OFF TARGET

The Economics Literature Does Not Support the 1.5°C Climate Ceiling

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FRASER INSTITUTE

2021

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Executive Summary

Many advocates of government intervention to curb greenhouse-gas emissions have called for a temperature ceiling on global warming. The consensus was originally 2 degrees Celsius, but advocates of more aggressive action succeeded in shifting the goal to 1.5 degrees, at least as an aspirational target. This new goal is epitomized in a 2018 report issued by the United Nations' Intergovernmental Panel on Climate Change (IPCC) titled *Special Report: Global Warming of 1.5°C* (SR1.5). In the present report, we leave aside the extremely difficult issue of translating a temperature goal into an emissions target, and focus on the temperature goal itself.

It is widely but mistakenly believed that the SR1.5 recommended the 1.5°C target on the basis that it was needed to avoid large net economic and social losses. But in fact the report specifically eschewed cost-benefit analysis, and made no assertions about what such an analysis would conclude. For the most part, the IPCC simply tried to compare the model-projected impacts of a 2.0°C warming to that of 1.5°C, and not surprisingly concluded that the former would be larger.

In this report, we argue that pursuit of the 1.5°C ceiling on global warming is incompatible with mainstream economic analysis. Indeed the 1.5°C goal did not arise from the economics literature or from formal cost-benefit analysis. The SR1.5 simply took the goal as given externally. Our report provides several lines of argument to show that the economics literature as a whole does not support the 1.5°C target.

For example, on the same weekend that the UN released its *Special Report*, William Nordhaus was awarded the Nobel Memorial Prize for his pioneering work on the economics of climate change. Major media treated the two events as complementary, assuming Nordhaus' work supported the 1.5°C goal. Yet, on the contrary, his then most recent (2016) modeling work projected that the "optimal" global warming by the year 2100 would be 3.5°C, a full two degrees higher than the popular target. In fact, Nordhaus' model estimated that a 1.5°C ceiling would be so harmful to the economy that it would be better for humanity if governments did nothing at all about climate change rather than pursue such a draconian policy.

Or, consider the "social cost of carbon," which economists define as the present value in dollar terms of future damages caused by the emission of an additional metric tonne of carbon dioxide. The Biden Administration's EPA in February 2021 estimated the social cost of carbon for the year 2030 at US$62. Yet, the SR1.5 admitted that the

policies it detailed for achieving the 1.5°C goal would only be justified for a social cost of carbon in 2030 ranging from $135 to $5,500 per ton, costs that are 2 to 89 times the EPA's estimate.

The SR1.5 in many respects represented a departure from views the IPCC had expressed in its 2014 *Fifth Assessment Repor*t about the economic effects of climate change. We show that the UN chose a very different team of authors for the SR1.5. The *Fifth Assessment Report, Volume II* summarized, among other things, the economic consequences associated with climate change projections. Notwithstanding the similarity of that topic to the SR1.5, and the short interval between the reports, comparing the relevant chapter from the *Fifth Assessment Report* (Chapter 10) to that of the SR1.5 (Chapter 3), there was no overlap between the Coordinating Lead Authors, Lead Authors, Review Editors, or Chapter Scientists. Among the 69 Contributing Authors to the *Special Report*, Chapter 3, there was only one who had also contributed to the *Fifth Assessment Report*'s chapter on the impact of climate change.

Finally, we show that the UN *Special Report* based its reversal of the earlier consensus largely on the basis of two new studies that asserted a much larger drag on economic growth from climate change compared to that found in many previous studies. In doing so, the SR1.5 overlooked other new studies that had upheld the earlier consensus. The two new studies have, in the years since the *Special Report*, been criticized on methodological grounds, and other authors have not confirmed their findings.

Although advocacy of aggressive climate-change policies is often draped with the mantle of science, mainstream economists who follow the scientific literature have shown that the popular 1.5°C policy target will pose costs that far exceed the benefits, and that the emission reductions flowing from strict adherence to the 1.5°C target would be worse for the world than doing nothing at all.

1 Introduction

Although overshadowed by the COVID-19 pandemic, the threat of climate change has for decades dominated public-policy discussions in a variety of arenas. In recent years, many advocates of government intervention to curb emissions have unified behind a ceiling for cumulative global warming by the year 2100, as it gives a seemingly concrete objective that the general public can understand. The consensus ceiling was originally 2 degrees Celsius, but eventually advocates of more aggressive action succeeded in shifting the goal to 1.5 degrees, if not as an absolute ceiling then at least as an aspirational target.

This shifting of the original 2°C to the more stringent 1.5°C climate goal is crystallized in the United Nations' publications on climate change. For example, the website of the United Nations Framework Convention on Climate Change explains: "[The Paris Agreement's] goal is to **limit global warming to well below 2, preferably to 1.5 degrees Celsius**, compared to pre-industrial levels" (UNFCCC, 2021; emphasis added).

In this report, we argue that the 1.5°C climate goal is incompatible with mainstream economic analysis. There is a critically important distinction between the question of what is an optimal target and what policies are adequate for achieving a given target. The distinction is often ignored when discussing the 1.5°C goal. Many countries are not on track to achieve emission reductions consistent with conventional estimates of what would suffice to achieve the 1.5°C goal. A common complaint, therefore, is that they are not acting as quickly or as aggressively as they should. But their failure to impose policies consistent with a 1.5°C target more likely reflects the fact that the target is too stringent when weighing all the relevant social, economic, and environmental considerations.

