THE ROLE OF INDIVIDUALS AND INSTITUTIONS
IN CLIMATE CHANGE MITIGATION

by

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Abstract

People seeking to lower their carbon footprints can consult a broad, quantitative literature to help them identify the most impactful lifestyle decisions. Absent from this literature is research into which political actions might be more effective in reducing greenhouse gas emissions. Here I report my findings on obstacles and opportunities for motivated individuals to contribute to climate change mitigation both by changing their lifestyles and by taking political actions. I begin by examining how individuals can model low-carbon mobility in the workplace. Using data collected at the University of British Columbia, I found preliminary evidence that academics could lead by example in reducing air travel without limiting their academic productivity. Next, I surveyed 965 members of the North America public and found that individuals underestimated the emissions associated with air travel and meat consumption, while overestimating the emissions of symbolic actions like eating organic food. Furthermore, participants rarely considered political actions to be the most effective way to reduce emissions. To follow up on the question of how effective political actions are, I used the 2019 Canadian federal election as a case study. In that election, where climate change was a central concern of voters, I found the emissions responsibility associated with voting was higher than the emissions typically associated with lifestyle choices. While I was unable to quantify the emissions associated with other political actions, I attempted to further our understanding of which political actions are more effective through a field experiment. In partnership with a non-profit organization, members of the public sent generic emails to their elected officials, requesting that the officials post a pro-climate message to their social media accounts. I analyzed the elected officials’ social media accounts, and combined with interviews of their staffers, the data suggest that generic campaign emails are only marginally persuasive. I conclude that motivated members of the public may be missing opportunities, in multiple domains, to maximize their impact on the climate.
Lay Summary

Many individuals are motivated to reduce the greenhouse gas emissions that cause climate change, but how should they focus their efforts? I found that members of the North American public underestimate how useful it is to avoid air travel and eat a plant-based diet, while overestimating the effect of symbolic actions like avoiding plastic bags. Though it is harder to evaluate how political actions compare to lifestyle choices, I used the 2019 Canadian federal election as an example, finding that the emissions associated with voting can be higher than those associated with high-impact lifestyle choices (like living car-free). I also used a real-world experiment where citizens asked elected officials to post pro-climate messages to their social media accounts, finding that generic, campaign emails are only somewhat effective in persuading politicians. I conclude that motivated members of the public may be missing opportunities to effectively fight climate change.
Preface

This thesis is original work completed by Seth Wynes. Guidance was given by the supervisory committee.

A version of Chapter 2 was originally published as a research article (Wynes et al., 2019) in the Journal of Cleaner Production. I was responsible for data analysis and writing the text. My coauthors assisted with data collection and reviewing the manuscript before publication. This research received approval from the UBC Behavioural Research Ethics Board under UBC ethics certificate number H17-01125.

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Chapter 3 has been submitted for consideration as a research article. I was responsible for experimental design, data analysis and writing the text. My coauthors, Simon Donner and Jiaying Zhao assisted with experimental design and reviewing the manuscript before publication. This research received approval from the UBC Behavioural Research Ethics Board under UBC ethics certificate number H17-01053.

Chapter 4 was prepared as a short format article and is under review. An accompanying discussion piece has been included in Appendix A. I was responsible for conceiving the research, data collection, data analysis and writing the text with guidance from my supervisor, Simon Donner.

Chapter 5 has been submitted for consideration as a research article and is under review. I was responsible for experimental design, data analysis and writing the text, with guidance from my coauthors Simon Donner and John Kotcher. This research received approval from the UBC Behavioural Research Ethics Board under UBC ethics certificate number H19-00933.
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<th>Description</th>
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<tbody>
<tr>
<td>BEIS</td>
<td>Department for Business, Energy and Industrial Strategy</td>
</tr>
<tr>
<td>CO₂</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>GHG</td>
<td>greenhouse gas</td>
</tr>
<tr>
<td>hI-a</td>
<td>hI-annual index</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>kgCO₂e</td>
<td>kilograms of carbon dioxide equivalents</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>MP</td>
<td>Member of Parliament</td>
</tr>
<tr>
<td>MtCO₂e</td>
<td>megatonne (million tonnes) of carbon dioxide equivalents</td>
</tr>
<tr>
<td>MTurk</td>
<td>Amazon Mechanical Turk</td>
</tr>
<tr>
<td>pkm</td>
<td>passenger kilometer</td>
</tr>
<tr>
<td>SUV</td>
<td>Sport Utility Vehicle</td>
</tr>
<tr>
<td>tCO₂e</td>
<td>tonnes of carbon dioxide equivalents</td>
</tr>
<tr>
<td>TR</td>
<td>Travel Requisition</td>
</tr>
<tr>
<td>UBC</td>
<td>University of British Columbia</td>
</tr>
<tr>
<td>Wh</td>
<td>watt-hour</td>
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Dedication

To my wife, Althea.
Chapter 1: Introduction

Avoiding dangerous climate change caused by the human production of greenhouse gases will require immediate and radical reductions in worldwide emissions (Anderson and Bows, 2011; Friedlingstein et al., 2014). To limit global temperature increases to 2°C, per capita emissions must reach just 2.1 tonnes of carbon dioxide equivalents per year by 2050 (Girod et al., 2013). While technological changes may contribute to efficiency gains that reduce per capita emissions, those gains cannot be accomplished via technology alone; humans must interact with new technologies and therefore human behaviors must be accounted for when designing mitigation policies (Gram-Hanssen, 2013). And yet, the climate mitigation literature focuses on infrastructure and technology at the expense of behavioural and demand driven measures, partially because the latter are more difficult to quantify (Creutzig et al., 2016).

Climate change has been described as an issue requiring trans-disciplinary research solutions, where engineers, political scientists, economists, psychologists and various practitioners must work together to achieve more rigorous solutions (Creutzig et al., 2018). The approach I take in this dissertation is trans-disciplinary in that I integrate methods from multiple fields and partner with groups outside of academia to research common solutions. In most of this research I focus on the ways that individuals can contribute to climate change mitigation, elaborating on how governments, organizations and institutions can support them to make better decisions. Broadly speaking, there are two ways through which individuals can act to reduce the greenhouse gas emissions that cause climate change: by making lifestyle changes or by taking political action. The optimal way for an individual to influence politics will vary based on the political situation they are embedded in, and so it is important to understand the context before finding ways to act
within that system. In this introduction, I begin by discussing the political context of climate change mitigation in North America, where the research for my dissertation was conducted (Section 1.1.1). I also discuss ongoing climate movements in North America which are constantly interacting with and shaping those political systems (Section 1.1.2).

Next I transition to the question of lifestyle change. Because there is ongoing debate over the extent to which lifestyle change should play a role in climate change mitigation, I discuss the benefits and limitations of lifestyle choices, outlining the central arguments in this discourse (Section 1.2). I then examine the psychological barriers that oppose widespread adoption of climate-friendly lifestyles (Section 1.3.1). My background in education informs much of the research in this dissertation, so I also focus on the role that knowledge can play, both as a barrier and as a motivator for action (Section 1.3.2). Finally, in Section 1.4, I discuss the ways that institutions can empower individuals and model sustainability for society at large.

1.1 Political action in North America

1.1.1 North American climate change politics

Here I discuss some of the political challenges associated with climate change, detailing their various manifestations in North America. I also discuss some solutions proposed in the literature and provide a few examples of how they might be applied today.

1.1.1.1 Barriers to political action

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) summarizes the many obstacles to good governance of climate change (IPCC, 2014). Prominent
examples include market failures (where actions which benefit the public do not align with business interests), hyperbolic discounting (where long term needs are assigned low value), and coordination failures (where action requires cooperation from multiple government offices). Due to the confluence of hindrances that oppose or delay action, some researchers have described climate change as a “super wicked problem”. Some of the characteristics of a super wicked problem manifested by climate change include it being caused by the same group needed to engender a solution, the absence of a strong central authority, and the presence of irrational discounting which pushes the problem further into the future (Lazarus, 2008).

On a cognitive level, humans are not well-equipped to deal with climate change. The consequences are delayed and diffuse, and humans are more attuned to avoiding threats that are immediate and dramatic (Gifford, 2011). Climate change especially is subject to “a socially constructed silence” as the topic is actively avoided because it generates anxiety in conversations (Marshall, 2014). This gives little motivation for the public to remain engaged with the issue, or for the media to reinforce this engagement. Without public enthusiasm there is less incentive for public officials to spend political capital legislating solutions (Baumgartner and Jones, 1993).

Elected officials may be especially prone to ignore climate change. Politicians are by definition individuals who have succeeded after multiple gambles, and are therefore disinclined to make small sacrifices for large, distant threats (Marshall, 2014). Politicians are also typically elected for short terms, so they are not rewarded for passing legislation that addresses long term issues. Finally, policy makers are accustomed to using cost-benefit analysis (which advantages dependable, economic gains) and solving problems through compromise, which is not always
possible when preserving finite resources (Lazarus, 2008). For all these reasons climate change is generally difficult to address in a democratic system.

In the United States, political obstacles are more pronounced than in many other nations. The ideologically driven conservative movement in particular has stalled or blocked most substantial climate change legislation. This has been accomplished by misrepresenting or obfuscating scientific research, intimidating individual scientists, passing legislation that limits the effectiveness of government environmental units and invoking bias in the media to drive messages of confusion (McCright and Dunlap, 2010).

The success of this movement is partially due to the great availability of funding for such efforts (Brulle, 2014). There is severe financial asymmetry in the funding of climate movements: those seeking to enforce environmental laws or protest pollution have limited resources, while those associated with the status quo have significant budgets (Lazarus, 2008). This financial imbalance aids misinformation efforts but also anti-environmental politicians; oil and gas companies reward legislators who vote against the environment with increased campaign donations (Goldberg et al., 2020b). Beyond financing, the US Senate is generally reluctant to ratify international treaties as the political right is suspicious of the United Nations and fearful of anything that might interfere with US sovereignty (Harris, 2013). With the world’s wealthiest and second most-polluting nation refusing to take a leadership role, climate becomes difficult to solve at the international level.
Many of the obstacles that have stalled progress on climate change in the United States are also present in Canada, though often to a lesser extent. Canada is home to the Albertan oil-sands deposit, which has a massive influence on Canada’s economy and greenhouse gas emissions (Swart and Weaver, 2012). As in the United States, there are links in Canada between fossil fuel interests, third-party advocacy groups, and the dominant right-wing political party (Greenberg et al., 2011). Yet the more conservative, anti-reflexive movement is not homogenous across the nation. The province of British Columbia implemented a carbon tax that has served as an international model (Harrison, 2015) and has established climate targets and policies that are generally more ambitious than in almost any other jurisdiction in North America (Dale et al., 2019).

Differences in the inter-provincial approaches to climate change are sometimes substantial. Media in Alberta are more likely to tout the benefits of fossil fuel infrastructure than the rest of the country (Dusyk et al., 2018) and while climate change was the number one election issue for voters in British Columbia and Quebec in 2019, it was not in the top five for Albertans (Bricker, 2019). Since Canada has a decentralized federal system, with regional variations in greenhouse gas emissions, individual provinces have the ability and often the incentive to weaken national climate progress (Mildenberger et al., 2016).

1.1.1.2 Overcoming these political barriers

Overcoming the many obstacles facing successful political action on climate change requires careful consideration of possible policy outcomes. Levin et al. (2012) identifies three diagnostic questions to test the feasibility of climate policies: 1) what can be done to make the immediate
reversal of the policy difficult, 2) how can support be entrenched over time, and 3) how can the population of support be expanded? Immediate reversal of policies can be avoided by creating sunk costs or training a workforce (such as building a school for photovoltaic workers who then become the expanding population of support). Support can be entrenched over time by concentrating benefits in a certain population (such as schools and municipalities in British Columbia who benefit from carbon tax revenue).

But legislation is not the only way to accomplish national change. “Schattschneider mobilization” can be used by citizen groups to expand conflicts from skeptical venues to sympathetic ones (Baumgartner and Jones, 1993). This might include recent efforts to litigate against oil and gas companies for damages associated with a changing climate (Heidari and Pearce, 2016). Lazarus (2008) also suggests legislative and institutional strategies to protect environmental legislation or institutions. Commissions can be created to make political recommendations while providing plausible deniability to elected officials. Indeed, the recently formed Canadian Institute for Climate Choices may play such a role in the Canadian context (Wherry, 2020). Additionally, natural disasters and other large-scale interruptions of the status-quo offer moments of plasticity where politicians may have the ability to pass more radical climate legislation or fund projects that would otherwise be considered infeasible (McAdam, 2017). The recent COVID-19 pandemic may serve as such an opportunity.

Unfortunately, elected officials cannot be relied upon to decarbonize modern societies only through clever legislation, policy design and institutional strategies. Instead elected officials are likely to require increased support from their constituents and greater pressure from social
movements in order to accelerate mitigation efforts (Willis, 2018a). In the following sections I briefly explain how developments in the climate movement can spur political change and policy action.

1.1.2 Climate movements

1.1.2.1 Learning from failures and successes in recent climate movements

Many of the policies aimed at mitigating climate change in Canada have centered on constraining demand for fossil fuels. This includes promoting electric vehicles, home retrofits, and carbon pricing. While politicians have aimed to reduce demand, the climate movements in Canada and the United States have focused on constraining the supply of fossil fuels. Advocating for supply reduction has the advantage of appealing to concrete imagery, such as pipelines and power plants (Marshall, 2014). Key activists in this domain have described their movement as part of a resistance (McKibben, 2013b) spurring proliferation of oppositional narratives. Success has also been found through creating small wins, forming hybrid identities, and generating a positive feedback cycle where greater corporate or government opposition engenders more commitment to the cause (Cheon and Urpelainen, 2018).

If an issue can be broken down into many smaller problems, then a movement can gain momentum and encourage its participants by finding success in stages (Cheon and Urpelainen, 2018). These small victories increase participants’ sense of self-efficacy, which is an important consideration in maintaining participation (Roser-Renouf et al., 2014). Movements opposing new fossil fuel infrastructure, as well as the divestment movement can both take advantage of this principle.
Although there have been cases of allied movements fragmenting due to disagreements (Dietz and Garrelts, 2014), researchers describe hybrid activism as a generally positive feature for the success of social movements (Cheon and Urpelainen, 2018). Fielding support from more than a single organization has been found to be a critical determinant in swaying public officials and reducing the likelihood of fossil fuel projects being approved (McAdam and Boudet, 2012). Special effort can be taken to reach out to marginalized groups who have incurred disproportionate damage from environmental degradation. In Canada, First Nations groups have had success in using the courts to gain respect for their rights, which is especially relevant for cases involving the construction of oil sands pipelines (Hoberg, 2013). As I show in the next section, climate movements have recently taken great efforts to expand their framing and their coalition well beyond typical environmental tropes and allies.

1.1.2.2 Near term prospects for the climate movement

The divestment movement is a worldwide effort to convince pension managers and shareholders to divest their funds from fossil fuel companies. Initially, the movement was criticized for a lack of efficacy, since it was viewed as an ineffective way to reduce emissions that failed to have an economic impact (Ritchie and Dowlatabadi, 2015). Defenders note that the movement is focused more on revoking the social license afforded to fossil fuel companies, though the utility of such an approach is also questionable; the industry is already disliked by the public, but remains profitable because they are so necessary (Cheon and Urpelainen, 2018).
More marginal successes over the last five years may have gone unnoticed by many, but were anticipated by the founders of the movement (McKibben, 2013a). Social movements can create new social networks or organizational structures that go on to have delayed success (Piggot, 2017). In the case of divestment, there is evidence that highly involved student activists gain relevant skills which they end up applying when they join other campaigns in leadership roles (Cheon and Urpelainen, 2018). Divestment could also be responsible for reframing discourse; an analysis of mainstream media sources showed that the movement introduced radical phrases like “carbon bubble” into public discussion (Schifeling and Hoffman, 2017). Overall this has resulted in a shift of the Overton Window, such that discourse has ensconced notions of “stranded assets” within the financial sector (Schifeling and Hoffman, 2017).

A major goal of the divestment movement was to generate awareness of climate concerns amongst financial backers of fossil fuel projects (Braungardt et al., 2019), and recent events suggest that this goal may have been achieved. Insurance executives, concerned about the risks of climate change, are refusing to insure new coal mines, which in turn makes coal more costly and less competitive in the energy market (Oliver, 2018). BlackRock, the world’s largest fund manager, now intends to divest from coal (Partridge, 2020), and major financial institutions are refusing to invest or insure oilsands production in Alberta, on the rationale that their product is especially carbon intensive (Flavelle, 2020). Meanwhile, portfolios that divest from fossil fuel stocks and invest in clean energy companies have outperformed the portfolios that do not divest (Henriques and Sadorsky, 2018), making the decision increasingly prudent. Models predict that the combined effects of a divestment movement and investors fearful of a carbon bubble could
lead to a tipping point away from a fossil fuel economy (Ewers et al., 2019). If the divestment movement could contribute to such a shift, it would represent a huge win for climate activists.

In recent years, running alongside anti-fossil fuel campaigns, has been a movement originating in the United States calling for a Green New Deal: a massive spending program intended to simultaneously tackle social inequalities while investing in the large-scale societal changes required to decarbonize (Goh, 2020). In Canada, the Green New Deal found support not only from the New Democratic Party but also from major industrial unions (Aivalis, 2019). This is consistent with the original intentions of advocates who outlined plans for a broad coalition that includes environmentalists, minorities, organized labour, and farmers (Aronoff et al., 2019). While this egalitarian plan originally garnered approval across party lines in the United States, opinions on the Green New Deal quickly polarized along the expected left-right spectrum (Gustafson et al., 2019). Still, the policy goals have managed to inspire an energized social movement, unlike less ambitious proposals for carbon pricing.

