme or imposition of a tax on fossil fuels" (5).

Cap and trade is easy to understand, appears to address the market failures identified by Stern, and enjoys broad popularity. On paper, it looks like a market-based silver bullet for tackling climate change. Unfortunately, the research is more mixed.

Like other environmental programs, the cap and trade strategy has proven successful when applied narrowly. The most cited example of this is the U.S. Acid Rain Program ("ARP"), which was enacted in 1990 to establish a cap and trade system for emissions sulfur dioxide (SO2) and nitrogen oxides (NOx) that are the "primary precursors" of acid rain. Between 1990 and 2010, the ARP's emissions cap for the target compounds was gradually decreased until the maximum SO2 emissions were set to half of emissions levels in 1980 ("Acid Rain Program"). The ARP provides for allocation of emissions credits in two ways. First, through an annual EPA-sponsored auction where firms, brokers, and environmental groups may bid for credits. Second, through listings of third-party brokers that can facilitate sales of credits between groups ("Allowance Markets"). After thirty years, the ARP is deservedly held up as an example of a successful cap and trade system. The EPA reports that, as of 2019, annual SO2 emissions are down by 93% from 1990 levels and NOx emissions are down by 86%. Environmental indicators suggest acid rain has been reduced by more than 70% ("Acid Rain Program Results"). However, some of the factors that make the ARP successful distinguish it from more ambitious cap and trade programs. The ARP is designed to specifically target two types of pollutants that are emitted by the energy sector in particular. Policymakers made the program simple and flexible for energy firms that wished to buy and sell emissions credits, with minimal government management of the credits market. For cap and trade programs that aim to capture an entire economy, the success attained by the ARP may not be feasible.

Much of the cautionary rhetoric around cap and trade comes from the largest cap and trade system put in place to date: the European Union Emissions Trading System (EU ETS). Starting in 2008, the EU implemented a continental cap and trade scheme that was meant to help Europe achieve its Kyoto Protocol goal of reducing emissions by 8% by 2012 (Bayer and Aklin 8805). Member states would submit plans to allocate – not auction – credits to various approved entities within their borders, who could then trade credits throughout the EU (Bayer and Aklin 8805). While this program was designed with sound economic theory, the scale at which the EU ETS was implemented, combined with the complex political system of the EU, caused issues almost immediately.

A government made up of multiple sovereign nations can be unwieldy, and the presence of industry lobbyists and other interest groups turned the rollout of the EU ETS into a political slog. The program became subject to intense “lobbying and rent capture,” as governments sought revenues and firms tried to minimize any additional expenses they would incur under the new

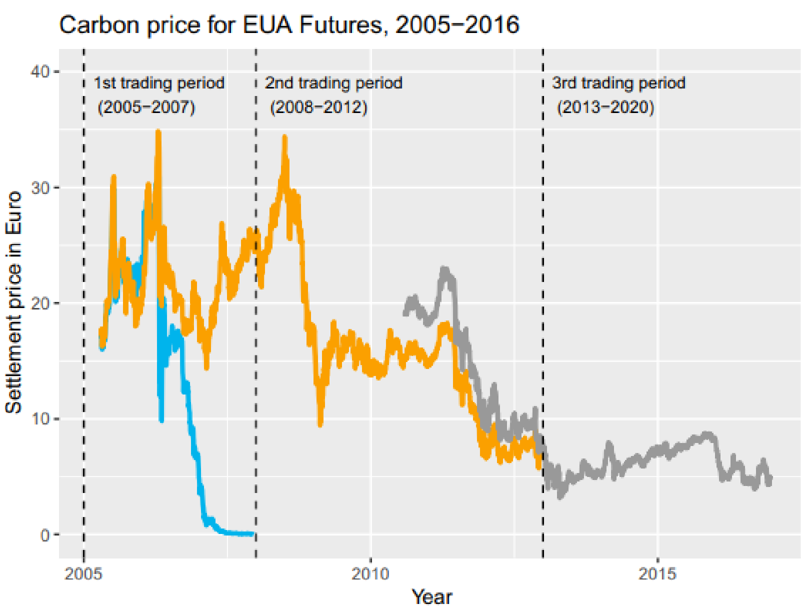

Figure 2 Future prices for an EU ETS emissions credit covering one ton of CO2. The program took place over three phases, and credits for one phase did not roll over into the next. The blue line shows prices for credits that expired in 2007, the orange line for prices of credits expiring in 2012, and the gray line shows prices for credits expiring in 2020. Prices have declined since the EU ETS’s rollout but recovered slightly after the announcement of the Market Stability Reserve in 2018 (Bayer and Akrin 8805).