The 1.5°C goal did not arise from the economics literature or from formal cost-benefit analysis. In fact it arose by explicitly setting cost-benefit analysis aside. In 2018, the Intergovernmental Panel on Climate Change (IPCC)—which is the UN-sponsored organization that periodically issues authoritative summaries of climate change research to guide policy makers—released *Special Report: Global Warming of 1.5°C* (IPCC, 2018; hereinafter, SR1.5). In the opening chapter of the report, the authors describe the many challenges associated with measuring the impacts of climate change and state: "Thus standard cost–benefit analyses become difficult to justify (IPCC, 2014a; Dietz *et al.*, 2016) and are not used as an assessment tool in this report" (SR1.5: 76).

By ruling out cost-benefit analysis from the outset the SR1.5 was thus never in a position to recommend a policy target. Much of its analysis simply contrasts projected climate impacts from 1.5°C of warming with those of 2°C. The following conclusions are typical of the report:

> Risks to natural and human systems are expected to be lower at 1.5°C than at 2°C of global warming (*high confidence*). (SR1.5: 178)
>
> The projected frequency and magnitude of floods and droughts in some regions are smaller under 1.5°C than under 2°C of warming (*medium confidence*). (SR1.5: 179)
>
> Global warming of 2°C is expected to pose greater risks to urban areas than global warming of 1.5°C (*medium confidence*). (SR1.5: 180; emphasis in original)

In other words (and as we will explain in greater detail later in this study), the SR1.5 does not try to justify the 1.5°C target on its own terms. Instead, it merely estimates the additional benefits (through the mitigation at the margin of various potential climate impacts) of limiting global warming to 1.5°C, rather than 2°C. The report does not discuss the costs of adopting the more stringent target nor does it offer guidance as to whether doing so is worth the cost.

Despite this, major media subsequently embraced the 1.5°C ceiling as if it were a prescribed target. To coincide with Earth Day 2021, a New Yorker article by a prominent climate activist carried the headline, *How 1.5 Degrees Became the Key to Climate Progress*, while the sub-headline explained, "The number has dramatically reorganized global thinking around the climate" (McKibben, 2021). As well as endorsing the 1.5°C target, discussions in the media amplified the complaint that humanity is not doing nearly enough to curb emissions. These claims continue today. For example, in a *Vox* article on the Biden Administration's climate plan for 2030, a climate journalist explained:

> To limit climate change, the whole world needs to act not only to zero out greenhouse emissions but also to begin withdrawing them from the air by the middle of the century.
>
> At the [2021] Earth Day summit, other world leaders highlighted their own new targets. Canada is now aiming to reduce its emissions 40 to 45 percent below 2005 levels by 2030. Japan is aiming for 44 percent under the same benchmarks.

> And China is expecting that its emissions will continue to rise over the next decade but will peak in 2030 and decline thereafter …
>
> …
>
> **But the total global commitments to date are still not enough to reach the 1.5-degree target, and that target is slipping further out of reach every day.** That's going to be even more challenging as lower-income parts of the world develop. About 13 percent of the planet's population, 940 million people, still don't have access to electricity. They desperately need energy, and fossil fuels are often the only sources available to them. (Irfan, 2021; emphasis added)

The above excerpts are typical of the public discussion of climate change policy that takes the 1.5°C goal as universally prescriptive. In this context, it is very important for Canadians to realize that the bulk of the literature on climate economics does not support the 1.5°C target. For example, on the same day that the UN's *Special Report* was released, William Nordhaus was announced as a co-recipient of the 2018 Nobel Memorial Prize in economics, for his pioneering work on the economics of climate change. Yet when he won the prize, Nordhaus' most recent (2016) calibration of his model recommended an optimal carbon tax that would allow global warming of 3.5°C by the year 2100. In fact, Nordhaus' research concluded that a 1.5°C ceiling was so costly that it would be *better for governments to do nothing at all* about climate change than pursue such a draconian goal.

The gap between economists' thinking on climate policy and prescriptions from physical scientists and others was recently described as follows:

> Mainstream climate economics takes global warming seriously, but perplexingly concludes that the optimal economic policy is to almost do nothing about it … The contrast is striking. While climate science is sending out loud-and-clear messages that fossil-fuel disinvestment must start now, letting go of coal and oil and diverting resources into renewable energy technology systems, to keep warming below the 2°C limit (IPCC, 2014), mainstream climate economics claims that overly ambitious climate targets will unnecessarily hurt the economy and immediate de-carbonization is too expensive. Most climate economists thus recommend humanity to just wait-and-see. (Storm, 2017: 1307)

This publication explores how a misunderstanding of the IPCC's 2018 *Special Report* and the literature on climate economics more broadly is pushing Canada and other nations into an ill-conceived policy agenda that, on all reasonable grounds, fails

standard cost-benefit tests. Our study is organized as follows. Section 2 elaborates how Nordhaus' Nobel-winning modeling work on carbon-tax design estimates that the 1.5°C target has much higher costs than benefits. Section 3 uses a different approach to show that the economics literature cannot support the target. Specifically, we quote from reputable authors—who are sympathetic to the goal—to establish that the 1.5°C target implies a carbon price that is far higher than standard estimates of the optimal level, including those originally produced by the Obama Administration's EPA and now endorsed by the Biden Administration. Section 4 critically analyzes a few of the small number of studies that do claim the 1.5°C target passes a cost/benefit test, showing that they contain serious flaws. Section 5 concludes.