The Sunrise Movement is the organization largely responsible for promoting the Green New Deal, and it shares both ideals and ambition with some other rising organizations in the climate movement. Extinction Rebellion, for one, has taken a prominent role in the media, largely from their controversial public protests which include acts of civil disobedience like blocking transport routes (Westwell and Bunting, 2020). Interestingly, their high-risk actions may be beneficial for engendering loyalty: activists have described being arrested as an important experience that increased commitment to a cause (Cheon and Urpelainen, 2018).
Fridays for Future (also known as the School Strike for Climate) has also become a prominent force in the climate movement, mobilizing millions of young people across the globe, most notably in the March 2019 event which was likely the largest climate rally to date (Grace, 2019). The youth-led climate strikes are an interesting example of a social movement intersecting with choices concerning lifestyle change. While the ostensible purpose of these strikes was to raise awareness and demand action from political figures, many of the protestors also believe that lifestyle changes have a role in mitigating climate change. An international survey of individuals who participated in the March event found that almost 60% of youth agreed with the statement, “stopping climate change must primarily be accomplished through voluntary lifestyle changes by individuals” (Wahlström et al., 2019). Many students described the example of Greta Thunberg, the young Swedish activist who founded the climate strike protests, as a central motivation for joining the movement (Wahlström et al., 2019). Although Thunberg’s oral pronouncements focus on the importance of government action, she has gained widespread attention for her commitment to her own low-carbon lifestyle, including her vegan diet and refusal to travel by air (Watts, 2019). In the next section, I discuss the intersection between lifestyle change and the climate movement, including the role that lifestyle plays in signaling consistency and urgency from climate leaders.

1.2 Encouraging lifestyle change

There is controversy as to whether experts, climate communicators and policymakers should advocate for personal changes in behaviour (which I refer to as lifestyle choices) at the expense of encouraging individuals to participate in political action. It is not a trivial point. A substantial amount of energy goes into encouraging people to change their lifestyle to reduce greenhouse
gas emissions. Documentaries are funded, filmed, and promoted. Carbon calculators are designed to help people understand emissions from their commute, their vacations and their household energy use. Pledges are circulated, in one case resulting in thousands of people committing to not fly for an entire year (Irfan, 2019). Yet some experts believe that this energy is misplaced.

Much of the disagreement over what to emphasize takes place in informal fora, where prominent climate activists and thinkers spar over the optimal way to catalyze societal change. Some thinkers contend that climate action should focus on holding corporate interests to account, and that lifestyle change represents a misguided distraction (Lukacs, 2017). Supporters of this view point to a report finding that 71% of industrial emissions can be traced to only 100 companies (Hyman, 2020), though the author of the report has explained that these companies provide consumers with fuel for private vehicles, household heating and air travel (Valle, 2018). Still, there is no doubt that a small group of corporations bear additional responsibility for misinforming the public (Supran and Oreskes, 2017), and may legally benefit from discourses that center responsibility on consumers (Hyman, 2020; Schwartz, 2018). Prominent climate activists have gone further than blaming specific corporations, instead labelling capitalism as the ultimate cause of climate change, and arguing that mitigation efforts must restructure our systems towards more egalitarian modes of organization (Klein, 2014).

More moderate voices see a focus on lifestyle as a purity test that disenfranchises potential allies (Grist, 2020). There is some evidence that climate advocates with exemplary climate lifestyles may be less persuasive than somewhat sustainable experts since they seem to engender feelings
of defensiveness in their audience (Sparkman and Attari, 2020). But the difference in efficacy is small and only marginally significant whereas advocates with exemplary lifestyles are still viewed much more positively than experts who make no efforts to be sustainable (Sparkman and Attari, 2020).

There is also a concern that lifestyle change is simply a less-powerful lever than policy change (Grist, 2020; Mann and Brockopp, 2020). NASA climate scientist Gavin Schmidt has voiced this worry, saying, “I think people should bike instead of driving, and they should take the train instead of flying … But those are small, compared to the really big structural things…” (Osaka, 2020). To be sure, there is an upper limit to how effective lifestyle changes alone can be in mitigating climate change. The COVID-19 pandemic has caused millions of people to work from home and avoid air travel, and yet the projected single year drop in emissions is still only comparable to what is needed every single year to reach the 1.5ºC target agreed upon as a safe limit to warming by the international community (Le Quéré et al., 2020). It is unlikely that a social movement based around lifestyle change could reduce emissions by this magnitude year after year, and so we can probably conclude that structural and policy-based change is needed at a minimum.

Even if lifestyle changes are insufficient for limiting warming to safe levels, they still may be useful, or even necessary. We know that there are benefits to lifestyle changes that go beyond the emissions reductions that can be measured per person, for example. Households are more likely to install solar panels when they see their neighbours leading by example (Graziano and Gillingham, 2014). There is also evidence for this “neighbour effect” in the purchases of hybrid
vehicles (Liu et al., 2017; Mau et al., 2008; Axsen et al., 2009), and a similar effect may be observed with changing perceptions of battery electric vehicles in the workplace (Axsen et al., 2013). People not only imitate their neighbours and coworkers, they also follow the direction of larger societal trends. Cafeteria goers are more likely to select a meat-free meal when they are primed with knowledge that plant-based diets are growing in popularity (Sparkman and Walton, 2017). Thus, actions labelled as individualistic can actually be communal: eating, homeownership and mobility choices occur in community, not in isolation, and influence the choices of others.

Much of this social influence can be attributed to local leaders. In one study, community organizers who had already installed solar panels on their own homes recruited 63% more residents to do the same than organizers without solar panels on their roofs (Kraft-Todd et al., 2018). The authors explained this phenomenon by making a comparison: when asking individuals to undertake a potentially high-cost behaviour, like eating a wild mushroom, leadership through action matters: “seeing someone eat the mushroom after they say it is edible gives you much greater confidence that they truly believe it is safe to eat, relative to someone who merely says that the mushroom is edible” (Kraft-Todd et al., 2018).

The role of social signaling may be even more critical for climate leaders and experts (Sparkman and Attari, 2020) who are under considerable scrutiny for their lifestyle choices (Gunster et al., 2018). Climate scientists in particular are viewed as more credible if they have low-carbon lifestyles, with this credibility affecting their audience’s willingness to engage in lifestyle change (Attari et al., 2016) and support climate policies (Attari et al., 2019). This is consistent with
evidence that the fly-less movement and the Fridays for Future movement have both benefited from the role of leaders (like Greta Thunberg) whose lifestyle choices are aligned with their policy demands (Westlake, 2017; Söderberg and Wormbs, 2019).

Efforts to focus on lifestyle change could be distracting, however, if they result in inefficient allocation of political capital or resources. Many behavioural interventions result in only small effects over a limited duration (Nisa et al., 2019), which would make them poor large-scale investments. But there are situations where behaviour change can be encouraged without wasting resources that could be spent in more effective ways. Young children can be educated on how to conserve energy and pass their learning onto adults at home (Boudet et al., 2016), for instance.

Research I conducted as part of my PhD comprehensive exam examined a range of interventions that encourage pro-environmental behaviours (Wynes et al., 2018). Many were straightforward, low-cost or even cost-saving approaches that institutions could implement without government support or incentive. Changing menus at a restaurant to encourage plant-based food consumption (Campbell-Arvai et al., 2014) or allowing employees to telecommute (Pendyala et al., 1991) would be two such examples.

Other interventions, however, might change lifestyles but reduce support for policy action. The most robust example of this in the literature comes from Japan, where participants who increased energy conservation efforts showed reduced support for carbon pricing (Werfel, 2017). Another study found that individuals who were made aware of the option to reduce emissions through a simple behavioural nudge became less supportive of more stringent policies like a carbon tax (Hagmann et al., 2019). Importantly, this effect was diminished when participants were informed
which of the two policies was more effective, so the obstacle does not appear insurmountable. Furthermore, encouraging lifestyle change does not always reduce policy support. Instead, in some domains it is easier to find support for a policy that curbs behaviours from those who already make voluntary reductions. Individuals who fly less are more likely to support soft and hard measures to reduce aviation emissions, while individuals who have stopped flying altogether prefer the most stringent measures for curtailing air travel (Gössling et al., 2020).

In summary, there is evidence that encouraging lifestyle change can be useful (though not sufficient) for mitigating climate change because it sends a social signal that inspires others to adopt the same actions and avoids charges of hypocrisy in climate leaders. Although there are certain areas when promoting lifestyle change is unlikely to compete with promoting political action, communicators and policy makers need better information on which situations warrant the allocation of resources to lifestyle change. Political actions that could reduce emissions (signing petitions, emailing elected officials) have not been quantified in the same way as lifestyle actions, where researchers have outlined a clear hierarchy based on assessments of greenhouse gas reductions. This makes it difficult to compare political actions to lifestyle choices, or even to other political actions.

Deciding which actions deserve greater attention is only a starting place. Actors seeking to increase pro-climate behaviours, whether they are related to lifestyle change or political actions, face considerable obstacles, many of them rooted in human psychology. In the following section I detail some of these obstacles, focusing on the role of education in overcoming them.
1.3 The psychology of behavioural change

1.3.1 Psychological barriers to lifestyle change

Even if the many structural barriers that currently prevent willing individuals from adopting climate-friendly lifestyles were removed, cultural and psychological forces would still oppose widespread action. Robert Gifford classified 39 such psychological barriers, which range from system justification, to perceived inequalities to optimism bias (Gifford, 2011). Some of these barriers are particularly relevant for this dissertation.

Technosalvation, a belief that technology will solve climate change is pertinent for institutions seeking to reduce air travel; promises of sustainable developments in aircraft technology have continually failed to materialize, but create enough uncertainty that officials hesitate to implement policy change (Peeters et al., 2016). Social norms and comparisons with others can likewise hinder progress. Academics who fly frequently sometimes justify their behaviour by making comparisons to colleagues who have even larger carbon footprints from air travel (Nursey-Bray et al., 2019). Even individuals who are motivated to act on climate change may engage in tokenism, where making one change is used to justify further inaction. This is especially harmful if individuals lack a sense of which actions are more important and can thereby morally license high-carbon behaviours by performing mostly symbolic actions instead. There are signs that certain psychological barriers may be growing less relevant as social dynamics and environmental cues shift. The segment of the American population that is alarmed about climate change has reached an all-time high (Goldberg et al., 2020a) and in Canada climate change has become a priority for the voting public (Bricker, 2019). Previously, the abstract nature of a seemingly distant problem like climate change made it difficult for the public
to feel genuine concern for a warming planet (Gifford, 2011). While humans are likely unable to perceive slow increases in temperature over multi-year timelines, the public may be more sensitive to extreme events (Moore et al., 2019). Residents in Florida who experienced a hurricane were more likely to believe that climate change was the cause of that event and more willing to make sacrifices for environmental solutions (Bergquist et al., 2019). In a study of 10 U.S. communities impacted by extreme weather, conservatives who were personally harmed by events were more likely to express support for climate policies (Zanocco et al., 2019). As extreme events increase in frequency and severity, people may no longer struggle to perceive climate change as an immediate danger.

Going forward it is even possible that psychological mechanisms which previously acted as barriers may begin to facilitate positive change. Our tendency to rely on social norms is a hindrance if a social norm is highly-polluting, but when norms shift towards low-carbon behaviours or towards political views and actions that favour climate advocacy, then change can be rapid. The Fridays for Future protests offer an example of this. If a small number of school children go on strike, then there are large social costs for the individual to joining. But as the percentage of a population engaging in a strike increases, costs to joining decrease, facilitating the growth of a movement (Farmer et al., 2019).

1.3.2 The role of education in overcoming cognitive barriers to action

Another barrier to climate change action is ignorance, either of the existence of the problem, or of potential solutions. Knowledge is not a sufficient condition for environmental action: even the most knowledgeable individuals sometimes have very high carbon footprints (Balmford et al.,
2017). But understanding the problem and how to solve it is still an important predictor of pro-environmental behaviors (Bamberg and Möser, 2007; Hines et al., 1987).

Regarding climate in particular, greater objective knowledge is associated with increased belief in climate change, though this relationship can be overshadowed by opposing partisan tendencies (Hornsey et al., 2016). Certain items of knowledge are more resistant to these polarized filters, such as knowledge of the scientific consensus on climate change. Conveying understanding of the scientific consensus has been shown to increase worry about climate change and increase support for public action (van der Linden et al., 2015; van der Linden et al., 2019). Given ongoing misinformation campaigns, there is still value in presenting well-crafted, educational messages on climate change.

As for knowledge of solutions, my own research showed that recommendations in government documents and educational resources do not focus on the most effective actions to reduce personal emissions (Wynes and Nicholas, 2017) and that secondary schools may not be focusing on the aspects of climate change that would be expected to result in greater policy support or pro-climate behaviour (Wynes and Nicholas, 2019). It is important that we understand gaps in the public’s knowledge regarding information that is likely to cause greater support for climate action, and regarding those actions with the greatest impact to reduce an individual’s personal emissions.
1.4 Public institutions as agents of change

Public institutions represent an intersection of scales for climate mitigation. They are small enough that single individuals can either help to catalyze positive change or prevent it from happening (Ferrer-Balas et al., 2008). But they are also large enough that their tested solutions can be adopted by local and regional governments. Prominent environmental experts have voiced a need to connect global efforts to curtail emissions with polycentric efforts at smaller scales, acknowledging the need for greater policy experimentation (Ostrom, 2012). Here I briefly describe some of the ways that institutions, especially universities, can act as role models and case studies for societies in need of solutions to rapidly decarbonize.

Universities have had a long-standing role of contributing to the cultural and economic development of their local region (Trencher et al., 2014). In recent times, this contribution has been framed under the living laboratory approach, where “stakeholders develop and test new technologies and ways of living to address the challenges of climate change and urban sustainability” (Evans et al., 2015). The benefits of this approach extend in multiple directions. Students gain practical experience solving real-world problems while being exposed to ideals of social responsibility. Institutions use the expertise of their student body to improve campus functioning and governments can scale up experiments with positive outcomes to their city or region.

The University of British Columbia, where this research was conducted, has taken sustained steps towards adopting this approach by embedding sustainability learning in undergraduate courses as well as sustainability initiatives that bring together faculty with university
stakeholders (Marcus et al., 2015). A similar living lab process can occur when governments test out climate mitigation initiatives. These can be implemented anywhere from the local to the federal level, and cover high-emitting divisions like government fleets (Government of Canada, 2018) and buildings (Government of Canada, 2019). Many energy saving initiatives also reduce costs, which helps to reduce ideological opposition by demonstrating savings for taxpayers (Feiock and Bae, 2011). Initiatives that were limited to government buildings or fleets can then be extended to the rest of the community with less risk that the next government will revoke the policies.

Sometimes, institutions can transfer sustainable practices to the rest of society simply by modelling them. For instance, at universities, the transfer of cultural practices occurs when those who engage with the university (public and industrial partners, students etc.) are exposed to those practices (Stephens et al., 2008). But if universities are to act as models for sustainable practices, then they must undergo transformational change themselves.

One of the main barriers to creating such change has been the lack of incentive for individuals (often faculty, but also administrators) to alter their practices (Ferrer-Balas et al., 2008). Instead of being rewarded for modelling sustainable behaviour, faculty are likely to encounter perverse career incentives. For instance, air travel can occupy a significant portion of an academic’s carbon footprint, yet promotions are often contingent on delivering international lectures and attending a large number of conferences. Additionally, researchers are incentivized to focus on publishing within their subject silos, instead of seeking interdisciplinary collaborations or
conducting outreach beyond the walls of academia (Cortese, 2003). This limits the potential impact academics can have on their communities.

Here we see an interconnected series of impediments. Institutions could model decarbonization for their regions, but are constrained by faculty and administrators, who are themselves constrained by institutional rules and cultures. Politicians could legislate climate action, but are confined to the will of their electorates, who are in turn demotivated by misinformation and innate psychological barriers. This dissertation seeks to understand some of the select obstacles that oppose positive change.

1.5 Motivating the research questions

I previously noted that members of the public take the efficacy of climate policies into account when forming preferences (Hagmann et al., 2019). This hints at an underlying assumption motivating the research questions in this dissertation; people want to use more effective tools to tackle climate change. Individuals who have given up air travel describe the realization that flying occupied a large part of their carbon footprint as an important moment in their decision-making (Söderberg and Wormbs, 2019). Research has shown that people are more willing to undertake behaviours that they view as having greater potential to tackle climate change (Truelove and Parks, 2012). It then seems reasonable to answer a few broad questions: Which lifestyle choices are more effective at reducing greenhouse gas emissions? Which political actions are more effective? How do individuals rank these different actions? Can these actions be undertaken without causing harm to one’s personal interests? These are some of the questions that I attempt to answer over the course of this dissertation.
1.6 Structure of this dissertation

Chapter 2 examines the case of business air travel at the University of British Columbia, using data originally collected for a report with the Pacific Institute for Climate Solutions (Wynes and Donner, 2018). Based on travel reimbursement reports from eight units on campus, I analyze the air travel habits of students, faculty and administrators on campus. Patterns in travel are used to understand two central areas of concern. First, are faculty who study areas related to sustainability taking on a leadership role in reducing their greenhouse gas emissions from air travel? Second, do faculty who reduce their air travel face competitive disadvantages in terms of their academic productivity? Answering these questions sheds some light on the extent to which undertaking lifestyle changes might harm one’s personal interests. In this case the result is important because air travel is a highly visible activity, and one which societal elites who drive cultural change engage in quite frequently.