system (Helm). Continued pressure from industry groups scuttled an attempt to set up an auction system for allocating credits, similar to the U.S.'s ARP design, and lobbying weakened the EU ETS even further during 2013 revisions (Helm). Political issues aside, there were also structural issues with the EU ETS's carbon market once it was up and running. There were too many emissions credits created, and allocation proved to be inefficient due to the lack of an auction. This led to a surplus of credits, which drove down carbon prices "below levels generally believed to be needed to curb emissions" (Bayer and Aklin 8805). Between price volatility under the EU ETS, a "negligible" effect on R&D, and the failure of the system to deliver emissions reductions promised by the Kyoto Protocol, critics have concluded that it is "unlikely that the EU ETS will provide the main driver for carbon reductions in Europe" (Helm).

Despite these flaws, supporters of the EU ETS argue that it has not been a complete failure and can be adjusted to deliver emissions reductions. The EU implemented the Market Stability Reserve, where it announced that 900 million permits scheduled to be released in 2018 would be held back to 2019/20, which did cause a temporary rebound in prices (Bayer and Aklin 8805). A 2020 analysis as the EU ETS's Phase 3 wound to a close concluded that the program ultimately reduced emissions in the EU by 8.1-11.5% and boosted "green R&D by about 10%" (Bayer and Aklin 8807). The EU ETS has already been renewed for a Phase 4 that will last until 2030. An auction system has been added to streamline allocation of credits, which will hopefully also mitigate rent-seeking behavior by governments ("Start of phase 4"). Supporters of the EU ETS argue that the program's stability will help incentivize firms to continue reducing emissions and innovating sustainable technology even if prices are low in the short term, since they know that the cap will continue to be reduced and carbon prices may increase in the future (Laing and

Mehling 9). For now, it is still unclear if the EU ETS can truly deliver necessary emissions reductions while prices remain low and flaws in the carbon market persist.

The challenges associated with the EU ETS raise doubts about whether a system would be successful in the U.S. Referring to Criteria Three, it is clear that the debate over how to set emissions caps and allocate credits would be bitterly partisan. The fact that standards have to be adjusted over time to provide lasting emissions reductions opens the system up to being undermined by an overly business-friendly administration. A price jump in the price of carbon would create "political pressure to relax the carbon cap, thus removing the primary benefit of a cap and trade system" (Avi-Yanoh and Uhlmann 6). And despite the claims of cap and trade advocates, a low price of carbon that does not – at least in the short term – internalize the social costs of emissions does not solve the basic problem of the Greenhouse Gas externality in Criteria One.

Over the long-term, as emissions trading system has the potential to signal firms that "future tightness" in the carbon market is a sufficient incentive to develop sustainable technology and cut emissions in a way that would satisfy Criteria Two and Three (Laing and Mehling 9). However, the research remains mixed and the EU's experience shows that such a system can become overcomplicated politically fraught. Cap and trade has appeal but a successful rollout in the U.S., let alone internationally, would have significant hurdles to clear.

Pollution Taxes

One rule of thumb used by economists discussing environmental policy is that as a government intervention into the market gets "more intricate…the less likely it is to reach an efficient outcome" (Moran 74). This reasoning is why many economists favor a straightforward tax on carbon emissions: it is simple and effective at solving the market failures associated with climate change without introducing the need for complex government intervention. Use of a tax to ‘internalize’ an externality is a classic solution to such a problem, first proposed by Arthur Pigou roughly seventy years ago (Weisbach and Metcalf 500). These so-called Pigouvian taxes allow the government to easily set the price of carbon to a level that accurately incorporates the “social cost” of carbon into firms’ decision-making (Dietz et al.). The simplicity and solid economic theory behind a carbon tax make it an intriguing policy option for reducing emissions.

In comparison to a cap and trade system, Stern writes that carbon taxes are effective because they help in “establishing a consistent price signal across regions and sectors,” “raise public revenues” with lower enforcement costs than a cap and trade system, and “can be kept stable,” which ensures greater success in meeting emissions reduction goals and prevents price volatility experienced by EU ETS (320). The simplicity of the carbon tax means that it can be easily put in place and tweaked as needed across various sectors. It is estimated that a carbon tax collected from emitting firms and “upstream” from consumers would “make it possible to accurately and cheaply cover 80% of U.S. emissions” (Weisbach and Metcalf 501). In comparison, the EU ETS captured only about 50% of annual emissions at the end of Phase 3 (Bayer and Aklin 8805). The fact that a carbon tax is harder to avoid makes it less popular among firms, and it may suffer in the U.S. where ‘tax’ is a dirty word. Among economists, however, the question is not whether a carbon tax would capture and deter emissions, but “how much, how fast, and how costly” the tax should be when put in place (Nordhaus 202). The political realities of the U.S. and other countries should not be ignored, and economic questions that need to be answered in designing a carbon tax do expose the policy to a risk of being neutered.