Taken as a whole, our study will demonstrate that the bulk of the literature concludes that the 1.5°C target is so draconian that the damage it would do to economic well-being is far higher than its benefit, the expected reduction of damage from climate change. Moreover, those few studies that purport to show otherwise suffer from serious flaws. These facts should give serious pause to Canadian policy makers and the general public, who may assume that the celebrated 1.5°C target is a desirable goal around which carbon taxes and other legislation should be designed.

2 Nordhaus Model Shows 1.5°C Target Has Costs Much Higher than Its Benefits

Before going further, we should note that discussions of how much warming will occur in the 21st century, and how a particular level of warming relates to particular volumes of greenhouse-gas emissions, and the extent to which warming harms or benefits different regions and the world as a whole, are all fraught with enormous uncertainties that we make no attempt to resolve in this study. A policy goal such as limiting average warming to 2°C does not on its own imply any specific trajectory for greenhouse-gas emissions; instead it could be consistent with a wide range of emission paths depending on how they affect the climate and how warming is measured. Claims about the global costs of warming and the optimal warming target also embed profound uncertainties. Our aim is simply to explain that, when we take at face value the mainstream scientific and economic approaches to modeling these processes, the 1.5°C target fails a cost-benefit test. There may be further arguments against such a target based on more fundamental criticisms of the models involved, but we do not explore those here.

The IPCC released its *Special Report: Global Warming of 1.5°C* on the same day that economist William Nordhaus of Yale University was announced as a co-recipient of the Nobel Memorial Prize for his work on the economics of climate change. Because the two events were apparently so complementary, prominent news outlets covered them in the same story. Here is how the *New York Times* explained their relation:

> The Yale economist William D. Nordhaus has spent the better part of four decades trying to persuade governments to address climate change, preferably by imposing a tax on carbon emissions.
>
> His careful work has long since convinced most members of his own profession, and on Monday he was awarded the 2018 Nobel Memorial Prize in Economic Sciences in recognition of that achievement.
>
> …
>
> **The award was announced just hours after a United Nations panel said large changes in public policy were urgently needed to limit the catastrophic consequences of rising temperatures**. The prize committee said its choice of laureates was meant to emphasize the need for international cooperation.

> "The message is that it's needed for countries to cooperate globally to solve some of these big questions", said Goran K. Hansson, the secretary general of the Royal Swedish Academy of Sciences. (Appelbaum, 2018; emphasis added)

As the *New York Times* story illustrates, the standard reaction to Nordhaus' Nobel and the IPCC's *Special Report* was to assume that one reinforced the other. Yet ironically, Nordhaus' work concludes that the 1.5°C target is far too extreme, and that a much looser target—one that allows a higher temperature rise—would be more beneficial to humanity.

In this section, we will reproduce two separate facets of Nordhaus' results to show that they reject the 1.5°C target. First, we show that, as of the 2016 calibration of his Dynamic Integrated Climate-Economy (DICE) model, Nordhaus recommended an "optimal carbon tax" that would place the Earth on a trajectory to warm 3.5°C by the year 2100. Second, we show that Nordhaus' 2016 results conclude that the effects of a 1.5°C ceiling on global warming would be so severe that it would be better for humanity to do nothing about climate change, rather than pursue such a stringent goal.

2.1 Nordhaus' "optimal carbon tax" (circa 2016) allows warming of 3.5°C by 2100

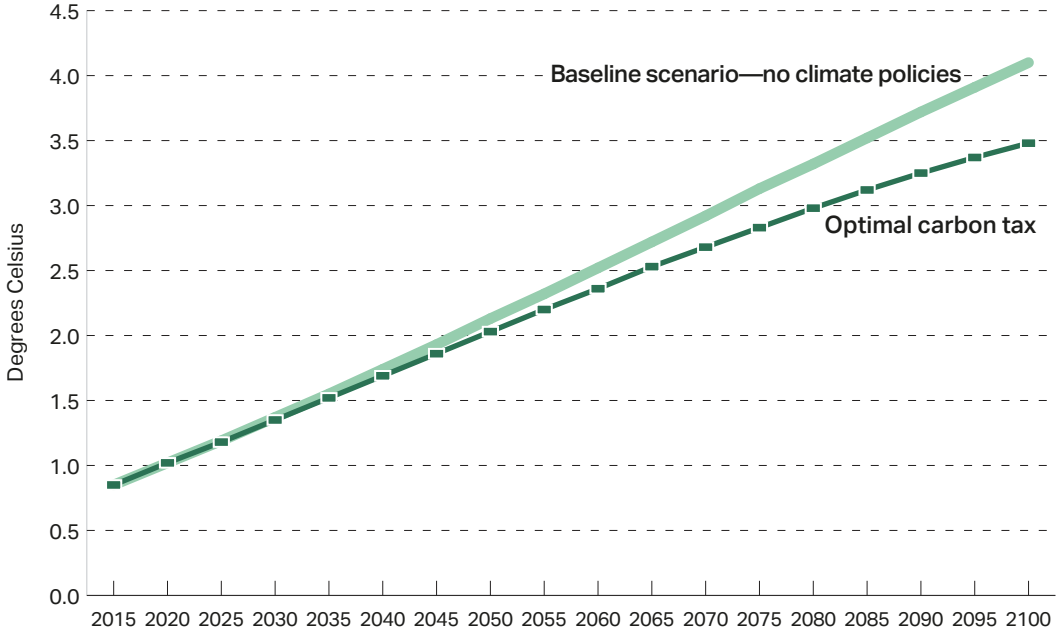
In a paper summarizing the results of the 2016 calibration of his DICE model, Nordhaus (2018) presented a chart (partially reproduced here as **figure 1**) showing the modeled temperature rise through the year 2100 under different scenarios. As figure 1 indicates, Nordhaus' model showed that under a baseline scenario (where governments implement no climate policies), global warming by 2100 would exceed 4°C. The "optimal" path—in which the marginal benefits of avoided warming were set equal to marginal compliance costs, [1] and which the world would follow under the implementation of Nordhaus' recommended global carbon tax—would allow for 3.5°C of warming by 2100. Although Nordhaus' optimal trajectory allows for less warming than the baseline, it is still far above the 1.5°C ceiling that has become so fashionable.