Travelling by air can form a substantial portion of an individual’s carbon footprint (Lacroix, 2018; Wynes and Nicholas, 2017), but other lifestyle choices also matter. In Chapter 3 I report the findings of surveys taken of students at the University of British Columbia and of the general North American public which elaborates on some of these other decisions. In this research I seek to understand whether individuals understand the most effective ways that they can mitigate climate change. I test this through four trade-off questions, a ranking question and an open-ended question. The trade-off questions allow me to understand how the public’s knowledge might interact with their behaviour through moral licensing. The other two types of questions allow me
to compare the public’s understanding of how political actions compare in efficacy to lifestyle actions.

Having surveyed the public’s beliefs on lifestyle versus political action, I hoped to then find a way to quantitatively compare these two areas. In Chapter 4 I use the 2019 Canadian Federal Election as a case study to understand the emissions responsibility associated with one type of political action: voting. By comparing the emissions responsibility with lifestyle choices, I draw some conclusions of the relative value of voting. I also suggest some changes that democratic jurisdictions could implement in order to enhance the ability of their citizens to make decisions regarding climate change. When trying to understand the emissions responsibility of political actions, voting is a good place to start both because it is the foundational political action of democracies, and also because cause and effect are more closely related than for other political actions.

Although it may not be possible to quantify the efficacy of most political actions in terms of greenhouse gases reduced, it might be possible to arrange a sort of hierarchy of efficacy. Perhaps actions such as voting could be shown to be consistently more politically effective than signing a petition, for example. In Chapter 5 I discuss a field experiment where members of a non-partisan organization emailed their elected officials requesting that those officials post pro-climate messages to their social media accounts. By analyzing changes in those social media accounts, I evaluate the actual efficacy of campaign emails in persuading elected officials to take greater action on climate change. I also describe findings of interviews conducted with legislative staffers, which imply a rough hierarchy for modes of communication with elected officials in
Canada. Taken on its own, this study only sheds light on communication with elected officials in a particular context, leaving a whole range of other actions untested. But it does give a blueprint for how subsequent studies could build a picture whereby the most effective political actions could be evaluated.

In Chapter 6 I synthesize some of these findings, placing them in the context of existing literature. I also return to the question of lifestyle choices, making recommendations on which lifestyle choices deserve attention and where political action should take precedence. Finally, I make specific suggestions for future work that could be carried out to answer some of the questions raised by this research.
Chapter 2: Academic air travel has a limited influence on professional success

2.1 Introduction

In recent decades, aviation has been one of the fastest growing sources of greenhouse gas pollution (Bows-Larkin and Anderson, 2013). Growth in air travel shows no signs of slowing, as the number of air travel passengers is projected to nearly double by 2036 (IATA, 2017). Meanwhile, technological developments in aviation are slow and unlikely to offset growth in demand, and neither governments nor the aviation industry has made significant progress in regulating the industry (Bows-Larkin et al., 2016). If the mitigation efforts of international aviation continue to underachieve compared to other sectors, the share of global carbon dioxide (CO₂) emissions for this sector could grow to 22% of the global carbon budget (Cames et al., 2015). Researchers have therefore claimed that reductions in demand for air travel may be necessary for meeting climate targets (Girod et al., 2013; Bows-Larkin, 2015).

Business is an important driver of air travel; for example, the World Tourism Organization finds that 13% of international trips are conducted for business or professional purposes (UNWTO, 2017). In person meetings are part of the culture of many industries, and travel is therefore believed to be key for professionals in maintaining the social networks that are associated with success (Urry, 2012). Kroesen (2013) conducted a survey of Dutch travellers, finding that 10% of the sample, who tended to be older, high-earning, frequent flyers, justified their air travel by the need to perform well at work, additionally stressing that there were no alternatives to flying. A study conducted at the Tyndall Centre for Climate Change Research found that half of respondents agreed that they flew to maintain and develop work relationships, and over 30% felt an expectation to fly from their university (Le Quéré et al., 2015).
While air travel for personal reasons can be highly discretionary – motivated by the desire to simply get away for a single weekend (Higham et al., 2014) or to tick destinations off a mental list of places visited (Randles and Mander, 2009) – professional travel may be more driven by perceived or actual necessity. In academia, international teams meet to coordinate their research, conferences host graduate students and lecturers, and field work involves flights to distant locations. Missing research or networking opportunities may reduce an academic’s ability to collaborate, to publish frequent, high-impact research, or to maintain visibility in a field in order to be frequently cited (Storme et al., 2013). Indeed, internationally collaborative research results in publications with higher citation impact scores (Adams, 2013) and “mobile scholars” (those who change affiliations) have 40% higher citation rates than non-mobile scholars (Sugimoto et al., 2017). Efforts to mitigate greenhouse gas emissions from air travel may come into conflict not just with cultural norms of many professions and industries but could also interfere with the general efficacy of those industries. Yet to date, no studies have evaluated whether academic success is related to air travel.

One might expect that in a professional setting where climate change and sustainability are readily available subjects, individuals might be more cognizant of their carbon footprint and less likely to undertake polluting behaviours like air travel. This would certainly be the case for academics who study climate change, sustainability, and closely related topics. Indeed, there is additional motivation for such academics to track their carbon footprints: the size of a climate researcher’s carbon footprint from air travel (specifically for work-related purposes like lectures and conferences) has been shown to affect their credibility in the eyes of the public (Attari et al.,
Furthermore, a ten-year study of English-speaking media coverage found that 32% of all accusations of hypocrisy levelled against pro-climate actors mentioned their flying behaviour – more than for luxury behaviours, driving, or diet (Gunster et al., 2018). Yet pro-environmental behaviours are contextually driven; individuals are more likely to undertake pro-environmental behaviours in their home than at a hotel, for instance (Miao and Wei, 2013; Baker et al., 2014). Balmford et al. (2017) investigated the carbon footprints of various academics, finding that conservationists fly substantially less than economists for work purposes and slightly less for personal purposes. It is difficult to know if this disparity between work behaviour and personal knowledge is caused by environmental values, or differences in work expectations between fields.

In this study, we examine the drivers of air travel behaviour at a large university using a unique database of air travel and publicly-available records on research productivity and compensation. Observed measurements have the advantage of avoiding failures in recall which often lead to underestimations in travel surveys (Clarke et al., 1981). Although other studies have used self-reported results to quantify the air travel behaviour of individuals or companies (Balmford et al., 2017; Lu and Peeta, 2009; Denstadli et al., 2013; Andersson and Nässén, 2016; Alcock et al., 2017), ours is the first that we are aware of to create an air travel emissions inventory and use it as a natural experiment. First, we assess the relationship between common measures of academic success (e.g., bibliometrics such as h-index, authors per publication, university salary) and emissions from air travel. Second, we classify academics as either “Green” or “Not-green” based on their areas of interest and then analyze differences between the two groups in travel behaviours, searching especially for differences in types of air travel that could be avoided with
minimal effort on the part of the academic. By identifying the interests of academics spread through several departments, we aim to control for workplace norms and understand how personal motivations influence behaviour.

2.2 Materials and methods

For this study, we created a database of air travel undertaken over an 18-month period by travellers at the University of British Columbia (UBC). Ethics permission for the study was obtained from the UBC Behavioural Research Ethics Board. We contacted 26 academic departments, institutes, and faculties (henceforth referred to as units) representing the administrative homes of all faculty on UBC’s Vancouver campus, eight of whom agreed to participate in our study. These units provided access to hard or soft copies of their travel requisition (TR) forms. From these forms, we entered the name (later anonymized), date, TR form number, cost, ticket class, length of trip (in number of overnight stays), airport codes, primary and secondary purpose, and additional information (number of flight segments) into the database. Trips were coded as Conference (e.g. conferences, workshops, group meetings), Fieldwork, Lecture (colloquiums etc.), University Business (board meetings, faculty searches) and Other. TR forms which did not include information on ticket class were assumed to be Economy class. We collected data on a total of 997 travellers taking 1,769 trips. This study employs data for 705 of those travellers who were academics with identifiable positions (undergraduate students and guests with unknown affiliations were excluded).
2.2.1 Air travel emissions data

Greenhouse gas emissions per flight segment and per trip were computed following methods developed by the United Kingdom’s Department for Business, Energy and Industrial Strategy (BEIS). The calculator uses CO₂ emissions factors for fuel burned in an average flight by representative aircraft with emissions allocated per passenger kilometer (pkm) based on average seating capacities and load factors (BEIS, 2016). Distance between the airports was calculated using greater circle distance and an 8% uplift factor was applied to account for additional distance travelled for holding patterns, etc., as recommended by the BEIS. Different factors are used for Economy, Economy Plus, Business, and First Class flights as higher class seating occupies more space aboard the aircraft and passengers in those seats can be considered responsible for a larger fraction of emissions (BEIS, 2016). The average quantity of greenhouse gases (measured in CO₂e, carbon dioxide equivalents) produced per pkm by domestic, short, and long haul flights, in the different classes, and accounting for average occupancy of the aircraft are shown below (Table 1). Finally, in our calculations, we include the radiative forcing multiplier of 1.9 to account for the additional net warming influence of high-altitude emissions (Lee et al., 2009). While some might choose to forgo this multiplier or even the 8% uplift factor, their inclusion in this study only affects the absolute reported values and not the findings of the study, which are based on comparisons within our sample.

Table 1: Emissions factors for different types of air travel (kgCO₂e/pkm)

<table>
<thead>
<tr>
<th>Class</th>
<th>Economy</th>
<th>Economy Plus</th>
<th>Business</th>
<th>First</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Haul</td>
<td>0.27867</td>
<td>0.27867</td>
<td>0.27867</td>
<td>0.27867</td>
</tr>
<tr>
<td>Medium Haul</td>
<td>0.16508</td>
<td>0.24761</td>
<td>0.24761</td>
<td>0.24761</td>
</tr>
<tr>
<td>Long Haul</td>
<td>0.14678</td>
<td>0.23484</td>
<td>0.42565</td>
<td>0.58711</td>
</tr>
</tbody>
</table>
2.2.2 Academic profiles

To test for the relationship between academic achievement and professional air travel emissions, we collected data on publicly available measures of professional success (salary, h-Index, and seniority within an institution) and on field of expertise for the UBC faculty, Research Associates, and Lecturers in the sample (data were available for 165 of the 208 faculty, Research Associates, and Lecturers [teaching faculty]).

Academics’ salaries were retrieved from publicly available financial summaries which UBC publishes annually. Since salary increases with seniority, we created a new metric to separate these variables. Adjusted salary of individual \( i \), measures salary increase per year and is calculated by subtracting the average starting salary for this sample (estimated by using the y-intercept of the linear regression for salary versus academic age) and dividing by academic age (number of years since first publication).

\[
AS_i = \frac{S_i - 95013}{AA_i} \quad (1)
\]

The h-index, a measure of the number of publications produced by a researcher and the number of citations those publications receive, was computed using Harzing’s Publish or Perish Version 5 software, which retrieves bibliometric information on faculty from Google Scholar. We searched all faculty members listed on the departmental websites of departments that we sampled, first by searching their Google Scholar profiles. When no profile was available, we chose the name to search in the software from their publications list as shown on the website,
e.g., “TM Jordan.” Where a name was common, we disambiguated using the recommendations provided in the Publish or Perish software, and also added each institution at which the faculty member had worked or been a student when that information was available (found on UBC’s website or the website LinkedIn) under the advanced search function “Any of these words.” Other possible measures of professional success or academic productivity, like number of research grants held, grant dollars received, and number of followers on Twitter, were not used here because data was not available for a sufficient fraction of the sample population.

Many metrics of academic productivity, including h-index, are highly correlated with career length, as well as the field in which they publish. To make comparisons between researchers in different career stages and in different fields, we therefore chose to use the hI, annual index, or hIa. The hIa can be calculated by taking the total number of citations for each paper divided by the number of authors on the paper, finding the h-index number of this normalized citation count, and then dividing by academic age (Harzing et al., 2014). The hIa is particularly sensitive to false positives generated when two different researchers share the same name, especially when very old publications are ascribed to a young researcher (thus giving them a substantially longer career length). We therefore sorted the list of publications by year and eliminated those published prior to the start of the faculty member’s career in academia (as listed on their curriculum vitae or biography found on the UBC website). To further eliminate false positives, we searched the list of generated references for papers with titles that were dissimilar to the researcher’s field of interest and for authors with names that were similar but not specified by search terms (e.g., when searching for “C Miller,” Publish or Perish may produce false positives for “CJ Miller” or “TC Miller” which we excluded if they were not the author in question). Since
h-index (and also hIa) removes the effect of a small number of seminal papers with a high number of citations, we also tested for relationships between travel behaviour and total citations (as well as citations normalized by academic age and authors per paper).

To test for the relationship between a faculty member’s area of research and their professional air travel emissions, we coded each of the faculty members found in our sample into either a Green or Not-green academic classification. To do this, three raters read through the UBC profile of each faculty member present in our travel data, searching for one of eleven keywords (or variants of those keywords) which we anticipated would be associated with increased knowledge and concern for the climate impacts of aviation: sustain*, climat*, environment, greenh*, conserv*, biodivers*, ecosystem service*, carbon, renewable, green, and natur*. Identified keywords were ignored if the context of the keywords did not indicate further relevance. Searches were limited to a faculty member’s area of research and teaching interest, which did not include a list of courses taught or a list of past or current projects. This method was employed to avoid false positives; for example, a statistics professor might collaborate on a climate project but not have any research interests in that particular field. Searches were also limited to UBC online profiles, unless the departmental website clearly indicated that the individual in question was a full-time instructor or academic and their interests were described on their own webpage. Faculty who did not meet these criteria (no available profile) were excluded from this analysis. The coding of all three raters was compared against each other (88% initial agreement, n=165) and then the three raters discussed profiles where there was disagreement. Conflicting ratings were settled by further referencing other online information retrieved from a ResearchGate or LinkedIn profiles or a list of their publications.
Because data availability varied between the categories (e.g., a clinical instructor may have had salary information but no online profile and no bibliometric information), the maximum possible sample size varies between the different statistical tests that we conducted (Table 2). To maintain consistency, where possible, all tests were conducted on a core group of research academics for whom salary, bibliometric, and online profile information was available (n=128), which we refer to as the Core Sample. The Green Profile sample contains a larger group of academics for whom online profile data was available to classify researchers as Green or Not-Green, but for whom bibliometric data may not be comparable (e.g. Research Associates). The Career Stage sample is used for analysis involving seniority and only includes Graduate Students, Postdoctoral Researchers, Assistant Professors, Associate Professors and Professors. To check for bias in our sample, we also collected information on the academic positions of 220 guests (whose air travel was paid for by UBC) by conducting online searches for their names (Guest Sample).

Table 2: Demographic breakdown of the sample

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Male</th>
<th>Female</th>
<th>Green</th>
<th>Not-green</th>
<th>Professor</th>
<th>Associate Professor</th>
<th>Assistant Professor</th>
<th>Other Employees1</th>
<th>Post-docs</th>
<th>Grad Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Sample</td>
<td>128</td>
<td>83</td>
<td>45</td>
<td>49</td>
<td>79</td>
<td>74</td>
<td>30</td>
<td>15</td>
<td>9</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Green Profile</td>
<td>165</td>
<td>105</td>
<td>60</td>
<td>63</td>
<td>102</td>
<td>77</td>
<td>35</td>
<td>18</td>
<td>35</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Career Stage</td>
<td>450</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>78</td>
<td>35</td>
<td>20</td>
<td>N/A</td>
<td>59</td>
<td>258</td>
</tr>
<tr>
<td>Guest Sample</td>
<td>220</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>52</td>
<td>25</td>
<td>16</td>
<td>67</td>
<td>14</td>
<td>46</td>
</tr>
</tbody>
</table>

1Includes Deans, Adjunct Professors, Instructors, Research Associates, etc.

2.2.3 Statistical analyses

We used the collected data to test for relationships between travel behaviour, as measured by trips taken, distance traveled, and emissions produced, and the individual characteristics
described in the academic profile. We analyzed relationships between variables first with t-tests, ANOVAs, and Spearman correlations. Student t-tests were used in cases of equal variance, but where F-tests showed unequal variance, Welch’s t-tests were used. Welch’s ANOVA was used for comparing data with unequal variance, followed by Games-Howell Post Hoc tests. We built OLS regression models to understand which variables were independent predictors of increased emissions or kilometers travelled. Breusch-Pagan tests were used to check for heteroskedasticity, and where p<0.05 we conducted power transformations of the data. To avoid extensive trial and error, we identified the optimal exponent for transformation using the Box-Cox technique (Osborne, 2010). When investigating relationships between characteristics of researchers and binary outcome variables (such as whether faculty did or did not bill air travel during the assessed time period) logistic regression was performed and evaluated with repeated cross validation.