As Nordhaus pointed out in his criticism of the Stern Review, the central question to be answered when implementing a carbon tax is how high it should be. A simple answer would be to set the price of carbon to whatever is needed to reduce emissions by the necessary amount: this is the strength of a Pigouvian tax. Unfortunately, there is widespread disagreement among economists, politicians, scientists, and lobbyists from firms and environmental groups over exactly how much emissions need to be reduced.

Economists prefer to model a carbon tax the same way an investor would balance his willingness to spend in the present against potential future losses or benefits. The discounting of the future costs of inadequate action on climate change is where Stern and his critics disagree. As described above, accurate forecasting of the costs of climate change into economic quantities is difficult and subjective. Stern considers water shortages, severe weather events, climate refugees, energy costs, loss of shore to rising sea levels, and numerous other factors in his report. He estimates that, in the U.S., if warming were to move "above 3ºC, total output could fall by 5 – 20% even with effective adaptation because of summer drought and high temperatures" (Stern 173). As the Stern Review reasons, the severity and unpredictability of climate change supports a lower discount rate since people in the present should give more weight to these future impacts. Critics argue that Stern takes this reduction in discount rates to the "extreme," which causes him to estimate a carbon price that would be costly to current output and much higher than what is optimal (Nordhaus 202). Using traditional discount rates, economic models suggest that a lower carbon tax now could maintain output, then be raised as climate impacts worsen and justify a higher price on carbon.

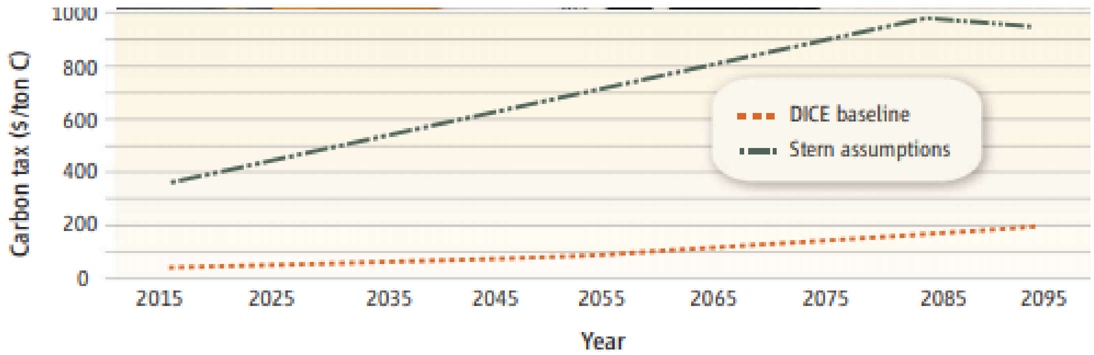

Figure 3 Comparison between tax rates on carbon under the Stern Review's discounting of future climate impacts and the tax rates estimated by the Dynamic Integrated model of Climate and the Economy (DICE), which uses traditional discounting assumptions and "is designed to choose levels of investment in tangible capital and in GHG reductions that maximize economic welfare" (Nordhaus 201).

Given the potential difficulties of raising political support for a carbon tax, some proponents use different standards for calculating the ideal carbon tax. Debates among economists over discount rates and long-term modeling are hardly likely to inspire public enthusiasm, so carbon tax proponents that focus on grassroots support for the policy turn their attention elsewhere. Groups such as the Citizens Climate Lobby (CCL) eschew the economic models and simply argue for a U.S. carbon tax to be set at rates that put the nation on track to meet its emissions targets for whatever international framework is in place at the time – currently the Paris Climate Accord ("Bwiasics of Carbon Fee"). Using the U.S. target of 50% reduced CO2 emissions by 2050, the CCL would set tax rates accordingly, proposing an initial tax of $15/metric ton of carbon that increases by $10 annually (Saucedo et al.). This method uses international agreements rather than economic models because some policymakers prefer emissions reduction targets be based on what is scientifically necessary to halt climate change, rather than what would be a "good investment." Skeptics point out that the supposed "purity" of scientific data is still subject to grant money, which tends to "go where the predictions are most dire" (Helm). As designers of the EU ETS learned, it is impossible to implement a truly apolitical carbon pricing policy. Economic, scientific, and political debates will play a role in any rollout of a carbon tax.