2.2 Nordhaus' DICE model (circa 2016) showed "doing nothing" better than 1.5°C target

In the same 2018 paper, Nordhaus presented a table showing how his DICE model (in its 2016 calibration) evaluated the benefits and costs of various climate goals. We summarize some of his findings in **table 1**, which shows that different climate goals

[1] Economists generally believe that the damages from climate change increase more than proportionally with additional warming, while the damage to the economy also increases more than proportionally with tighter emission limits. In a standard cost-benefit framework, the "optimal" climate policy would continue to reduce emissions until the point at which additional limitations would hurt economic growth more than it would spare additional climate damages.

Figure 1: Increases (°C relative to preindustrial time) in the global mean temperature under baseline and optimal carbon tax, according to Nordhaus' DICE-2016



Source: William Nordhaus' Excel file provided for DICE-2016R; discussed in Nordhaus, 2018 and shown in figure 4.

Table 1: Benefits and costs (2010 US$ trillions) of various climate goals, according to Nordhaus' DICE Model (2016 calibration)

Scenario	Damage from climate change	Abatement cost	Damage from climate change + abatement cost	Reduction in total harm relative to baseline
[1] Baseline—no-controls	134.2	0.4	134.6	0.0
[2] Nordhaus' optimal carbon tax	84.6	20.1	104.7	29.9
[3] Ceiling of 2.5°C imposed	43.1	134.6	177.8	**−43.2**

Source: Nordhaus, 2018: table 2 (p. 349).

can have vastly different benefits and costs. For example, in the first scenario where governments implement no controls—or what is sometimes referred to as "business as usual"—there will be relatively negligible compliance (or "abatement") costs, which Nordhaus estimates at $400 billion. However, under the no-controls baseline, the world will suffer—according to the DICE model's 2016 calibration—a present-discounted [2]

[2] In this literature, much of the damage from climate change is projected to occur decades and even centuries in the future. However, economists generally believe that $100 in damage in the year 2100 is not as significant as $100 in damage in the year 2030. In order to convert future damages into a common denominator, a discount rate is applied to future dollars, to convert them into their (smaller) present value.

sum of $134.2 trillion (in 2010 US$) in climate-change damages from unrestricted global warming. The two figures combined constitute the baseline total harm against which Nordhaus contrasts the other two policies we have reproduced here.

If we look at the second option, in which Nordhaus' prescribed carbon tax is implemented by governments around the world, then damages from climate change are limited to $84.6 trillion, which is about $49.6 trillion less than the baseline. We can thus say that the marginal benefits of Nordhaus' optimal carbon tax consist of $49.6 trillion in avoided climate damage. However, we must also consider the marginal costs. As table 1 indicates, the "optimal tax" carries with it abatement costs of $20.1 trillion, which of course are far higher than the mere $400 billion of abatement costs in the business-as-usual baseline. Therefore, the net marginal benefit of Nordhaus' optimal carbon tax relative to the no-policy baseline is only $29.9 trillion (as indicated in the last column). As Nordhaus explains it in his paper, "the optimal case raises discounted world income by $30 trillion" (2018: 349).

Now that we understand how Nordhaus' table works, we can see what his model said about the 2.5°C target. (Note that we are here discussing 2.5°C, because at the time of his 2016 calibration, Nordhaus considered the 1.5°C ceiling so far out of reach that he didn't even bother to model it as a policy option, though he had included it among policies discussed in his 2008 book.) Because it is far more aggressive than the optimal carbon-tax scenario (which we recall from figure 1 allowed for 3.5°C of warming by 2100), the 2.5°C ceiling limits climate change damages to $43.1 trillion, compared to $134.2 trillion under the baseline, for a marginal benefit of $91.1 trillion. However, this aggressive goal carries with it $134.6 trillion in abatement costs. Thus, the total harm—from both climate change and the compliance costs of government policies necessary to limit warming—from the 2.5°C target is $177.8 trillion. This is $73.1 trillion worse than the optimal path of 3.5°C of warming. It is also $43.2 trillion worse than the baseline scenario in which governments do virtually nothing to slow climate change.

In short, as of the 2016 calibration of Nordhaus' model, his analysis reported that it would be better for humanity if governments did nothing at all about climate change, rather than pursue a 2.5°C ceiling on global warming. If that is the case, then it follows directly that a more draconian ceiling of 1.5°C would be even more harmful, and that the mismatch between avoided climate damages and increased abatement costs would be even greater.

3 The Carbon Price Required to Achieve the 1.5°C Target Far Exceeds Standard Estimates of the "Social Cost of Carbon"

In this section, we discuss the huge gap between the implied "social cost of carbon" associated with a 1.5°C target, and the much lower estimates of the social cost of carbon from authoritative (and sympathetic to climate action) sources.