We tested for differences between Green and Not-green flyers by examining total emissions and also by searching for differences in specific types of flights that might be easily avoided (referred to here as “avoidable emissions”). These were flights that would require minimal effort to replace, including: brief trips (less than one or just a single overnight stay), brief but long distance trips (greater than 3,700 km round trip but with only a single overnight stay), short trips that could reasonably be replaced by other modes of transportation (less than 312 km one way), and flights with higher class tickets (Economy Plus, Business, or First Class seats). Testing specifically for differences in “avoidable emissions” is important because the effect of these actions on total emissions of a flyer might be undetectable. For instance, a conscientious flyer might have a large emissions footprint because of long haul flights to attend a week-long
conference or perform a month of field work, deemed by that person to be well worth the emissions, but may still take actions like substituting short distance flights with public transit or avoiding any non-economy class travel. We therefore tested for differences in total emissions in these avoidable categories as well as for differences in each individual category.

2.3 Results

Our collected data contains 1,769 trips taken by 997 individual travellers from January 2015 to June 2016. These trips were responsible for 3,018.81 tCO$_2$e. Two hundred and eight of the travellers were faculty, Research Associates, or Instructors in the eight units, and they were responsible for 47% of the total air travel emissions from the sample. Guests to UBC comprised 22% of all individuals in the sample and 41% of professors (assistant, associate, or full). Guest Professors were responsible for 82% fewer emissions (157.80 tCO$_2$e) than UBC Professors (882.00 tCO$_2$e) because the guests generally only had one trip billed to UBC.

This data allows trips to be classified by purpose and by category, like distance and length. Focusing on academic air travel (excluding trips by undergraduate students and administrative staff), the primary purpose of most trips was for conferences (60%), with the remainder attributed to fieldwork (16%), university business (6%), lectures (5%) or other miscellaneous and unreported purposes (13%). Air travel trips that could be categorized as avoidable – same day return, one night long-haul trips, or short distance – comprised 5-10% of all trips in the samples (Table 3). Some individuals also flew with tickets that were higher than economy class (e.g. business class). The number of trips that took place that were either avoidable, or where at least
one leg of the journey was booked with higher class tickets comprised 16-26% of trips in these
samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total Trips</th>
<th>Same day returns</th>
<th>&gt;3700km, one overnight</th>
<th>&lt;312km</th>
<th>Percent of avoidable trips*</th>
<th>Higher class tickets</th>
<th>Percent of trips with avoidable emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Sample</td>
<td>548</td>
<td>22</td>
<td>12</td>
<td>21</td>
<td>10%</td>
<td>87</td>
<td>26%</td>
</tr>
<tr>
<td>Green Profile</td>
<td>635</td>
<td>22</td>
<td>13</td>
<td>23</td>
<td>9%</td>
<td>101</td>
<td>25%</td>
</tr>
<tr>
<td>Career Stage</td>
<td>997</td>
<td>22</td>
<td>13</td>
<td>15</td>
<td>5%</td>
<td>111</td>
<td>16%</td>
</tr>
<tr>
<td>Guest Sample</td>
<td>248</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>8%</td>
<td>23</td>
<td>17%</td>
</tr>
</tbody>
</table>

*Percent of trips that are either same day returns, longer than 3700km but with only one overnight, or less than 312km in distance (and therefore replaceable by ground travel).

The greenhouse gas emissions per individual flyer increase with career stage in the sample (Figure 1). According to Welch’s ANOVA one-way test for unequal variance and Games-Howell post-hoc tests (which control for multiple comparisons of unequal size and variance), graduate students (M=2.44 tCO₂e) and post-doctoral students (M=2.49 tCO₂e) in the sample had lower mean emissions than Associate Professors (M= 5.40 tCO₂e) or Professors (M=7.52 tCO₂e) (p<0.05 and p<0.001 respectively). Testing revealed no significant differences in emissions between genders when comparing within the group of Professors, Associate Professors, or Assistant Professors (data on gender of graduate students is incomplete). Logistic regression showed no statistical difference in the likelihood of researchers from differing career stages to take a trip in the avoidable emissions category or not. However, in terms of the quantity of emissions produced by travelling with higher class tickets, Welch’s ANOVA showed significant
differences between career stages ($F=4.77$, $p=0.001$), where Professors had greater emissions from purchasing higher class tickets than Postdoctoral Researchers or graduate students.

![Box plot of emissions by career stage](image)

**Figure 1:** Emissions of individual travellers grouped by career stage, $n=450$. Note that some points beyond 20 tCO$_2$e are not visible here.

### 2.3.1 Metrics of academic performance

We found no statistically significant relationship in the Core Sample between the emissions from professional air travel of faculty members who flew during the time period of our sample and their h-index scores ($r_s=0.13$, $p=0.14$) (Figure 2). While h-index is a popular metric for an author’s productivity and citation impact, it is heavily influenced by academic age and by field of research, making hIa more appropriate for our purposes. There was also no correlation between hIa and emissions from professional air travel emissions ($r_s=0.04$, $p=0.69$). When we compared academics at the same career stage (for instance, the 74 Professors in the Core Sample), the correlation between hIa and emissions was also not significant ($r_s=-0.10$, $p=0.37$). Neither total
citations, nor citations normalized by academic age and authors per paper had a correlation with trips taken, distance travelled, or emissions from air travel (see Figure 2). Finally, we expected that increased air travel would allow for greater collaboration with other academics, and that there might be a relationship between the average number of authors per paper listed on a researcher’s publications and their aviation emissions, but the correlation was not significant ($r_s = -0.05$, $p=0.55$).

Figure 2: Correlation matrix showing Spearman correlations; ⋅ indicates significance at the 10% level, * indicates significance at the 5% level, ** at the 1% level, *** at the 0.1% level

We repeated these tests using kilometers travelled, instead of emissions, to evaluate whether the use of different emissions factors for short, medium, and long haul air travel as well as different classes of tickets influenced the results. No relationships that were significant became not significant and vice versa using distance travelled as opposed to emissions (the correlation between distance travelled in kilometers and emissions produced is 0.99 for this sample).
Salary is correlated with emissions \((r_s=0.29, p<0.001)\) in the Core Sample, but because salary increases with seniority, adjusted salary (or salary increase per year) is a more informative measure. Adjusted salary is also significantly correlated with emissions \((r_s=0.28, p<0.01)\) (Figure 3). We would expect to find that a university would compensate researchers who are more highly cited with greater salaries, and we do find that adjusted salary is positively correlated with hIa \((r_s=0.41, p<0.001)\). There was no significant difference in mean adjusted salary between men and women in the Core Sample \((t=-1.70, 95\% \text{ CI } [-912.94, 71.00], p=0.09)\) or in the more homogenous sample of core Professors \((t=0.20, 95\% \text{ CI } [-482.49, 590.06], p=0.84)\) (see Section 3.3).

**Figure 3**: Adjusted salary (salary increase per year) versus emissions generated by air travel for research faculty (Core Sample).

To test whether the findings are affected by excluding faculty who did not travel by air, we repeated the analyses using a sample containing all full-time faculty listed on departmental
websites (n=188) which includes the travellers in the sample and the faculty who did not bill travel by air during the assessed time period. A larger fraction of male faculty (69%) than female faculty (66%) flew during the sample period, though this difference was not significant, \( \chi^2(1, N = 188) = 0.28, p = 0.597 \). A t-test showed significant differences in hIa between those who did fly (mean hIa = 0.79) and those who did not bill air travel during the period (mean hIa=0.68, p=0.047). Further analysis with logistic regression confirmed that hIa is significant in predicting whether a faculty member billed air travel during our sample time frame, including when controlling for academic unit and position.

2.3.2 Green flyers

Of the 165 academics with sufficient information to classify as Green or Not-green, 63 were classified as Green. Two of the units contained no Green academics, one unit contained only Green academics, and the remaining five units were mixed. Since this sample is quite diverse in terms of academic positions (including Lecturers, Adjuncts, Instructors, etc.), we report the results for the more homogenous Core Sample and confirm with the larger Green Profile sample. Travel behaviour as measured by emissions produced, distance travelled, or trips taken, was very similar between the Green and Not-green academics (Figure 4). Mean emissions in the Core Sample (n=128) for Green academics was 9.12 tCO\(_2\)e and 7.73 tCO\(_2\)e for the Not-green academics with no significant difference in means (Welch Two-sample t-test, 95% CI [-6.10, 3.30], p=0.55). Mean distance travelled was 45,199 km for the Green academics and 46,310 km for the Not-green academics with no significant difference in means (Two-sample t-test, 95% CI [-16,742, 18,962], p=0.90). Mean number of trips taken for Green academics was 4.39 and 4.20 for the Not-green flyers with no significant difference in means (Two-sample t-test, 95% CI [-
1.64, 1.27], p=0.80). Differences between Green and Not-green academics were also not significant for the larger group of 165 academics.

There was also no difference between Green faculty and Not-green faculty in the Core Sample for total avoidable emissions (t=-1.04, 95% CI [-3.74, 1.19], p=0.30) or total avoidable trips (t=-0.14, 95% CI [-0.85, 0.74], p=0.89). There were also no significant differences between the mean emissions for Green and Not-green flyers in any of the avoidable emissions categories (brief trips, brief but long distance trips, short trips, and flights with higher class tickets). This was true for both the Core Sample (n=128) and the larger, Green Profile sample (n=165).

![Figure 4: Air travel behaviour of 128 research faculty in the Core Sample divided into "Green" or "Not-green" area of interest. Note that some values beyond the edge of the y-axis are not visible in each graph.](image)

2.3.3 Drivers of air travel behaviour

To better determine which of these variables is driving changes in emissions or kilometers travelled between individuals, we conducted linear regression analyses (Table 4). All models were heteroskedastic (with Breusch-Pagan Test, p>0.05). We therefore used the Box Cox procedure to find appropriate exponents for transformations to achieve homoskedasticity. The
best model incorporates career stage (position), salary, and academic unit (department) as predictor variables but still only explains 25% of the variance in the data.

Table 4: Regression models predicting $tCO_2e$ emitted from professional air travel

<table>
<thead>
<tr>
<th></th>
<th>Model 1 ($tCO_2e^{0.15}$)</th>
<th>Model 2 ($tCO_2e^{0.15}$)</th>
<th>Model 3 ($tCO_2e^{0.15}$)</th>
<th>Model 4 ($tCO_2e^{0.15}$)</th>
<th>Model 5 ($tCO_2e^{0.15}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant</td>
<td>0.27</td>
<td>0.36</td>
<td>0.38</td>
<td>0.39</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>(0.41)</td>
<td>(0.40)</td>
<td>(0.41)</td>
<td>(0.41)</td>
<td>(0.41)</td>
</tr>
<tr>
<td>Professor</td>
<td>0.44*</td>
<td>0.38</td>
<td>0.41</td>
<td>0.40</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(0.26)</td>
<td>(0.26)</td>
<td>(0.26)</td>
<td>(0.27)</td>
</tr>
<tr>
<td>Dean</td>
<td>2.12***</td>
<td>1.99***</td>
<td>1.96***</td>
<td>1.96***</td>
<td>1.83***</td>
</tr>
<tr>
<td></td>
<td>(0.46)</td>
<td>(0.46)</td>
<td>(0.46)</td>
<td>(0.46)</td>
<td>(0.48)</td>
</tr>
<tr>
<td>Adjusted Salary</td>
<td>0.0003**</td>
<td>0.0003**</td>
<td>0.0003**</td>
<td>0.0003**</td>
<td>0.0003**</td>
</tr>
<tr>
<td></td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
</tr>
<tr>
<td>Gender (Male)</td>
<td>0.42*</td>
<td>0.40*</td>
<td>0.40*</td>
<td>0.40*</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.23)</td>
<td>(0.23)</td>
<td>(0.23)</td>
<td>(0.23)</td>
</tr>
<tr>
<td>hIa</td>
<td></td>
<td>-0.23</td>
<td>-0.24</td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.32)</td>
<td>(0.32)</td>
<td>(0.35)</td>
<td></td>
</tr>
<tr>
<td>Green (Yes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 1</td>
<td>-0.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.33)</td>
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<td></td>
<td></td>
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<tr>
<td>Unit 2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.55)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 3</td>
<td>-0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.59)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 4</td>
<td>-0.58*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.32)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 5</td>
<td>-0.73*</td>
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<td>(0.34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted r-squared</td>
<td>0.24</td>
<td>0.25</td>
<td>0.25</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td>N</td>
<td>128</td>
<td>128</td>
<td>128</td>
<td>128</td>
<td>128</td>
</tr>
</tbody>
</table>

Standard errors are in parentheses. ‘*’indicates significance at the 10% level, ‘*’ indicates significance at the 5% level, ‘**’ at the 1% level, ‘***’ at the 0.1% level.
While men in our sample produced significantly higher emissions than women \((t=-3.4497, p<0.001)\), this relationship was only marginally significant after controlling for salary and position (though the relationship was still significant for kilometers and for number of trips travelled). This may be explained by historical hiring practices which have resulted in men holding more senior positions (including both senior faculty positions and administrative positions such as Dean), both of which are associated with increased pay and increased emissions. Evidence of this can be seen in the salaries of these two groups; mean salary for men in our Core Sample was $162,083 and mean salary for women was $134,072 \((t=-4.75, p<0.001, df=118.25)\), despite salary adjusted by academic age being similar in both groups. Furthermore, while only 28% of Professors in the Core Sample were female, 43% of Associate Professors and 67% of Assistant Professors were female.

Academic unit (department) had a significant influence on emissions when controlling for salary and position, suggesting that the departments in this sample have differing cultures or research needs that affect flying behaviour. Individuals with leadership roles in their unit (Deans, Assistant Deans, etc.) travelled substantially further than other positions, which is expected given their increased duties for the university. Adjusted salary was a significant predictor of emissions and kilometers travelled even while controlling for department, position, and gender. The hIa was not significant in predicting emissions or kilometers traveled in any model tested. Finally, models testing for the significance of h-index while controlling for department and position were also generated. This accomplishes approximately the same goal of using hIa instead of h-index since it controls for citing norms within a field as well as seniority. Neither models for CO\(_2\) nor
models for kilometers travelled (not shown) found h-index to be a significant predictor when controlling for department and position, as expected.

2.4 Discussion

Using a database of professional air travel at a major Canadian university, we found that emissions from air travel, distance, and number of flights taken were unrelated to academic productivity as measured by h-index (adjusted by academic age and discipline) or to an academic’s area of interest (Green academics did not fly less than their counterparts). Instead, we found that academics who were further in their career and academics with higher salaries took more trips and were responsible for greater emissions than their colleagues.

The fact that Green academics create similar emissions from professional air travel as the rest of the sample could be seen as further evidence supporting the knowledge-action gap, e.g., those who know more about the environment still do not adopt pro-environmental behaviours. Yet there are a number of alternative explanations for the similarities in behaviour between the two groups. First, it is possible that Green academics are more likely to conduct field work that requires more frequent and even more distant air travel (a researcher studying polar ecosystems may have more need of air travel for field work than a psychologist). Additionally, their fields of research may also be cutting edge and policy-relevant, and may therefore involve them in more international initiatives or committees (e.g., Intergovernmental Panel on Climate Change; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services).
Such reasoning may explain overall differences, but not the lack of difference between the Green academics and the rest of the sample on easily avoided flights and purchases of higher class tickets. However, some academics may view the marginal effects of their own air travel as nil or negligible (based on the reasoning that their flight would occur whether they were on it or not). Certainly the feeling that one’s own actions are nothing but a “drop in the ocean” is a commonly reported obstacle to motivating personal action on climate change (Lorenzoni et al., 2007; Hope et al., 2018). Others may not see a disconnect between their professional air travel and their area of research. Instead, professional air travel may be viewed as a useful tool that outweighs any environmental harm by enabling academics to collaborate effectively, communicate their findings, and contribute to solutions in global sustainability. For instance, defenders of Al Gore’s air travel while filming and promoting An Inconvenient Truth suggest that the importance of his message compensates for his emissions from flying (Olson, 2007). The case of Gore’s travel raises a more general problem – the fact that the air travel of climate researchers has been frequently used in ad hominem attacks on researchers, climate delegates, and environmentalists (Gavin and Marshall, 2011; Gunster et al., 2018).

Because increased air travel seems unrelated to academic productivity or collaboration, increased air travel may not be causing success (as measured by salary increase per year) in our sample. Instead, causation may operate in the opposite direction. Certainly, greater ambition or managerial skill may lead to promotions into administrative roles with higher salaries and more duties requiring air travel, as evidenced by the higher emissions of those in such roles in our sample. But the regression shows that adjusted salary is related to emissions even when controlling for seniority. Esteemed academics, with or without promotions, may be invited to
deliver more lectures and have access to larger grants to afford frequent air travel (or purchase higher class tickets) and would also receive greater remuneration from their universities for the prestige they bring to the institution. Additionally, personality traits such as “niceness” and “demandingness” are related to a person’s willingness to initiate salary negotiations (Bowles et al., 2007), and early negotiations over salary (whose outcomes are influenced by gender) can have large monetary consequences over a career (Gerhart and Rynes, 1991). The type of person who would successfully negotiate for a higher salary may be of the same personality that would request higher class air travel. For example, Canadian federal funding agencies do not allow for higher class air travel, and purchasing air travel tickets in a class higher than Economy at UBC requires permission of a senior administrator (Board of Governors, 2010). Andersson and Nässén (2016) similarly found a significant relationship between income and personal air travel, which is reasonable as those individuals with more income have more funds to afford it, and Balmford et al. (2017) found higher personal carbon footprints from academics who reported larger salaries.