Regardless, disagreements over how to decide the carbon tax do not detract from its effectiveness in meeting whatever goal is set. A carbon tax's ability to harness market forces to achieve environmental goals means that it is an "effective mitigation strategy for carbon dioxide emissions" that can serve as "the centerpiece of any successful program to combat global climate change" (Avi-Yonah and Uhlmann 8). If policymakers establish a "trajectory of rising tax rates" on emissions, firms will be incentivized to not only reduce emissions but additionally pursue "innovation in low-carbon technologies" (Marron and Toder 564). The carbon tax meets the three criteria for emissions-reducing policy tools with a broader scope than information disclosure programs and fewer logistical hurdles than cap and trade. Its basis in sound economic principles puts it ahead of the competition in serving as a market-based strategy in slowing down global warming.

Conclusion

As the planet warms, the stakes of continued inaction to reduce emissions increase. Scientific data indicates that "the consequences of climate change will become disproportionately more severe with increased warming" (Stern 203). Current human activity is damaging the Earth, its natural processes, and its ecosystems beyond tolerable levels. This creates the risk of not only economic damage in dollars, but the "sickly seasons, epidemics, pestilence, and plague" foreseen by Thomas Malthus over two hundred years ago, as he wondered if humanity could restrain its growing demand for resources (Heilbroner 43). Fortunately, even Malthus himself was optimistic about the future of humanity. Suggesting that the right amount of "restraint" could contain population growth enough to preserve the land and resources necessary for survival, Malthus believed in the ability of nations and individuals to make smaller, short-term sacrifices in the name of humanity's long-term future (Heilbroner 43).

Economics can provide key policy insights for incorporating the long-term costs of pollution and other environmental damage into current markets. The main challenge identified by economists is the "Greenhouse Gas Externality," in which environmental policy must incorporate the social and environmental costs of emissions into the market. Policy instruments must also stimulate innovation of "cleaner" technologies and methods while still being politically feasible. These three criteria – internalizing the externality of emissions, promoting innovation, and political viability – help distinguish among the available policy options. In particular, market-based instruments such as cap and trade and a carbon tax are appealing in their ability to capture most or all of an economy's emissions into the market.

However, even the best-laid carbon pricing schemes in the U.S. are limited if implemented alone. The success of a carbon tax depends on "future economic developments … and policies elsewhere in the world" (Marron and Toder 563). To truly mitigate emissions, sovereign nations around the world must agree on a "broadly similar carbon price," or else emissions reductions by some nations may be dampened by continued emissions from others (Stern 513).

In order to muster the substantial, long-term international collective action required to stop climate change, leadership from the U.S. and other developed nations is particularly important. First and foremost, American action on climate change is important because "developed countries like the United States have contributed the most to global warming" (Avi-Yonah and Uhlmann 12). Second, involvement from the U.S. and its wealthy counterparts in international climate agreements and future global carbon pricing systems is important because large developing economies, which will be responsible for a large portion of future emissions, cannot go it alone. The Stern Review remarks that,

> "For developing countries, and especially the poorest developing countries, adaptation to climate change will substantially raise the costs of some investments, and may also require investments in new areas. These new demands will place pressure on already very scarce public resources" (Stern 598).

American refusal to join international climate action because of the inability or unwillingness of developing nations to reduce their own emissions dates back to negotiations over the 1997 Kyoto Protocol (Avi-Yonah and Uhlmann 17). However, American skepticism over international action to combat climate change only serves to exacerbate the process. Developing countries are less inclined to come to the negotiating table if they believe "too little is being done" to reduce emissions and support international action by a wealthy nation such as the U.S. (Stern 598). Adopting a domestic carbon price not only provides an economically efficient option for the U.S. to reduce emissions, but bolsters the credibility of future international agreements that will lay the foundation for global climate policy.

The threat climate change poses to Earth and humanity is a serious one. Projections of the economic, social, and environmental costs of warming and habitat loss are widespread and sobering. But despite its reputation as the "dismal science," economics has the ability to inject optimism into the debate over a solution to climate change. Just as Malthus in 1798 believed in the power of combined human action to avoid a fall over the "very brink of the precipice of existence," Lord Stern concluded in 2006 that "with the right incentives, the private sector will respond and can deliver solutions" to reduce emissions before it is too late (Heilbroner 36; Stern

616). Policies informed by economics make it possible to mitigate climate change and preserve natural resources through committed, unified action.

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