3.1 Conventional estimates of the social cost of carbon (SCC)

The social cost of carbon (SCC) is defined as the present-discounted value of the future net social damages caused by the emission of an additional unit of carbon dioxide (CO_2). Typically, it is measured in dollar terms and is indexed to a particular year, and the size of the emission unit is one metric tonne of carbon dioxide (though originally in the climate-change literature the unit was often a tonne of pure carbon).

An additional complication arises because the SCC involves the future flow of additional climate-change damages over great periods of time—even spanning centuries. Therefore, in order to come up with a single dollar figure of total damages quoted in the year of emission, an estimate of the SCC must be associated with a discount rate, and the resulting estimate can be very sensitive to the chosen rate.

For a sample of estimates of the SCC based on the mainstream literature [3] featured in IPCC reports, in **table 2** we reproduce the estimates produced in February 2021 by the Biden Administration, which were largely updates of the estimates prepared by an Interagency Working Group on the Social Cost of Carbon that had been organized under the Obama Administration. [4] To reiterate, the Biden Administration's estimates produced in table 2 reflect mainstream economic reasoning and assumptions

[3] Specifically, the Obama Administration's Interagency Working Group derived its estimates using three of the leading computer Integrated Assessment Models (IAMs). Besides Nordhaus' DICE model, they relied on the FUND and PAGE models. All three models are well respected in the economics of climate change community, though advocates of more aggressive government intervention argue that such approaches understate the danger of climate change (*e.g.*, Roberts, 2018; Weitzman, 2011).

[4] The EPA under the Trump Administration produced much smaller estimates of the SCC because of differing instructions on how to handle global *versus* domestic impacts and the discount rate to be used.

Table 2: Biden administration's estimates (2020 US$ per metric tonne of CO_2) of the social cost of carbon for various years and discount rates, as of February 2021.

	Discount Rate		
	5%	3%	2.5%
2020	$14	$51	$76
2025	$17	$56	$83
2030	$19	$62	$89
2035	$22	$67	$96
2040	$25	$73	$103
2045	$28	$79	$110
2050	$32	$85	$116

Source: Interagency Working Group on Social Cost of Greenhouse Gases, 2021.

found in the climate-economics literature. It is typical to pick the 3% discount rate as the default and, therefore, when the estimates were first announced, the media reported that the social cost of carbon was $51 (expressed in 2020 US$).

The IPCC has also published estimates of the SCC. In table 3, we reproduce the summary provided in the IPCC's *Fifth Assessment Report* (or AR5) (Arent *et al.*, 2014). As table 3 indicates, if we restrict our attention to the then most recent studies (published after the literature covered in the 2007 *Fourth Assessment Report*), regardless of the pure rate of time preference (which is a component of the discount rate) the averages of published estimates of the SCC were all below $75 per tonne of CO_2. Although these rates are higher than those of the Biden Administration, they are in the same range and are consistent with the published economics literature.

3.2 Implied "shadow price" of carbon associated with a 1.5°C target

Because the social cost of carbon (SCC) is the estimated additional damage that an extra tonne of emissions will inflict on the world, a government policy that reduces emissions by one tonne will correspondingly confer that same dollar amount in marginal social benefits. To a first approximation, an "optimal carbon tax" should not exceed the SCC; more precisely, it should be deflated by an index of the inefficiency of the tax system (called the Marginal Cost of Public Funds; see McKitrick, 2016). In principle, the response of emitters to a carbon tax at this level will yield the optimal balance between the benefits and costs of emission reductions.

Table 3. Averages of published estimates of the social cost of carbon (US$ per metric tonne of CO_2), according to IPCC Fifth Assessment Report (AR5)

Pure rate of time preference	Average SCC in studies post-AR4 (2007)	Average SCC in studies pre-AR4 (2007)
0%	$74	$203
1%	$49	$63
3%	$9	$12

Note: In the original AR5 table, estimates of the social cost of carbon estimates were expressed per tonne of carbon. We have divided by 3.67 to convert to cost per tonne of CO_2.
Source: Arent *et al.*, 2014 (IPCC AR5): table 10-9 (p. 691).

The SR1.5 makes no attempt to justify the 1.5°C target by showing that its pursuit would confer greater benefits than costs. Instead it simply takes the 1.5°C ceiling as a constraint derived from the climate policy discussions. To the extent that economic analysis does enter the discussion in the UN's report, it is in the context of how to minimize the cost of achieving the 1.5°C target, given that it has been adopted through the political process.

The SR1.5 itself explicitly distinguishes between the two approaches, and explains how they can be compared. The following excerpt comes from a pullout section, *Cross-Chapter Box 5: Economics of 1.5°C Pathways and the Social Cost of Carbon.*

> … In CEA [cost-effectiveness analysis], the marginal abatement cost of carbon is determined by the climate goal under consideration. It equals the shadow price of carbon associated with the goal which in turn can be interpreted as the willingness to pay for imposing the goal as a political constraint. Emissions prices are usually expressed in carbon (equivalent) prices … **Since policy goals like the goals of limiting warming to 1.5°C or well below 2°C do not directly result from a money metric trade-off between mitigation and damages, associated shadow prices can differ from the SCC** [social cost of carbon] **in a CBA** [cost-benefit analysis]. In CEA, value judgments are to a large extent concentrated in the choice of climate goal and related implications, while more explicit assumptions about social values are required to perform CBA. (IPCC, 2018: 2-76, 2-77; citations removed, emphasis added)

As the quotation explains, if we take the 1.5°C as a given constraint emanating from the political process, we can then ask what would the price on carbon emissions have

to be in order to achieve it. This is called the *shadow price* associated with the emissions target. The implied shadow price of a climate target—in this case, the 1.5°C ceiling on warming—shows what threshold the social cost of carbon would have to exceed, in order to make the target pass a cost/benefit test.