These results highlight some of the interrelationships between salary, gender, and travel behaviour. Men travelled more than women in our sample, and even when controlling for salary, seniority, and department, men undertook more trips and travelled greater distances (though the difference in emissions between men and women was only marginally significant when controlling for other factors). This is consistent with past research showing that female academics are constrained in their ability to participate in sabbaticals abroad (Jöns, 2011) and generally have less mobile careers than male academics (Kulis and Sicotte, 2002).
We found some evidence that researchers who did not fly at all during the sample period may have lower academic productivity, though this relationship is not present in the samples where faculty took at least one trip by air. The results of this particular analysis should be interpreted with caution since some of the individuals may have no travel due to sabbaticals, parental leaves etc., while others may have flown but not billed expenses through the university. Still, the results do further suggest that some threshold of individual air travel may be necessary for success at a university (Storme et al., 2013) or for the success of research in general (Adams, 2013; Sugimoto et al., 2017), but the threshold is very likely below that of prolific flyers. The effect of increased collaboration on knowledge creation (as measured by impact factor) has been shown to follow a pattern of diminishing returns, which may be explained by the opportunity cost of maintaining many professional relationships (McFadyen and Cannella Jr, 2004). A similar phenomenon may be at work here, where additional travel to share research or collaborate comes at the cost of time that could be used for research, grant writing, etc. The lack of relationship between hIa and emissions in the Core Sample (or trips taken or distance flown) could represent preliminary evidence that there is room for at least high-emitting academics to decrease their business air travel emissions without suffering negative consequences to their publication output. Indeed, academics at the beginning of their career who would arguably benefit most from air travel to establish their careers are actually flying the least in our sample. Green academics might be easily encouraged to “pick low-hanging fruit”, such as not upgrading their travel tickets, in order to reduce their personal carbon footprints. Replacing higher class tickets with Economy tickets was found to be the most significant professional air travel mitigation measure at UBC, with the potential to reduce overall emissions attributed to the university by 7.8% (Wynes and Donner, 2018).
It should be noted that our data does not capture all of the professional air travel conducted by the individuals in this sample. Those flights which are billed to other institutions (including for instance, guest lectures, government consultations, and job interviews) are not included in this dataset. If the flights for certain groups are disproportionately billed to offices outside of UBC then this may cause bias in our results. For instance, if senior Professors tend to accept multiple requests for talks at other institutions, then they may be flying more in total than what we present (assuming this is not offset by a similar amount of young academics attending job interviews, etc.). We found that guest Professors represented only 18% of all emissions from Professors. If other institutions invite guests at a similar rate to UBC then a simple extrapolation might suggest that our sample fails to capture approximately 18% of emissions from flights taken by faculty. We have no reason to suspect that flights paid for by other institutions would favour Green academics, but they do seem to favour senior travellers; there are far more Professors than Assistant Professors, and graduate students are greatly underrepresented in the guest sample (see Table 2). While this indicates a limitation of our study, it is perhaps unavoidable if our research questions are to be answered without self-reported results.

Our data also represents an eighteen-month window in time which limits our ability to understand success over the course of an individual’s career. Present travel behaviour may be a good indicator of past travel behaviour; other forms of mobility are very habitual (Moser et al., 2018; Verplanken et al., 2008). This might also be the case for academic air travel, where researchers make a habit of travelling to certain conferences by air every year. Ideally, future
research exploring air travel behaviour would include longitudinal data so that causation could be established.

The study findings could also be influenced by the chosen setting and the available metrics of academic productivity. UBC is an environmentally progressive institution, meaning there may be a narrower gap in personal beliefs or environmental knowledge between the Green and Not-green groupings than at other institutions. Although we found no relationship between authors per paper and emissions, this is perhaps a weak indicator of academic collaboration and should be taken with a grain of salt, as it is likely to be highly influenced by norms in a field. The h-index and hIa are more reasonable measures for academic success; regardless of their flaws (Bornmann and Marx, 2011) and criticisms of their effect on academic culture (Lawrence, 2008), such measures of scholarly output are frequently used in hiring or grant funding decisions and are moderately but significantly correlated with salary in our sample (Figure 2). Future research could measure academic success in numerous other ways (public outreach, patent applications, grant funding, number of students supervised, etc.), but when investigating the claim that air travel is an unavoidable workplace expectation, and may be necessary to garner increased standing in the field, the indicators employed in this study are highly relevant.

Our findings are potentially meaningful for institutions considering ways to decrease their air travel. Possible initiatives might include an internal cap and trade program, offsets or mitigation charges (Menton, 2018), regulations, etc. Since 26% of trips for core faculty were associated with what we categorized as avoidable emissions, and since senior researchers fly considerably more than junior researchers, some senior researchers can likely reduce their air travel without a
measurable impact on their scholarly productivity. Conversely, graduate students and Postdoctoral Researchers seeking faculty positions may have less flexibility to reduce their air travel without making career sacrifices. For institutions, these initial results suggest that an overall reduction in air travel, assuming that it still allows for a base level of mobility and does not penalize populations that already fly infrequently, may be feasible without affecting the productivity of the institution.

These results add to a nascent area of research showing the potential for leadership through reducing excess air travel. Because climate messengers are viewed as more reliable if they fly less (Attari et al., 2016) and because early evidence suggests that those who fly less influence the attitudes, choices and policy preferences of those who know them (Westlake, 2017; Murray, 2019), academic air travel has consequences beyond the emissions of those actually flying. Millions of students each year will be introduced to societal norms regarding professional behaviour through universities, and so a university culture that endorses prolific air travel will make public acceptance of policies that curtail air travel and promote videoconferencing that much more difficult to implement. Our results are therefore potentially relevant for climate leaders, other scientists, and academics across the world.

2.5 Conclusions

Drawing from a sample of 705 travellers at UBC, we investigated the relationship between academic achievement, research interests, and emissions from air travel. To our knowledge, this is the first time that observational data has been used to test the relationship between professional success and air travel. We found no relationship between academic productivity (as measured by
h-index adjusted for academic age and discipline) and emissions from air travel. Although university salary was related to emissions, the direction of causation could not be firmly established. Finally, we found no difference between the travel behaviour of Green and Not-green academics, even in categories of emissions that might be avoided with minimal effort, such as upgrading to First Class air travel. We conclude that academics, especially Green academics with professional incentives to fly less, may be able to reduce their air travel emissions without making significant career sacrifices and thereby act as cultural leaders.
Chapter 3: The limits to public carbon numeracy

3.1 Introduction

People exhibit greater willingness and intentions to perform pro-environmental behaviours that they believe are more effective in combating climate change (Truelove and Parks, 2012; De Boer et al., 2016). It is therefore important that members of the public can distinguish between actions that are low- or high-impact for mitigating climate change. The most effective actions for reducing an individual’s greenhouse gas emissions have been ranked (Gardner and Stern, 2008; Wynes and Nicholas, 2017; Lacroix, 2018; Ivanova et al., 2020), though important questions still remain: Do people understand these rankings? Can they make tradeoffs between different actions? Attempts to improve carbon numeracy are common: Educational curricula instruct students to investigate their own carbon footprints (Wynes and Nicholas, 2019), and researchers communicate the impact of specific actions as components of low-carbon lifestyle interventions (Cornelius et al., 2014). Despite this growing engagement, the “carbon numeracy” of the public is not well understood.

We define carbon numeracy as the ability to correctly understand and manage one's own carbon footprint (or budget). The concept is derived from the ability to manage similar budgets as part of day-to-day living. For example, people manage their bank accounts to balance income and expenses. Many also count calories, using dietary labels to balance their caloric intake against the energy demands of exercise. A person with basic literacy is likely able to identify the most consequential ways they can save money or calories. Someone with greater literacy could also rank different products according to their costs, in the case of financial literacy, and an individual with strong literacy would be able to make tradeoffs between decisions (e.g., skipping X cups of
coffee would result in enough savings to purchase a new phone). Those same skills can be applied to management of a personal carbon footprint (e.g., switching to an electric vehicle will reduce emissions more than hang drying laundry).

Past research investigating carbon numeracy has been limited in scale or focused within related domains like energy use or diet. For instance, people have systematic biases against efficiency changes when estimating the impact of behaviours involving household energy use (Attari et al., 2010). Consumers are able to order foods according to relative climate impact, but are unaware of the magnitude of the differences in climate impact between food products (Shi et al., 2018). Consumers tend to underestimate the environmental impact of meat products (Camilleri et al., 2019; Lazzarini et al., 2016; Kause et al., 2019) or car travel (Grinstein et al., 2018). Because of these biases, improved carbon numeracy is believed to be key for individuals to make sustainable choices (Grinstein et al., 2018; Shi et al., 2018). However, little research has examined carbon numeracy across different domains.

Poor carbon numeracy could come from a lack of knowledge, but the translation of knowledge into action is complicated by many factors. These include reliance on “gut feelings” or heuristics (Turrentine and Kurani, 2007) or “moral licensing” (Gifford, 2011) where individuals engaged in pro-environmental behaviours show willingness to forego other pro-environmental behaviours (Truelove et al., 2014). Poor carbon numeracy can also come from limited numeracy skills. For example, people make substantial errors when estimating climate impacts in absolute quantities, as measured in Watts per household activity (Attari et al., 2010) or kilograms of CO₂ per liter of gasoline (Grinstein et al., 2018).
While people are likely to err in estimating the absolute impact of an action, they may still be able to make relative comparisons, like ranking different actions or performing tradeoffs (e.g. “I can do more of X because I already perform Y”, or “I will put more effort into X behavior because it is more important than behaviours Y and Z”). Evidence suggests that some people engage in a type of tradeoff thinking (referred to as “compensatory beliefs”) where they try to balance previous car use by restricting driving in the future, or they realize that certain actions have high climate impacts that are impossible to compensate for with other smaller actions (Hope et al., 2018). One study of compensatory beliefs across seven nations found, for instance, that a cross-national average of 47.6% of respondents believe that a few simple actions to protect the environment is sufficient, while 39.5% agreed that the environmental impact of flying on holiday can be compensated for by reduced car usage (Capstick et al., 2019). A UK study (N=770) on compensatory beliefs found 15.6% of participants agreed that not using a dishwasher can compensate for taking longer showers, 12.2% agreed that composting food can make up for buying imported food, and 3.6% agreed that flying abroad can be made up for by not eating meat (Kaklamanou et al., 2015). The authors suspected that their survey methodology may lead to conservative levels of agreement, suggesting that compensatory thinking is neither very widespread nor so negligible that it should be ignored by those designing education programs or behavioural interventions.

Even individuals who do not actively engage in compensatory thinking but who are still conscious of the impact of their decisions could benefit from greater carbon numeracy. For example, some studies of “food miles” have found that shifting diets can have a greater impact on one’s carbon footprint than buying local food (Weber and Matthews, 2008). One UK study
found that driving more than 7 km to a local farm shop for vegetables results in higher greenhouse gas reductions than vegetables being delivered by a long-distance, mass distribution system (Coley et al., 2009). In that hypothetical case, an implicit tradeoff is made, but emissions are not reduced because the individual prioritized a low-impact action (purchasing local food) over a high-impact action (driving a personal vehicle).

Understanding public carbon numeracy and its components, such as the ability to perform tradeoffs, is therefore important to education and outreach surrounding pro-environmental behaviours. As a demographic that has yet to firmly establish their lifestyles, students represent an important group that is more capable of developing low-carbon lifestyles. To assess carbon numeracy, we therefore surveyed undergraduate students at a major North American university. We also surveyed members of the North American public through an online survey tool distributed on Amazon Mechanical Turk, which allows us to better understand which beliefs are held by motivated and educated individuals (students) compared with the rest of the population. Participants were asked to rank various climate-related behaviours and then to perform tradeoffs between them (comparing air travel with diet, for instance). Results were similar between the two samples (e.g. demographic variables were not significant predictors of tradeoff accuracy) so we combined them in the analysis (separate analyses are available in Appendix B.1). The results provide insight into the factors that predict higher carbon numeracy and the limits of what can be expected even from engaged individuals.
3.2 Methods

A pilot study with 178 participants was conducted at the University of British Columbia in January 2017 (see Appendix B.2 for methods and results). Following analysis of the pilot results, we revised and expanded the survey and conducted pre-test surveys in spring of 2017, with edits made iteratively following the suggestions of 22 participants. Ethics approval was granted by the UBC Behavioural Research Ethics Board. Surveys were then conducted on the Qualtrics survey platform with North American participants recruited from Amazon Mechanical Turk in June of 2017. Additional surveys were conducted in the 2017-18 academic year (from September 2017 to March 2018) in seven undergraduate classes at the University of British Columbia. A total of 675 students were in attendance at these classes, but participation was optional; 414 of the student surveys were sufficiently complete to be included in data analysis (a completion rate of 61%).

Participants in both groups who failed to answer an attention check question were redirected to the completion message and excluded from the results. The responses of participants were removed from the sample where it was clear that answers were not provided in good faith (for instance, rating every single action as low impact). We also removed participants from the results when they finished the survey in less than five minutes. In total the responses of 55 Mturk participants and 42 UBC students who completed the survey were removed from the data for these reasons.
3.2.1 Survey design

There were five parts to the survey (see Appendix B.3 for the full survey). First, participants were asked an open-ended question concerning the most effective action they could take to reduce greenhouse gases that contribute to climate change. Second, the participants were asked to categorize 15 actions as low (<1% of a person’s carbon footprint), medium (1-5%) or high impact (>5%), following designations from Wynes and Nicholas (2017). Thirteen of the fifteen actions were chosen to represent a range of high-, medium- and low-impact actions. These included “Switch from an SUV to public transit for one year” (high-impact), “Wash your laundry in cold water for one year” (medium-impact) and “Don’t litter for one year” (low-impact). Two civic actions were also included to gauge whether participants viewed collective/civic actions as more effective than consumer behaviours (“Vote for a political party that is proposing a carbon tax” and “Vote in favour of a nuclear power plant”).

Third, participants were asked to perform four trade-off questions, such as a tradeoff between two household energy saving actions: “Hang drying clothing instead of using a dryer saves electricity, which reduces greenhouse gas emissions. If someone chooses to hang dry one load of laundry, how long can they leave an LED light bulb switched on and still produce the same amount of greenhouse gases as if they had used the dryer? Please give your best guess.” The other three tradeoffs were: a year of eating a vegetarian diet versus the amount of time needed to compensate for the same emissions by purchasing food without packaging, kilometers driving a hybrid vehicle compared to 100 kilometers of driving a conventional vehicle, and the quantity of hamburgers needed to equal an economy class ticket on a trans-Atlantic flight.
The tradeoff questions were selected to represent a spectrum of compensatory beliefs; one was between very similar products (a comparison between personal vehicles), two are within the same domain (one comparison within diet and one within household energy) and one crosses domains (diet and transportation). We included cross-domain comparisons because climate change is inherently a cross-domain problem: actions in different domains (e.g., travel, energy, diet) are quantified using the same climate metrics (kgCO$_2$e). Personal carbon footprint analyses and education around individual climate actions implicitly ask people to make cross-domain comparisons. Therefore, the core motivation for these tradeoff questions is to test the ability to compare carbon impacts of different activities.

Fourth, participants were asked two sets of control questions to test whether lack of knowledge, lack of numeracy or environmental biases was a barrier in providing correct answers. In the first set, explicit numeric information was provided, e.g. “We have provided more information to this question. Hang drying clothing instead of using a dryer saves electricity, which reduces greenhouse gas emissions. If someone chooses to hang dry their clothes for one load (thereby saving 3400Wh), how long can they leave an LED light bulb switched on (10W per hour) and still produce the same amount of greenhouse gases as if they had used the dryer? Please give your best guess.” The second set of control questions removed the climate context since biases in favour of environmentally symbolic actions (e.g., driving a hybrid vehicle) may cause biased estimates of the impacts of those actions even when sufficient mathematical information is provided (Süterlin and Siegrist, 2014). For example, the corresponding question to the above reads: “A scientist finds a very old tree and calculates that it is 3400 years old. How many decades (1 decade = 10 years) has this tree been alive? Please give your best guess.” Participants
who answered the non-climate control question correctly but not the first control question were either being misled by their environmental biases or find it more difficult to answer the same mathematical question in a climate context.

Lastly, participants were asked about their concern for climate change, about their estimate of the percentage of climate scientists that believe climate change is mostly caused by humans, and a series of demographic questions. The complete survey as well and calculations used to determine an accurate range of estimates can be found in Appendix B.3 and B.4.

3.2.2 Survey analysis

Responses to the open-ended question on the most effective action that the participant could take to reduce greenhouse gas emissions that contribute to climate change were coded into 25 categories adapted from Wynes and Nicholas (2017). Based on their approach, we separated out the most effective versions of some actions (e.g. eat a plant-based diet, live car free) from less comprehensive versions of the same action (e.g. eat less meat, drive less/more efficiently/carpool etc.). When respondents provided two or more actions that they saw as being the most effective, we only coded the first action described. Some respondents indicated policies that the government could make on their behalf (e.g. “better regulation from government regarding car use”), which we coded as “Government”. Others denied the existence of human caused climate change (coded as “Deny climate change”) while still others gave tautological responses such as “reduce carbon footprint”, coded here as “reduce GHGs”. Because of evidence that attitudes about climate change mitigation vary by political ideology (Hornsey et al., 2016), we also grouped the results by political orientation.
Climate concern was measured using a previously tested 4-item scale ($\alpha=0.88$ in our sample), with the third item reverse-coded (Attari et al., 2010). Numeracy was measured by taking the number of correct responses to the eight control questions: the four questions where participants were provided additional data to answer the estimates correctly, and the four questions where participants were asked to make the exact same calculation process but in an everyday context unrelated to climate change.