The SR1.5 also warns that the implied shadow price of a given target may differ from the standard estimates of the SCC, which may in turn correspond with the shadow price of a much less stringent target. But how big is this gap? To gain some idea, consider the following observations from an analysis by Resources for the Future (RFF) of the SR1.5 —an analysis, we should note, that was very sympathetic to the IPCC document:

> By design, the IPCC report is not policy-prescriptive. However, it does present a range of carbon prices necessary to keep emissions on track to meet the 1.5°C target. The level and significant range of prices—**from $135 to $5,500 per ton of carbon dioxide emissions in 2030**—have caught our attention. (Rennert and Hafstead, 2018; emphasis added)

As table 2 indicates, conventional estimates of the SCC for the year 2030 are around $62 per tonne of CO_2 (in 2020 US$, using a 3% discount rate). Yet the SR1.5 admits that the 1.5°C target implies a shadow price of carbon from 2 to 89 times that amount. This is yet another indication that the 1.5°C climate target comes nowhere near passing a conventional cost/benefit test.

4 IPCC versus IPCC—the Special Report's Rejection of the Prior IPCC Consensus

4.1 Basis for the changed position

In the previous section, we used two lines of argument to establish that the conventional economics literature on climate change does not support a 1.5°C target. In fact, the IPCC as of 2014 had given little indication that aggressive abatement policy was justified at all. The executive summary in Chapter 10 of the AR5 Working Group II Report says:

> **For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers (*medium evidence, high agreement*).** Changes in population, age, income, technology, relative prices, lifestyle, regulation, governance, and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change.

This finding reflected the views of the mainstream economics literature up to that point, as established by decades of research into the economic effects of climate change. The SR1.5, however, stated a very different view, in essence discarding the consensus on the basis of two new studies that had only just appeared in the literature.

Before examining their new position, we will point out that the team of authors who wrote SR1.5, Chapter 3 was completely different from that which had written AR5, Chapter 10. Upon comparing the two groups, we found no overlap among the Coordinating Lead Authors, Lead Authors, Review Editors, or Chapter Scientists. Among the 69 Contributing Authors to the SR1.5 there was only one who had also contributed to the IPCC AR5 WGII Chapter 10. In other words, the IPCC assembled a completely different team of authors to review the same topic they had reviewed a short time before, and this new team largely dispensed with the position the IPCC had held up to that point.

We will reproduce the paragraphs in which the SR1.5 team made their case in light of the economic literature, and intersperse our comments, so the reader can understand their argument.

> *Global economic impacts*: WGII AR5 [i.e. the report from Working Group II of the IPCC's Fifth Assessment Report, released in 2014] found that overall global aggregate impacts become moderate at 1°C–2°C of warming, and the transition to moderate risk levels was therefore located at 1.6°C above pre-industrial levels. This was based on the assessment of literature using model simulations which indicated that the global aggregate economic impact will become significantly negative between 1°C and 2°C of warming (*medium confidence*), whilst there will be a further increase in the magnitude and likelihood of aggregate economic risks at 3°C of warming (*low confidence*).

The starting point of the discussion is thus an acknowledgment that up to the publication of the SR1.5 in 2018, the IPCC had taken the position that aggregate global impacts of climate change would be positive or only slightly negative up to somewhere between 1°C and 2°C of warming. They continued:

> Since AR5, three studies have emerged using two entirely different approaches which indicate that economic damages are projected to be higher by 2100 if warming reaches 2°C than if it is constrained to 1.5°C. The study by Warren *et al.* ([2018]) used the integrated assessment model PAGE09 to estimate that avoided global economic damages of 22% … accrue from constraining warming to 1.5°C rather than 2°C, 90% … from 1.5°C rather than 3.66°C, and 87% … from 2°C rather than 3.66°C. In the second study, Pretis *et al.* (2018) identified several regions where economic damages are projected to be greater at 2°C compared to 1.5°C of warming, further estimating that projected damages at 1.5°C remain similar to today's levels of economic damage. The third study, by M. Burke *et al.* (2018) used an empirical, statistical approach and found that limiting warming to 1.5°C instead of 2°C would save 1.5–2.0% of the gross world product (GWP) by mid-century and 3.5% of the GWP by end-of-century … Based on a 3% discount rate, this corresponds to 8.1–11.6 trillion USD and 38.5 trillion USD in avoided damages by mid- and end-of-century, respectively, agreeing closely with the estimate by Warren *et al.* ([2018]) of 15 trillion USD. Under the no-policy baseline scenario, temperature rises by 3.66°C by 2100, resulting in a global gross domestic product (GDP) loss of 2.6% … compared with 0.3% … by 2100 under the 1.5°C scenario and 0.5% … in the 2°C scenario …

The first point to note is that the SR1.5 based its reversal on three new studies, namely those of Warren *et al.* (2018), Pretis *et al.* (2018) and Burke *et al*. (2018), although they paid little attention to Pretis *et al.* (2018), whose cost estimates did not match those of the other two.

Their selection of these studies does not mean that they were the only relevant ones that had appeared between 2013 and 2018—far from it. For instance, Nordhaus (2017) had published updated SCC estimates that were only slightly different from his previous estimates. Waldhoff *et al*. (2014) had published a new set of estimates arguing that non-CO_2 greenhouse gases were more damaging than previously estimated, but that CO_2 fertilization effects reduced the social cost of carbon dioxide. Dayaratna *et al*. (2017) had shown that new empirical constraints on the parameters of climate sensitivity (to carbon dioxide) that had emerged in the climatological literature implied much lower economic damages from greenhouse gases in the 21st century than even the AR5 had estimated. And Havranek *et al*. (2015) presented a review of 809 estimates of the social cost of carbon, concluding that publication bias prevented low estimates from appearing in the literature and it could not be ruled out that the credible range of estimates of the social cost of carbon had a lower bound of zero. The SR1.5 team made no mention of any of these (or many other) papers. Instead they elevated the papers by Warren *et al*. and Burke *et al*., which were outliers in the literature, to canonical status. To put their numbers in perspective, Burke *et al*. (2018) argued that the economic costs of half a degree of warming (going from 1.5°C to 2°C) would, over the coming 80 years, cause a loss of 1.5% to 3.5% of GDP annually, more than enough to eliminate global economic growth. By comparison, over the previous 130 years, the world had warmed by about a full degree while global economic growth has been continually, and dramatically, positive.

Later in this subsection we will discuss further concerns about the paper by Burke *et al*. (2018), but for now we return to the crucial discussion in SR1.5:

> Two studies focusing only on the USA found that economic damages are projected to be higher by 2100 if warming reaches 2°C than if it is constrained to 1.5°C. Hsiang *et al*. (2017) found a mean difference of 0.35% GDP … while Yohe (2017) identified a GDP loss of 1.2% per degree of warming, hence approximately 0.6% for half a degree. Further, the avoided risks compared to a no-policy baseline are greater in the 1.5°C case (4% …) compared to the 2°C case (3.5% …). These analyses suggest that the point at which global aggregates of economic impacts become negative is below 2°C (*medium confidence*), and that there is a possibility that it is below 1.5°C of warming.
>
> …
>
> In AR5, the transition from undetectable to moderate impacts [on the economy and biodiversity] was considered to occur between 1.6°C and 2.6°C of global warming reflecting impacts on the economy and on biodiversity globally,

> whereas high risks were associated with 3.6°C of warming to reflect the high risks to biodiversity and accelerated effects on the global economy. New evidence suggests moderate impacts on the global aggregate economy and global biodiversity by 1.5°C of warming, suggesting a lowering of the temperature level for the transition to moderate risk to 1.5°C … Further, recent literature points to higher risks than previously assessed for the global aggregate economy and global biodiversity by 2°C of global warming, suggesting that the transition to a high risk level is located between 1.5°C and 2.5°C of warming … as opposed to at 3.6°C as previously assessed (*medium confidence*). (IPCC, 2018: 265 (ch. 3); italics in original)

Thus, summarizing, the SR1.5 team acknowledged that the IPCC had previously found little evidence of concern for warming up to somewhere between 1.0°C and 2°C, but according to "new evidence" they were revising their position and concluding that the possibility exists for much greater harm at lower levels of warming. But, as we have pointed out, their "new evidence" was selective and omitted numerous studies that gave no basis for departing from the prior IPCC consensus.

We emphasize that the *Special Report* documents the potential benefits from limiting global warming to 1.5°C (compared to other possible thresholds), but it says nothing about the costs of doing so. As noted above, the SR1.5 specifically eschewed benefit-cost analysis so they were not in a position to make any policy recommendations.

4.2 Critical analysis of Burke *et al.* (2018)

The main source for the *Special Report*'s position was Burke *et al.* (2018), which found that limiting warming to 1.5°C rather than 2°C is "estimated to lead to median gains in global GDP per capita of 3.4% and discounted [using a 3% rate] avoided damages of US$36.4 trillion" by the year 2100 (Burke *et al*., 2018: 550). Since this particular study formed the backbone of the *Special Report*'s discussion of the climate economics literature, it warrants some scrutiny.

The damage estimates by Burke *et al*. (2018) were derived empirically, by running a regression on past data and estimating the (apparent) effect of short-term temperature fluctuations on short-term economic growth. Then they used climate-model-generated estimates (under various emission scenarios) of temperature change through 2100 in order to extrapolate the apparent reduction in baseline GDP by 2100. Burke *et al*. fit curves relating historical economic growth rates to nationally averaged temperature levels and found that small increases in temperature were associated with faster GDP growth in cooler countries, but slower GDP growth in warmer countries. This allowed them to construct a "response function" that models the impact of increasing

temperature on GDP growth. Starting from a low temperature, at first warming is good for an economy, but after an optimal temperature is reached, further warming slows economic growth. When Burke *et al*. then applied this response function to UN estimates of global warming by 2100, they concluded that there would be potentially enormous hits to the world economy under various emission scenarios because of the implied total warming.

There are several problems with this approach. In the first place, it fails to take account of adaptation. Even if it is true that a region has slower-than-usual economic growth during an unusually hot year, it does not follow that a permanently hotter country will suffer perpetual GDP losses. After all, rapid economic growth has been observed following economic liberalization in many hot regions including, among others, south Asia. Merely changing a factory's location from the northern to southern US entails a far greater experience of warming than even the worst-case climate scenario for the coming century, yet it does not impede economic growth because people adapt to the change. As Cass (2018) pointed out in reference to an earlier study by Burke (Burke *et al.*, 2015) and others in this genre, the projections lead to absurdities that defy common sense. For example, these projections would conclude that a northern US city such as Philadelphia would suffer more damage (in the form of heat deaths, for example) from climate change in the year 2100 than a southern city such as Houston suffered in the year 2010, even if the projected average temperature in the northern city in 2100 was lower than Houston's in 2010 (Cass, 2018: 8). [5] It is clearly fallacious not to take into account obvious adaptations—including more air conditioning, and changes in business and farming practices—that initially cooler locations would embrace, in the face of slowly rising temperatures occurring over the span of decades.