To compare accuracy across all four tradeoff questions we calculated the absolute log error (Grinstein et al., 2018) for each tradeoff question and then took the average error of the four tradeoff questions.

$$\text{(1) Absolute Error} = \left| \log_{10} \left( \frac{\text{participant estimate}}{\text{central value of actual calculation}} \right) \right|$$

For the purpose of using linear regression to understand which demographic variables predict accuracy, absolute values are preferable to estimation bias because, with estimation bias, overestimation in one category (positive sign) would counteract underestimations in another category (negative sign), causing a participant to incorrectly appear more accurate overall. We also calculated, “estimation bias” which uses the same calculation but without taking the absolute value, to test the direction of bias for each of the four tradeoff questions.

$$\text{(2) Estimation Bias} = \log_{10} \left( \frac{\text{participant estimate}}{\text{central value of actual calculation}} \right)$$
A participant overestimating by a factor of 10 would yield an “estimation bias” of 1, while underestimating by a factor of 10 would yield an estimation bias of -1.

We ran linear regression analyses with demographic data, numeracy and climate score (concern for climate change) as predictor variables and with average absolute log error as a response variable. To test if the outliers present in the data were affecting the results, we removed the outliers and repeated the analysis, finding no difference in outcomes (predictor variables that were significant remained significant and vice-versa). We used logistic regression with repeated cross validation to determine those variables that were significant predictors of choosing a plant-based diet in the open-ended question. These calculations were performed in R Version 3.5.1. Data is available upon request, as permitted by our Behavioural Research Ethics agreement. Incomplete survey data were handled as follows. In two tradeoff questions participants were asked to provide units. If they provided nonsensical units these were entered as NA values. Also, when performing regression calculations, we preserved the data from responses on the other tradeoff questions by imputing the values for the 39 individuals who failed to make a usable estimate for the vegan tradeoff question and the 125 values for the LED tradeoff question using the k nearest neighbour method (Kowarik and Templ, 2016). This is justifiable since these NA values are unlikely to be completely random. We also performed the regressions using a smaller sample where these individuals were omitted and found no substantial differences in the results (variables that were previously significant predictors remained significant and vice-versa).
3.2.3 Participant Information

414 students completed the survey. 62% were female, 22% were in their first year, 29% in second year, 27% in third year, 22% in their fourth year or higher. 55% described themselves as liberal (scores of 5-7), 14% as conservative (scores of 1-3) and 31% as moderates.

551 individuals completed the survey on Amazon Mechanical Turk. 53% female, 47 Canadian, with an average age of 37. Median income was $30000-$39000, 91% held high school diplomas or higher and 55% held Bachelor degrees or higher. 57% of the sample described themselves as liberal (scores 5-7), 23% as conservative (scores 1-3) and 20% as moderates.

3.3 Results

Participants were first asked to describe the most effective action they could take to reduce greenhouse gas emissions (Figure 5). The most frequent response type was actions related to reduced driving or “Drive less” (e.g. carpooling, buying a more efficient vehicle etc.). These had more than twice as many responses as using public transit, biking or walking. Very few participants (12 of 965) listed reducing air travel as the most effective action they could take, despite reducing air travel being one of the highest impact actions among wealthier people (Jones and Kammen, 2011). We did not request income data from students, but of the 550 MTurk respondents, 84 reported incomes of >$80,000 and 12 reported incomes >$150,000. Of the 84 participants with incomes above $80,000, only one selected reducing air travel as the most effective action they could take (four said “Recycle”, and 39 said “Drive less”). We separated the results by political orientation; no conservatives described voting as the most effective action and few selected eating a plant-based diet or eating less meat (Appendix B.5). Most responses
focused on consumer-oriented activities, with less than 5% of responses categorized as one of four types of political action (vote, raise awareness, join an organization, or contact an elected official).

Figure 5: The 25 most common responses to an open-ended question about the single most effective action the participant could take to reduce greenhouse gases. Color indicates self-reported political orientation. Two individuals with no self-reported political orientation not shown here.

Participants then categorized 15 pre-selected actions as high-, medium- or low-impact in terms of reducing greenhouse gas emissions (Figure 6). Switching from driving an SUV to public transit, which is a high-impact action (Wynes and Nicholas, 2017), dominated in terms of the highest average ranking. The same percentage of our sample ranked eating a vegan diet and switching from plastic to canvas bags as high impact, even though eating a vegan diet is roughly 180 times
more effective than switching bag types (Wynes and Nicholas, 2017). The distribution of rankings for a trans-Pacific flight was nearly equivalent to that for littering, despite the fact that a trans-Pacific flight would represent a large fraction of most people’s annual carbon footprint whereas littering has no effect on greenhouse gas emissions.

These findings appear to be robust to the choice of method: in the pilot experiment, when a student sample was asked to rank actions from 1-15 (with 1 being most effective) instead of sorting them into high-, medium- or low-impact, they provided rankings that resulted in similar relative orderings. For example, the action “Switch from an SUV to public transit” was, on average, perceived to be the most effective, while buying non-GMO foods was perceived to be the least effective (Appendix B.2).

We further examined individual accuracy by counting the number of times that a participant correctly ranked an action as high-, medium-, or low-impact. Poisson regressions showed that higher ranking accuracy was associated with numeracy and education, but not with age, gender, income, political orientation or concern for the climate.
Figure 6: Proportion of participants that ranked each of the 15 actions as low (dark blue), moderate (medium blue) or high impact (light blue). Each action is also labelled at right for the assessed impact based on past research (Wynes and Nicholas, 2017). Actions assessed as low impact account for less than 1% of an average North American’s annual carbon footprint, moderate impact account for 1-5% and high impact account for more than 5%. Note that not all percentage values add to 100% due to rounding.

After the ranking questions, participants answered four questions, each involving a tradeoff between two actions. For each tradeoff question, participants were asked to estimate how much of one activity would be necessary to achieve the same emissions reductions as the other activity (Table 5). For example, one tradeoff question is how many hamburgers a person would have to give up to offset the emissions from a flight from New York to London (see Appendix B.3 for the questions).
Table 5: Accuracy in making the four climate impact tradeoffs

<table>
<thead>
<tr>
<th>Tradeoff Question</th>
<th>Correct range</th>
<th>Median estimate</th>
<th>Percent of correct answers</th>
<th>Estimation bias [95% CI] (see methods)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles of driving hybrid vs 100 miles in conventional car</td>
<td>112-190 miles</td>
<td>200 miles</td>
<td>22.6%</td>
<td>46.2%</td>
</tr>
<tr>
<td>Numbers of hamburgers vs one trans-Atlantic flight</td>
<td>146-410 burgers</td>
<td>100 burgers</td>
<td>17.4%</td>
<td>82.6%</td>
</tr>
<tr>
<td>Hours of LED usage vs one load of hang-dried laundry</td>
<td>272-354 hours</td>
<td>60 hours</td>
<td>2.6%</td>
<td>71.0%</td>
</tr>
<tr>
<td>Years of unpackaged food vs one year vegetarian food</td>
<td>10-12 years</td>
<td>1.1 years</td>
<td>2.6%</td>
<td>68.2%</td>
</tr>
</tbody>
</table>

Based on estimation bias calculations, we find that participants underestimated the emissions from a flight compared to the emissions from a hamburger, as well as the emissions from drying laundry compared to use of an LED lightbulb, and they severely underestimated the emissions of a vegetarian diet compared to a diet that avoids food packaging (Figure 7). Participants were most successful at answering the hybrid vehicle question, although even with that question, less than one quarter (22.6%) of the responses were accurate. Only one out of 965 participants correctly answered three questions, and no participant made correct estimates for all four questions. The four tradeoff questions taken together do not constitute a valid measure of the carbon numeracy construct (Cronbach’s alpha for the Absolute Errors on the four tradeoff questions was 0.14).
Figure 7: Tradeoff accuracy: a) Distance travelled by a hybrid versus 100 miles in a conventional midsize vehicle (absolute emissions=25-32 kgCO\(_2\)e). b) Hamburgers versus a Trans-Atlantic flight (absolute emissions=477-907 kgCO\(_2\)e). c) Hours of operating an LED lightbulb versus hang drying one load of laundry (absolute emissions=1.9 kgCO\(_2\)e). d) Years of eating food without packaging versus one year of vegetarian diet (absolute emissions=1113 kgCO\(_2\)e). The red area highlights the correct range of answers. Note that some estimates beyond the range of the x-axes are not visible in each graph.

We further examined basic numeracy by asking the same trade-off questions but with additional numerical information provided as well as by asking trade-off questions with similar mathematical operations but where the climate context was replaced by a more familiar situation (Table 5). Participants were more accurate in answering these control numeracy questions. For instance, for the hybrid vehicle question, 22.6\% of the estimates to the original question were accurate, 46.2\% were accurate when given the additional numerical information, and 83.2\% were accurate for the same numerical questions with the climate context removed (\(\chi^2(2)=720.90,\)
Chi-squared tests with Bonferroni correction showed that the pairwise differences between the estimates and the controls for all four tradeoff questions were significant (full analysis available in Appendix B.5).

Table 6: Hierarchical regression of tradeoff accuracy (average error) on four tradeoff questions

<table>
<thead>
<tr>
<th>Model</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic numeracy</td>
<td>-0.04***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
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<tr>
<td></td>
<td>(-0.05, -0.03)</td>
<td>(-0.04, -0.02)</td>
<td>(-0.04, -0.02)</td>
<td>(-0.04, -0.02)</td>
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</tr>
<tr>
<td>Rank score</td>
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<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
</tr>
<tr>
<td></td>
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<td>(-0.04, -0.02)</td>
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<td>-0.002</td>
<td>-0.001</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(-0.01, 0.001)</td>
<td>(-0.01, 0.001)</td>
<td>(-0.01, 0.001)</td>
<td>(-0.01, 0.003)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
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<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
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<tr>
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<td>(-0.0005, 0.002)</td>
<td>(-0.0005, 0.002)</td>
<td>(-0.0005, 0.002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
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<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
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<td></td>
</tr>
<tr>
<td>(Female)</td>
<td>(-0.02, 0.05)</td>
<td>(-0.02, 0.05)</td>
<td>(-0.02, 0.05)</td>
<td>(-0.02, 0.05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political orientation</td>
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<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1=Extremely liberal, 7=Extremely conservative)</td>
<td>(-0.02, 0.01)</td>
<td>(-0.02, 0.01)</td>
<td>(-0.02, 0.01)</td>
<td>(-0.02, 0.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations†</td>
<td>965</td>
<td>965</td>
<td>965</td>
<td>957</td>
<td>955</td>
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<tr>
<td>R²</td>
<td>0.04</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.04</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

Note: 90% confidence intervals in parentheses. *p<.1, **p<0.05, ***p<0.01
†Models 5 and 6 have fewer observations due to the removal of eight participants who selected gender responses other than male or female and two participants who did not select political orientation

To identify factors determining tradeoff accuracy, we ran hierarchical regressions (Table 6) with the following predictors for the full sample: basic numeracy (the number of correct responses in the control tradeoff questions), rank score (accuracy in ranking the actions as high, moderate, or low-impact), climate score (items measuring concern for climate change), age, gender, and political orientation. We found that only basic numeracy and rank score were significant predictors of tradeoff accuracy (accuracy measured as the absolute value of the estimation bias). Basic numeracy and rank score were weakly correlated (r_s=0.10, p=.001). Neither age, gender,
income, nor education were predictive of tradeoff accuracy (Appendix B.1). Additionally, there was a weak correlation between concern for climate change and tradeoff accuracy ($r_s = -0.08$, $p = .028$) as well as between political orientation and tradeoff accuracy ($r_s = -0.08$, $p = .022$), though this relationship was no longer significant when accounting for basic numeracy in the regression models. Correlation between the accuracy on the four tradeoff questions was low (highest correlation of $r=0.10$, $p = .005$ between hybrid and flight tradeoff accuracy).

### 3.4 Discussion

Individual climate action is receiving increasing attention in the media and in public education. But motivated individuals will waste time and effort focusing on marginally effective actions if they hold substantial misperceptions about the climate impact of those actions. It is therefore important to understand which actions the public perceives as more effective and whether individuals have the skills that are necessary to estimate and manage their own carbon footprint. These results indicate that the public err substantially in their estimations of the climate impact of individual actions. Below we discuss three key implications of these findings. First, people correctly understand the impacts of personal vehicle use, but underestimate and overestimate the impacts of behaviours like littering and air travel. Second, we show that aspects of carbon numeracy, like tradeoffs, are inherently difficult, and discuss reasons for this difficulty. Last, there are few characteristics that predict increased accuracy in tradeoffs, suggesting a limited suite of options for improving higher-level carbon numeracy.
3.4.1 Notable underestimations

Consistent with previous research (Truelove and Parks, 2012), we find that individuals correctly comprehend the climate impacts of personal vehicle use, but overestimate the impacts of behaviours like littering or using reusable grocery bags. Judgments may be led astray by the availability heuristic in such cases: individuals underestimate the impacts of clothes dryers compared to LED lightbulbs (Attari et al., 2010), perhaps because household lighting is cognitively available. In the case of personal vehicle use, frequent communication from authorities on this topic (Wynes and Nicholas, 2017) may have resulted in the strong connection between cars and greenhouse gas emissions.

We find robust evidence that people underestimate the climate impact of air travel. Very few participants (1%) mentioned it in the open-ended question as the most effective action they could take even though flying frequently occupies a large proportion of many people’s carbon footprints (such as those with high incomes) (Lacroix, 2018). Participants were more likely to rank recycling or switching from plastic to canvas bags for one year as more effective actions than avoiding one trans-Pacific flight. The evidence from the tradeoff question on air travel is less conclusive. The poor estimation on the air travel and hamburger tradeoff question could have come from participants underestimating the emissions associated with flying, or from overestimating the emissions associated with hamburgers. However, the emissions from meat consumption was shown to be underestimated in two other items (Figure 5 and Figure 6). One possible explanation then is that participants underestimated the climate impact of meat consumption but underestimated the climate impact of the air travel to an even greater extent.
Underestimating the emissions of air travel may be especially problematic; in a recent survey of 673 Swedes who had given up or drastically reduced their air travel, individuals frequently credited a realization that flying occupied a large proportion of their “climate budget” as a motivator for reductions (Söderberg and Wormbs, 2019). Policymakers implementing carbon labels on airline tickets might therefore consider using cross-domain comparisons to illustrate the full impact of flying, rather than providing a quantity of emissions without context. Similar labels that reported greenhouse gas quantities in terms of “lightbulb minutes” were tested as carbon labels on soup cans and found to reduce purchases of the beef soup product (Camilleri et al., 2019).

Underestimations of air travel and meat consumption are consistent with a lack of focus on these actions in expert communications. For example, driving and recycling are mentioned more frequently in science textbooks and government documents (Wynes and Nicholas, 2017) and were more common as well here in the responses to the open-ended question. Our participants were more educated and more liberal than a representative sample of North Americans so the limitations in their carbon numeracy suggest that the population at large would have even less success at assessing the impact of their behavior on emissions. People overestimated the climate impact of well-known actions like recycling and switching to canvas bags, possibly due to conflation of pro-environmental and pro-climate actions.

The findings of the ranking question are somewhat limited. Because the survey required allocating behaviours into low-, moderate-, and high-impact categories, participants may have exhibited “partition dependence”, a phenomenon where people tend to allocate equally between
categories. The effect persists even when participants are told that the categories are arbitrary but is substantially reduced by expertise (Fox et al., 2005). This effect therefore would not explain 17% of our sample selecting littering as high-impact when it has zero climate impact, but might very well explain why so many individuals ranked a low-impact action like buying local food as moderate impact (40%). The broader finding that some actions (like recycling) are overestimated, while other actions (like meat consumption and air travel) are underestimated, was confirmed through a different approach not subject to partition bias, where participants in a separate sample (n=178) were asked to rank actions from 1-15, rather than sort actions into low-, medium- and high-impact categories (Appendix B.2).

3.4.2 Understanding tradeoffs

Participants showed less success in making tradeoffs than in ranking different actions. These limitations may be due to a general lack of numeracy (shown in linear regressions), lack of climate knowledge (participants performed 56% better on tradeoff questions once given the requisite starting values), motivated reasoning (Sütterlin and Siegrist, 2014), or the inherent difficulties of the climate context (participants scored 22% better on the non-climate numeracy control questions). There are also inherent limitations to determining one’s carbon footprint. Other budgeting activities undertaken by the public, like calories or bank balances, involve values with higher certainty. Even with expert knowledge, there remain large uncertainties in the warming effects of meat production and air travel. Researchers have called for better education of consumers to improve carbon numeracy (Shi et al., 2018; Grinstein et al., 2018), and there is evidence of successful interventions in related fields. For instance, providing simple heuristics about household energy use can lead to better understanding in that domain (Marghetis et al.,
Further research into the potential of such heuristics for solving misperceptions of people’s own carbon footprints would therefore be beneficial.

### 3.4.3 Limitations

Our intention with this research was not to define a measurable construct for carbon numeracy - the concept of numeracy by itself is a highly contested topic (Coben et al., 2003). Instead we sought to identify strengths and weaknesses in the public’s ability to manage a carbon footprint that would affect their decision making. Still our research provides a first step for others who would seek to define a measurable construct. Because individuals were overwhelmingly ill-equipped to answer tradeoff questions, agreement among the four tradeoff questions was very low. Researchers seeking to identify a robust measurement may benefit by using more straightforward questions, such as ranking the impact of a variety of actions or products, or using tradeoffs that are more intuitive and within domains. Limiting tradeoff questions to those within domain would also have the benefit of being more generalizable, since people are more likely to conceptualize tradeoffs in this way (Hope et al., 2018).