Another problem with such an exercise is that, for the purpose of extrapolating over nearly a century, tiny changes in the estimated growth rate compound into very large changes in the final result. But, the underlying data do not permit precise estimates of the relevant coefficients, and the modelers have considerable control over the final results based on how they do the econometric estimation. Newell *et al*. (2021) criticized Burke *et al*. (2018) as being overly reliant on a single functional form that yields conspicuously high cost estimates of warming, but does not fit the data any better than do rival model forms that yield strikingly different predictions. When Newell *et al*. (2021) take account of the uncertainty around the appropriate statistical model, they find the effects of temperature on GDP and economic growth cannot be distinguished

[5] The specific argument in Cass, 2018 about heat deaths focuses on absurd projections contained in a study by Mills *et al*. (2015). However, the general critique applies as well to papers by Burke *et al.* (2015, 2018), which likewise do not allow for adaptation in the face of prolonged temperature increases.

from zero and may even be globally positive, even when using the RCP8.5 scenario, which posits extremely high emissions over the coming century and which, as mentioned previously, has been sharply criticized for being exaggerated (see Hausfather and Peters, 2020; Burgess *et al.*, 2021).

The recent study by Greßer *et al.* (2021) is another that rebuts the findings of the SR1.5. They developed an expanded data set at the sub-national level that allowed them to control for country-level "fixed effects"—namely differences in the history and institutions that matter for explaining past economic outcomes. They state:

> Once we account for country fixed effects, we do not find a statistically robust relationship between regional temperature and three different measures of regional economic development … We also test whether temperature is non-linearly related to regional income (with hotter regions being potentially particularly prone to adverse effects of temperature on income) but find no systematic evidence in favor of such a relationship. Finally, we examine whether the effect of temperature on economic development is especially pronounced in poorer regions (*e.g.*, due to weaker adaptation). Again, we find no statistically robust link. (Greßer et al., 2021: abstract)

Brown and Saunders (2020) explored the different time scales between climate damages and abatement costs. Noting that damage estimates like those in Burke *et al*. (2018) need to be compared to the costs of attempting to prevent the damage, they took the damage model of Burke *et al*. (2018) and imported it into the DICE model. Applying a relatively low discount rate (3%) they still conclude that through the year 2100, the compliance costs from pursuing a 1.5°C (or 2.0°C) target exceed the benefits of avoided damages from climate change by a large enough margin that, again, it is worse than doing nothing. It is only by extending the timeframe—in their paper's case, through the year 2300—that Brown and Saunders (2020) are able to make the 1.5°C target produce cumulative net benefits.

In sum, the SR1.5 eschewed cost-benefit analysis and then cherry-picked a pair of studies that allowed them to jettison the prior consensus and put forward a very different conclusion regarding the economic costs of moderate warming. The studies they relied upon were new in the literature—leaving little opportunity for other researchers to comment upon them—and made implausible extrapolations that do not take adequate account of adaptation. They have subsequently been shown to lack robustness to reasonable testing of their econometric methods. The findings of the SR1.5 therefore fail to justify the view that a 1.5°C target could pass a cost-benefit test.

5 Conclusion

As the coronavirus pandemic subsides, the world's attention is returning to the threat of climate change, with many governments making commitments to drastically reduce carbon dioxide and other greenhouse-gas emissions. Those pushing for aggressive action have largely coalesced around a target, or at least aspirational goal, of limiting total global warming to 1.5°C. The discussion among policy experts, government officials, and major media would naturally lead the average Canadian to assume that the 1.5°C target was grounded in the peer-reviewed literature.

However, this is not at all the case, as we have demonstrated in this study. For example, William Nordhaus argues that a much more lenient target of 3.5°C would be optimal, and indeed that the 1.5°C target is so costly that it would be better for governments to do nothing at all rather than enforce such a draconian limit.

The United Nation's own 2018 *Special Report*, which lays out the ostensible scientific rationale for the 1.5°C target, does not even attempt to justify the 1.5°C ceiling by arguing its benefits outweigh its costs. Furthermore, the 2018 report departs from the consensus summarized in the UN's own earlier document from 2014. The small number of studies that the 2018 *Special Report* emphasizes are outliers in the literature, and achieve their large estimates of climate change damage through dubious methods that other researchers have criticized.

Canadian policy makers and the public should be wary of pursuing aggressive climate targets, in particular the 1.5°C ceiling, when such goals have been derived politically, not scientifically.

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Acknowledgments

The authors thank the anonymous reviewers for detailed and helpful comments on earlier drafts. The authors, however, are alone responsible for the report itself, its conclusions, and recommendations. As the researchers have worked independently, the views and conclusions expressed in this paper do not necessarily reflect those of the Board of Directors of the Fraser Institute, the staff, or supporters.

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ISBN

978-0-88975-657-1

Citation

Robert P. Murphy and Ross McKitrick (2021). *Off Target: The Economics Literature Does Not Support the 1.5°C Climate Ceiling*. Fraser Institute.

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