Future research that makes use of tradeoff questions could also consider directionality. We intentionally phrased tradeoff questions to avoid anchoring as much as possible, which explains the direction of some tradeoffs (e.g. we asked how many hamburgers are equivalent to one flight instead of how many flights are equivalent to one hamburger). Still, others could explore the robustness of these results by reversing the comparisons, e.g. “What distance could you fly while being responsible for the same emissions as are created from producing a single hamburger?”
3.4.4 Implications

Communicators and policymakers need to understand how members of the public perceive the climate impacts of their decisions. For instance, participants in our study consistently showed an understanding that personal vehicle use is a high-impact activity, and also showed some ability to perform tradeoffs in that domain. Based on this relatively strong understanding of personal vehicles, journalists and politicians may be justified in continuing to compare the magnitude of climate policies to the number of cars taken off the road, rather than making a comparison to other domains where the public routinely over or underestimates emissions.

Regarding those individuals who are motivated to monitor their own carbon footprint, our study may have identified an upper bound of potential competence. Unlike in past research where concern for climate change was associated with superior understanding of energy use (Attari et al., 2010), only numeracy and ability to rank actions was found to predict accuracy in tradeoff questions. Climate impacts are perhaps more complicated than personal finances, calories or energy use; they cross domains, involve understanding of not just electrical energy, but also agricultural intensity and fuel efficiency. The only tradeoff that participants managed with relative success (the hybrid vehicle question) was one that already demands day to day numeracy on the topic, is readily available cognitively, and did not involve multiple domains.

While education is still necessary to correct larger misperceptions (especially regarding air travel and meat consumption) and to provide the public with a basic hierarchy of action efficacy, consumers who want to maintain a low carbon footprint would be best served by carbon labels in intuitive displays at the point of purchase, or by a price on carbon. The former solution would relieve motivated consumers of the need to educate themselves on the intricacies of carbon
accounting by making the carbon footprint of a product explicit, while the latter solution would act as a signal of climate impact, but also as a motivator for indifferent consumers. In either case, some external nudge seems necessary as consumers are likely incapable of successfully balancing their own carbon footprints.
Chapter 4: Inform voters of their emissions responsibility

Climate change, like voting in a democracy, is a collective action problem. Individuals may hesitate to expend resources and effort to reduce their carbon footprints knowing that the marginal impact on the global carbon budget is close to zero. Likewise, the probability of casting the deciding vote is low; in a United States presidential election, the probability is estimated at one in sixty million (Gelman et al., 2012). Given the low likelihood of casting a decisive ballot, researchers have argued over the efficacy and even rationality of voting (Dowding, 2005). Yet elections certainly influence collective action on problems like environmental pollution and climate change; Green party strength is associated with lower air pollution on a national scale (Neumayer, 2003), and US states that vote for greener candidates have lower carbon dioxide emissions (Dietz et al., 2015).

While we know the relative impact of individual actions involving air travel, personal vehicles and diet (Wynes and Nicholas, 2017), the impact of political actions like voting is difficult to assess. Does the magnitude of greenhouse gas emissions associated with an election merit an individual’s effort? And if the only way to view voting as a rational act is to see it as a citizen’s responsibility, how much emissions responsibility can be attributed to a single vote? A slate of recent climate-focused elections provides opportunities to assess the emissions impact of an electoral outcome, and responsibility per voter. We look at some potential ways to assess this and then provide recommendations for governments and climate experts interested in helping voters make informed decisions.
Per capita emissions offer an entryway to this discussion. We often approximate both a nation’s and an individual’s responsibility for emissions by looking at per capita emissions in that nation. While it is true that every individual in a nation requires additional energy and resources, we would not ascribe responsibility to infants for their emissions. There are also many individuals in a democracy with little to no say over their own emissions since their lifestyle choices (e.g., drive or take public transit) are constrained by the decisions made by others in the voting booth (e.g., the winning party’s support for new public transit initiatives). In terms of responsibility for emissions in a democratic country, it is therefore more informative to examine emissions per voter. If we calculate emissions per voter instead of emissions per capita, each voter takes on roughly twice the responsibility (Figure 8), since the emissions which we previously attributed to adolescents or the disenfranchised are now assigned to those with political agency.

**Figure 8:** Emissions responsibility per voter in the ten most populous Annex I nations with Democracy Scores of six or greater. Emissions responsibility per actual voter is represented by blue bars, emissions responsibility per registered voter is represented by black points and emissions per capita is represented by diamonds.
4.1.1 Quantifying emissions responsibility of a single vote

It seems reasonable that voters have higher responsibility for emissions than those who cannot vote, but climate policy may not always be “on the ballot”. The 2019 Canadian federal election offers an instructive case study because there was a clear divide between the climate policies of the major political parties and because climate change was a top issue for voters (Bricker, 2019). Leading up to the election, four of the five major parties, including the ruling majority Liberal Party, presented platforms that would lead to modeled or stated reductions in greenhouse gas emissions. At the same time, the Conservative Party of Canada proposed removing existing policies, including the federal carbon tax, and enacting other policies that were widely criticized by climate experts. Because the Liberal Party was re-elected to the most seats in Parliament and is expected to at minimum maintain the climate policies which the second place Conservative Party promised to revoke, we can calculate the emissions potentially saved by this electoral outcome and suggest a few ways that responsibility for those saved emissions could be distributed among voters (for thoughts on calculating efficacy instead of responsibility, see Appendix A).

An analysis of the two front-running party platforms concluded that, by the year 2030, Canada would be emitting 100 MtCO$_2$e per year less under a Liberal-led government, which represents roughly 14% of current emissions (Jaccard, 2019). Assuming linear reductions, this would result in a cumulative sum of 612 MtCO$_2$e by 2030 (see Appendix C.1 for full materials and methods). Since the next election could either overturn or enhance the relevant policies, we take only those projected emission reductions that would be achieved over 3.4 years (the average duration of an
elected government in Canada between the last ten elections) and attribute them to this election (a total of 192 MtCO\textsubscript{2e}).

A cautious or conservative approach to estimating emissions responsibility of voters is to equally apportion the emissions total to the 338 electoral districts that elect Members of Parliament, and then give equal responsibility to every registered voter in those districts. This results in a median value of 6.7 tCO\textsubscript{2e} in reduced emissions per registered voter. That quantity of emissions is equivalent to an individual taking two round-trip flights from Canada across the Pacific Ocean (e.g., Vancouver to Hong Kong). This estimate is conservative because it assigns responsibility to individuals who were registered but did not vote and to individuals whose chosen candidate did not win in their district.

![Figure 9: Distributing emissions responsibility to “winning voters” in the 2019 Canadian federal election. Emissions values for consumer actions taken from Wynes and Nicholas (2017).](image)
Alternatively, we could apportion the projected emissions reductions from the election only to “winning electoral districts” – those electoral districts where either the Liberal Party or another party favoring progressive climate policies was successful. We then distribute emissions in each winning electoral district only to individuals who voted for the successful candidate (Figure 9). In this approach, the median winning voter is responsible for 34.2 tCO$_2$e reductions, while voters in the most influential electoral district are responsible for 228.7 tCO$_2$e of reductions. These estimates may be more intuitive because they only attribute responsibility for policy decisions to voters who supported a party advocating those policies. A wide range of values will occur in any electoral system, like that of Canada or the United States, which has an uneven distribution of voters and or multiple parties splitting the vote.

There are various other ways one could apportion responsibility, though most would result in values somewhere between those we have presented. Organizations running “get out the vote” initiatives or seeking to influence voters’ decisions might be more interested in the marginal effects of each additional vote, especially in swing districts. Such a calculation would result in higher values than those we present here. Regardless of which method we choose, for this particular election, the potential climate responsibility of voting is higher than most individual lifestyle decisions that the average person has the opportunity to make (Wynes and Nicholas, 2017).
The actual emissions impact of this or any other election cannot be known until years later, and changes in emissions may never be directly attributable to the election’s outcome. For example, the elected party may alter or fail to enact their platform, the proposed policies may not have the estimated impact, or other factors may influence emissions and negate, inflate or obscure the impact of the policies. Nevertheless, elections in which the platforms of the leading candidates could result in very different climate outcomes have been common in recent years, including the national elections in the United Kingdom in 2019, Brazil in 2018, and the United States in 2016.

Regarding the pivotal US election in 2016, it is difficult to quantify the difference between the two major Presidential candidates due to ongoing court cases about the proposed removal of Obama-era climate policies by the Trump administration. However, the Clean Power Plan alone (which President Trump revoked) was expected to reduce emissions by 200 MtCO₂e per year in 2025 (Kemp, 2017). Taking that one year’s reductions in emissions and apportioning it to every registered voter (a very conservative approach) based on the distribution of state electoral college votes would result in a median emissions responsibility of 0.9 tCO₂e increase per registered voter. In a less cautious approach where those same emissions are attributed only to winning voters in winning states, the median voter would be responsible for increasing emissions by 4.6 tCO₂e and the most influential voter (in Alaska) would be responsible for increasing emissions 12.1 tCO₂e. These estimates are lower than those from the Canadian election but are based only on the effect of one of many climate policy differences between the candidates in the 2016 election.
4.1.2 Recommendations

The IPCC reports that for a two thirds chance of limiting temperature increase to 1.5°C, emissions must be roughly halved within the next decade (Masson-Delmotte et al., 2018). Since most federal elections take place only once every four years, voters have only two or three more chances to elect national climate leaders that can meaningfully contribute to closing this gap.

4.1.2.1 Encourage voting for climate leaders

Many scientists and other researchers, including those who advocate for action on climate change, are reluctant to advocate for specific policy positions or specific candidates for fear of compromising the perceived objectivity of science. There is some evidence that scientists can advocate for climate policies without harming their personal credibility or the credibility of their discipline (Kotcher et al., 2017). This analysis provides reluctant scientists with empirical evidence that voting is one of the most meaningful actions individuals can take to reduce greenhouse gas emissions.

4.1.1.2 Estimate emissions impact of policies

In addition to electing climate leaders, the public in democracies occasionally has opportunities to vote directly on climate policies. Switzerland holds frequent referendums, some of which are climate-relevant (BBC News, 2017), and numerous ballot measures offer American citizens a chance to vote on climate policies (Table 7). These ballot measures often provide informative vignettes to voters, but rarely, if ever, include an estimate of the measure’s impact on greenhouse gas emissions. Providing such values requires modelling which is seldom conducted, partially
due to the large uncertainties and the effort involved. This represents a missed opportunity for ballot measures, but one that could be corrected for elections more generally.

Table 7: Recent climate-relevant ballot measures in the United States

<table>
<thead>
<tr>
<th>Year</th>
<th>State</th>
<th>Name</th>
<th>Status</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>California</td>
<td>Proposition 39</td>
<td>Approved</td>
<td>Funds projects for energy efficiency using a tax increase</td>
</tr>
<tr>
<td>2012</td>
<td>Michigan</td>
<td>Proposal 3</td>
<td>Defeated</td>
<td>Requires that utilities generate at least 25% of electricity from renewable sources by 2025</td>
</tr>
<tr>
<td>2016</td>
<td>Florida</td>
<td>Amendment 4</td>
<td>Approved</td>
<td>Exempts solar and other renewable energy devices from certain taxes</td>
</tr>
<tr>
<td>2016</td>
<td>Washington</td>
<td>Initiative 732</td>
<td>Defeated</td>
<td>Imposes a carbon tax on certain fossil fuels and fossil-fuel-generated electricity</td>
</tr>
<tr>
<td>2018</td>
<td>Nevada</td>
<td>Question 6</td>
<td>Approved*</td>
<td>Requires that utilities generate at least 50% of electricity from renewable sources by 2030</td>
</tr>
<tr>
<td>2018</td>
<td>Arizona</td>
<td>Proposition 127</td>
<td>Defeated</td>
<td>Requires that utilities generate at least 50% of electricity from renewable sources by 2030</td>
</tr>
<tr>
<td>2018</td>
<td>Washington</td>
<td>Initiative 1631</td>
<td>Defeated</td>
<td>Charges fees on greenhouse gas pollutants and uses the revenue to reduce pollution</td>
</tr>
</tbody>
</table>

*Must be approved a second time on the 2020 ballot in order to amend the Nevada Constitution

4.1.1.3 Create arms-length institutions to inform voters

The public should not have to depend on academics or independent think tanks to conduct analysis needed to choose between candidates and policies. Governments could help citizens make informed choices by establishing or empowering existing arms-length offices (like the Canadian Auditor General, the Congressional Budget Office in the United States, or the European Court of Auditors) to provide impartial assessments of a policy’s expected emissions
reductions. These offices could give estimates for ballot measures, government policies, and platforms submitted by political parties in advance of elections. Historically, legislative budget offices have been effective in increasing government accountability (Chohan and Jacobs, 2017), and the electorate may trust their analysis more than modelling performed by a policy’s proponent. The diminishing carbon budget to avoid dangerous warming indicates a need to not just legislate climate policies but to legislate them as quickly as possible (Goulder, 2020). Additional scrutiny may incentivize parties to put forward well-considered climate policies and platforms thereby increasing the likelihood that newly elected governments are ready to implement climate policies upon being sworn in.

4.2 Conclusion

Climate change has been framed as an issue of justice. Those who emit the most are least affected, which is true in both time and space. Recent climate movements have centered on young people voicing their right to a safe future, but most youth are unable to vote. When climate is on the ballot, voting outcomes affect many people beyond the voting population. Some researchers have argued that individuals have an ethical obligation to reduce their personal emissions (Schwenkenbecher, 2014) while others maintain that there is no obligation to reduce personal emissions except perhaps in the case of voting (Maltais, 2013). The quantity of emissions associated with certain elections suggests that the responsibility to vote for climate action is a moral imperative.
Chapter 5: Can citizen pressure influence politicians’ communication about climate change? Results from a field experiment

5.1 Introduction

The combined emissions targets of national governments are insufficient to avoid dangerous levels of planetary warming as defined by the Paris Climate Agreement (Rogelj et al., 2016). Partially in response to this lack of ambition, over one million people around the world attended protests in March of 2019 with the intent of pressuring government officials into greater action on climate change (Wahlström et al., 2019). Despite increasing political mobilization, when asked to describe what they see as the most effective way for individuals to reduce greenhouse gas emissions, a recent study found that members of the public favor consumer actions like reducing personal vehicle usage over political actions like voting (Anonymous et al., Under Review). Interestingly, political advocacy is often a necessary condition for enabling consumer action, since structural barriers may prevent widespread consumer change (Ockwell et al., 2009). And while consumers can seek out a broad literature on the most effective steps they can take to reduce greenhouse gas emissions (Wynes and Nicholas, 2017; Lacroix, 2018; Gardner and Stern, 2008), there is considerably less research to inform the decisions of an individual hoping to use political action to mitigate climate change (Han and Barnett-Loro, 2018).

It is difficult to compare the effectiveness of different political actions and different consumer actions, but it may at least be possible to create a hierarchy whereby an individual could identify the political actions that are most meaningful at effecting change. A survey of European Members of Parliament, for instance, suggested that politicians viewed voting as highly effective, writing letters or emails to elected officials as moderately effective and online
discussions as less effective ways to influence political decision making (Hooghe and Marien, 2012). But these approximate rankings may not hold in other jurisdictions or remain consistent across multiple issues. A sudden influx of constituent communications on a new issue, for example, might cause greater response from officials than the same volume of communication on an issue that officials are already addressing.

Much of the governmental inaction on climate change can be explained by pro-fossil fuel lobbying (Goldberg et al., 2020b) or a host of political or psychological mechanisms (see Introduction 1.1.1.1). But some of the dissonance between the policies being enacted by officials and the opinions expressed by constituents might be explained by the “spiral of silence” on climate change. Since climate mitigation measures only become effective when a sufficient number of actors participate, governments and individuals who perceive a large proportion of their peers as unmotivated may be less willing to take on the individualized costs associated with climate action (Mildenberger and Tingley, 2017). According to this theory on the role of “secondary beliefs” (beliefs about what others believe), climate action is then at least partially reliant on individuals signaling that they are willing to act on climate, and other individuals correctly interpreting those signals.

Unfortunately, individuals not only underestimate public concern for climate change in other nations (Taddicken et al., 2019), they also tend to underestimate concern for climate change among their own peers, causing them to self-silence (Geiger and Swim, 2016). Furthermore, both citizens and political elites underestimate public support for carbon regulation (Mildenberger and Tingley, 2017; Hertel-Fernandez et al., 2019), which depresses motivation for further action.
Additional research in the United States has found that the misperceptions of political elites may be partly driven by disproportionate contact from Republican constituents, who are more likely to be opposed to climate action (Broockman and Skovron, 2018). Such misperceptions have also proven difficult to correct, as officials are unwilling to revise their estimates of constituent preference even in the face of strong public polling data (Kalla and Porter, 2019). In the UK, research suggests that silence from constituents on climate change discourages Members of Parliament from acting on climate change, since they do not believe that doing so would be representing the needs of their electorate (Willis, 2018a). Some UK officials also believe that, while climate legislation is necessary, it should be accomplished “by stealth”, partially because ardent climate advocacy might lead to disapproval from peers, who are perceived as being less climate conscious (Willis, 2018b). Following the logic of secondary beliefs, “stealth” climate advocacy on the part of legislators with strong concern for climate would suppress perceptions of climate concern even further among governing officials. As citizen concern for climate change is partially driven by cues from elites (Brulle et al., 2012), there is value in either group jumpstarting a feedback loop where increased expressions of concern by elites or the public amplifies concern and action in the other group.

Many environmental activists currently rely on online campaigns through social media and email to recruit members of the public to apply pressure to elected officials. Prior to widespread use of digital communication, legislators could discern which messages came from constituents based on their address or the area code of their phone number, but emails and social media communications largely mask the location of the sender. Emails and social media have also lowered the cost of communication, such that issues which constituents are not very passionate
about can still generate a high volume of online correspondence (Cluverius, 2017). Thus a large volume of communication no longer signals salience, and legislators may rely less on these signals to inform their choices (Cluverius, 2017; McDonald, 2019).

The presence of dishonest communication strategies may exacerbate the lack of trust displayed by legislators. Astroturfing, the act of falsely imitating grassroots organizing (McNutt and Boland, 2007), includes dishonest mass communication campaigns from interest groups. Interest groups might make use of members’ contact information without their permission or contact legislators who are not in the same jurisdiction as the members. Legislators who become aware of such tactics may then devalue future communications with similar characteristics, even if they are sent by constituents in good faith.

Given indicators of change in the way that legislators interpret signals from their constituents, it is important for grassroots organizations and concerned citizens to know how their outreach is now received. Past research has demonstrated the variable ways in which officials react to correspondence from their constituents. A study in the United States made use of emails from fictitious citizens to show that politicians are less responsive to minorities (Butler and Broockman, 2011), and an experiment featuring letters from actual individuals found that politicians are more responsive to service requests than to policy requests (Butler et al., 2012). In the UK, elected officials provided higher quality responses to information rich letters than to information poor letters from citizen interest groups (Richardson and John, 2012). The results of this research suggest that even within a single type of action, such as writing a letter, changes to authorship or format can alter the effectiveness of that political action.
The Canadian political system offers an interesting case to examine mass communication campaigns on climate change. Support for climate change policies is higher in Canada than in the United States, with broad (though heterogenous) support for carbon pricing across the nation (Mildenberger et al., 2016). Canada is a parliamentary democracy; the national House of Commons is composed of 338 Members of Parliament (MPs), each representing constituents residing in their electoral district (or riding). The four major federal parties have varying levels of ambition on climate policies and targets, with only a fringe party formed in 2018 openly denying the existence of human-caused climate change. In the months leading up to the most recent election, climate change became a priority issue for Canadian voters (Bricker, 2019). Still, it is not clear that Canadian politicians have come to terms with this shift in preference of the electorate. Canadian climate policies are projected to fall short of Canada’s own target set out in its Nationally Determined Contribution to the Paris Agreement, for instance (Environment and Climate Change Canada, 2020).

An ideal experiment to evaluate the efficacy of a political campaign would be to test whether members of a legislature who receive a greater volume of constituent correspondence are more likely to vote or write new motions in line with stated constituent preferences. However, legislative voting usually conforms to party lines (Nokken, 2000). In Canada, for example, even a successful campaign might only sway one or two MP votes out of 338, and therefore go undetected by statistical tests. Surveys of legislators can instead be used to elicit the legislator’s opinions on what they believe is effective in changing their political decisions (Hooghe and Marien, 2012; Cluverius, 2017), but results from these investigations may be subject to social
desirability bias (Nederhof, 1985). For instance, a legislator may feel compelled to incorrectly report that they value constituent preference above party mandate in order to conform to public expectations. Survey techniques such as asking a participant for the perceived opinions of their peers, and randomized response or list experiment can be used to reduce social desirability bias, though they have limitations (Glynn, 2013). Additionally, surveys of elected officials often feature low response rates (Hertel-Fernandez et al., 2019; Docherty, 2001), which would preclude the use of list experiments for a small (generally <500) population like members of a Parliament or Congress (though not necessarily their staff). A real-world experiment designed to avoid social desirability bias or response bias is necessary to assess the responsiveness of legislators to constituent communications.

In this paper, we present the findings of an innovative field experiment testing the efficacy of online political participation. We partner with a non-partisan organization to run a real-world campaign where constituents asked their MPs to tweet about climate change. We then monitor the MPs’ Twitter accounts to evaluate the effectiveness of the communication campaign, thereby measuring the responsiveness of MPs to outreach from their constituents on the high-salience issue of climate change. By selecting Twitter behavior as a dependent variable we are able to generate greater statistical power than if we had relied on a binary, high-level behavior like voting outcome. We follow this experiment with interviews of political staff in MP offices to solidify our understanding of the efficacy of these campaigns. This serves the double purpose of exploring ways to encourage political elites to send stronger cues on climate change and of better understanding how climate activists can best engage with their political representatives.
5.2 Methods

5.2.1 Study Design

To run the experiment, we partnered with Evidence for Democracy, a non-partisan, non-for-profit organization that promotes the use of evidence-based decision-making in Canadian government. Evidence for Democracy was founded by co-organizers of the “Death of Evidence” protests of 2012, initiated in response to cuts to research funding and the closure of research stations (Chartrand, 2012). Both the current staff and board of directors are largely composed of researchers and academics. Membership is concentrated in Ontario, British Columbia and Quebec with a large segment of supporters consisting of academics, public servants, government researchers, and retired scientists. At the time of the campaign, approximately 6580 individuals followed Evidence for Democracy on Facebook, 5600 on Twitter and 250 on Instagram. In addition to running educational and research programs, Evidence for Democracy raises awareness of scientific and policy-based issues in Canada and encourages members of the public to engage directly with policymakers.

Members of Evidence for Democracy were contacted by the organization using the organization listserv and an additional post made on Evidence for Democracy’s Facebook page to recruit participation for the campaign. The initial email was sent to 15556 members on May 4, 2015, with a follow-up reminder sent five days later to 15335 recipients. Participating members were notified that the campaign was part of a study being conducted with researchers at the University of British Columbia. We assisted Evidence for Democracy in designing the text of a campaign email that asked Canadian MPs to post messages on their official Twitter accounts encouraging action on climate change. We then designed two different suggested tweets that MPs could post.
so as to reduce the cost of participation. One tweet represented a public health framing and the other an environmental framing. There is some evidence that framing climate communications in terms of their public health effects can lead to greater support for climate change mitigation (Myers *et al.*, 2012; Maibach *et al.*, 2010; Kotcher *et al.*, 2018). Since framing might influence the decision to participate, we included a public health frame and a more typical environmental frame as a control. This also allowed us to extend the research on framing by testing in an important new population: elected officials. Both the campaign email and the tweets were available in English and French, Canada’s two official languages (see Appendix D.1 for full text of the emails).

Public Health Tweet: Science tells us that climate change poses a significant public health threat, from increased asthma & heat stroke to the spread of disease due to extreme weather. Thanks to all the youth who voiced their concern #Fridays4Future #MarchforScience

Environmental Tweet: Science tells us that climate change stands to dramatically alter Canada’s ecosystems, putting our cherished landscapes and iconic wildlife species at risk. Thanks to all the youth who voiced their concern #Fridays4Future #MarchforScience

The campaign was timed to coincide with the March for Climate rallies which were happening around Canada in early May of 2019. Prior to the experiment, we used block randomization according to political party to assign each member of Parliament to one of two conditions. Randomization was conducted with the R package randomizr (Coppock, 2019). All MPs received the same email, but half were given the public health tweet as an example of a tweet
they might wish to send out and half were given the environmental tweet. When members of Evidence for Democracy followed a link to participate, they entered their postal code and were automatically given the version of the campaign email containing the tweet that was assigned to their Member of Parliament.

5.2.2 Data collection and analysis

When the campaign concluded we scraped tweets using the rtweet package from R (Kearney, 2019), starting 7 days before the start of the campaign to act as a control, and 10 days after the first day of the campaign to test the campaign’s efficacy. Two MPs did not have twitter accounts at the time of the campaign, and because the campaign was conducted just prior to some byelections, three seats were not filled. In total we scraped 18776 tweets from 333 MPs.

While collecting results it became clear that there was insufficient Twitter participation from MPs to decisively evaluate which frame was more effective (only one MP posted a tweet with the suggested text, for instance). We therefore focused our analysis on whether receiving emails from constituents was a predictor of increased pro-climate tweets. We first evaluated the efficacy of the campaign emails by searching for the exact wording suggested in the example tweets included in the campaign emails. It is possible however that an MP would still be motivated by receiving an email to tweet about climate change, but to choose their own distinct wording. We filtered the 18776 tweets by using a series of English and French keywords which included: “global warm*”, “climat*”, “ghg”, “greenhouse gas*”, “effet de serre”, “fossil”, “carbon”, “emit”, “emett”, “emis*”, and “pipeline”, thereby creating a subset of the data with 1723 relevant tweets (“pipeline” was included as the proposed expansion of the Trans-Mountain pipeline has
become emblematic of the larger political conflict surrounding the carbon-intensive oil and gas industry). Two raters then went through the reduced set of tweets and coded them as either “pro-climate”, “anti-climate” or “neutral”. Full instructions for coding are available in Appendix D.2. Once all relevant tweets were coded, the two raters identified codes that were not agreed upon and discussed the coding until a consensus was achieved. The initial agreement was satisfactory (κ =0.848).

To test for a relationship between campaign emails and tweeting about climate change, we created a variable to measure the responsiveness of MPs to emails.

\[
\text{Responsiveness} = \frac{\text{pro-climate tweets}_i - \text{anti-climate tweets}_i}{\text{total tweets}_i} - \frac{\text{pro-clIMATE tweets}_j - \text{anti-clIMATE tweets}_j}{\text{total tweets}_j} \tag{1}
\]

Where i denotes the time period after the experiment and j before the experiment.

We tested the correlation between Responsiveness and number of emails received and also ran a zero-inflated negative binomial regression with number of pro-climate tweets in the experimental period as the outcome variable to control for confounding variables including the likelihood of being re-elected. This is based on the rationale that politicians are more responsive to constituents when they are likely to face a competitive election in the near future (McAlexander and Urpelainen, 2020). The zero-inflated negative binomial model, which is appropriate for fitting over-dispersed count data, was run in the pscl package in R (Zeileis et al., 2008). To estimate likelihood of re-election, we used seat projections for each electoral district taken from
canada.com on September 22, one month before the election, which categorized the lean of each district on a seven-point scale.

5.2.3 Interviews

To triangulate the findings from our Twitter experiment, we conducted semi-structured interviews with staffers in the MP offices. We reached out to every MP by email, debriefing them on the experiment, and asking if a member of their office would be willing to answer interview questions. Through the interviews we sought to answer three research questions:

1) Are MP offices more responsive to larger volumes of communication from constituents?
2) Are MP offices more responsive to certain forms of communication (e.g. personalized emails versus campaign emails)?
3) Do MP offices receive a higher volume of constituent communication on climate change than on other issues?

Because political staffers act as gatekeepers, determining which messages are shown to an MP as well as often managing an MP’s social media accounts, we judged it more useful to speak with staffers than with MPs. This has the benefit of also increasing the likelihood of conducting more interviews, while contributing to a sparse literature on the role of legislative aides as actors in the political process (Hertel-Fernandez et al., 2019).

To staffers who responded, we provided letters of consent (see Appendix D.3), and in order to save time for ostensibly busy staffers, obtained consent orally. We contacted those who did not
respond initially up to two additional times with reminder messages. The interviews lasted ten to fifteen minutes. We transcribed interviews and then conducted thematic analysis according to a matrix based method to identify emerging trends (Bryman, 2008). Interviewees agreed to participate on conditions of anonymity, so some identifying details have been removed from the text. We received approval for all methods from the University of British Columbia’s Behavioural Research Ethics Board.

5.3 Results

5.3.1 Experimental findings

We collected a total of 18776 tweets for analysis. Of these, 1723 were flagged as potentially relevant to climate change based on our keyword search. We then coded each of those 1723 tweets as “pro-climate” (in favour of greater awareness or action on climate change) or “anti-climate” (dismissive of the existence, seriousness or need for action on climate change). 1327 tweets were coded as pro-climate with substantial differences in the fraction of pro-climate tweets by MPs in the various parties (Figure 10). 26 tweets were coded as anti-climate. 16 of the 26 anti-climate tweets were from MP Maxime Bernier, of the People’s Party of Canada, while the remaining 10 were posted by six MPs from the Conservative Party of Canada.
Figure 10: Boxplot showing the percentage of tweets which were coded as “pro-climate” for each Canadian Member of Parliament, grouped by major political party.

During the email campaign, a total of 392 campaign emails were sent to Members of Parliament (Table 8). Note that this excludes emails from constituents residing in the three ridings waiting on the results of a byelection. These emails were not evenly distributed (Figure 11). 181 MPs received no emails, while one MP received 28. Of these, only one MP, a Liberal Party member who received four emails from constituents, tweeted out the actual suggested text provided in the campaign emails.
Table 8: Composition of Canadian Members of Parliament at the time of the experiment

<table>
<thead>
<tr>
<th>Party</th>
<th>Members of Parliament</th>
<th>Female</th>
<th>Male</th>
<th>Tweets during analysis period</th>
<th>Campaign emails received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberal</td>
<td>177</td>
<td>50</td>
<td>127</td>
<td>10308</td>
<td>267</td>
</tr>
<tr>
<td>Conservative</td>
<td>97</td>
<td>18</td>
<td>79</td>
<td>4160</td>
<td>66</td>
</tr>
<tr>
<td>NDP</td>
<td>41</td>
<td>17</td>
<td>24</td>
<td>2218</td>
<td>48</td>
</tr>
<tr>
<td>Bloc Québécois</td>
<td>10</td>
<td>2</td>
<td>8</td>
<td>145</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>4</td>
<td>6</td>
<td>1945</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>335</td>
<td>91</td>
<td>244</td>
<td>18776</td>
<td>392</td>
</tr>
</tbody>
</table>

Figure 11: Histogram showing the distribution of number of emails received by Members of Parliament during the campaign.

We measured “responsiveness” as the change in pro-climate tweeting during the experimental period compared to the control period prior to the campaign. In a successful campaign we might expect that MPs receiving a greater volume of emails from constituents would have a higher responsiveness than MPs who received fewer or no emails. But we found no correlation between volume of emails and responsiveness ($r_s=-0.03$, $p=.57$). We also examined the correlation in
various parties, from the Liberal Party ($r_s=-0.02, p=.84$), the Conservative Party ($r_s=0.06, p=.58$), and the New Democratic Party ($r_s=0.10, p=.52$), in each case finding no evidence of a relationship (Figure 12).

![Figure 12: Number of emails received by Members of Parliament versus their responsiveness to those emails, separated by political party. p-values for Spearman’s correlation shown in upper right of each panel. Note: one outlier (number of emails=28) not visible in the Liberal Party plot.](image)

A high volume of emails could be less effective if it signals to MPs that the communications are either not from individuals in the riding, are not part of a grassroots effort, or are actually from bots. In such a case we might expect MPs who receive an email to be more likely to increase the number of pro-climate tweets, but we would not be able to detect a correlation between volume of messages and the MP’s response. Yet we found no evidence that MPs who received at least
one email behaved differently from MPs who received zero \((t = 0.13, 95\% \text{ CI } [-0.024, 0.027]), p=.900)\).

These results were confirmed in the zero-inflated negative binomial regression. In that model, the number of emails received by an MP was not a significant predictor of the number of pro-climate tweets posted in the experimental period and was only marginally significant \((p=.057)\) when controlling for the level of competition in the electoral district. When we instead treated contact from constituents as a binary variable, receiving an email was not a significant predictor even when controlling for level of competition \((p=.164)\).

Due to collinearity between variables, we were unable to control for party and level of competition in the same regression. However, when restricting the regression to only Liberal Party MPs, and controlling for level of competition, the effect of an additional email was estimated at 1.06 \((=\exp(0.060), p=.016)\). Thus, if other variables are held constant, a Liberal MP receiving one additional constituent email would be expected to post, on average, 6\% more pro-climate tweets. Still, the effect of receiving contact from constituents measured as a binary variable was only marginally significant, estimated at 1.60 \((=\exp(0.468), p=.064)\). Due to their smaller sample size we were unable to run this analysis for the remaining parties. See Appendix D.4 for full regression analysis.

### 5.3.2 Interview findings

We conducted interviews with 12 MP staffers from 11 MP offices. Provinces represented included British Columbia (5 MP offices), Ontario (3), Saskatchewan (1), Alberta (1) and
Manitoba (1). Staffers worked for MP offices from the Liberal Party of Canada (8), the New Democratic Party (2), the Conservative Party of Canada (1) and one office not belonging to the top four political parties. We specifically sought out staffers who were responsible for managing constituent communication and or managing the MP’s social media accounts.

5.3.3 Volume of communication

We began the interview by asking staffers if there was a threshold number of communications required from constituents to raise an issue with the MP. There was no consensus on how MP offices act in this regard. Only two staffers described an actual volume of constituent communications that would prompt them to involve their MP, and even then, the responses were more qualitative than quantitative:

Definitely if we receive more than two calls in a day about a topic, we would be letting him know … that’s pretty unusual for us to receive more than two calls in a day about a specific topic … there isn’t actually a codified threshold but we typically get little tricklings in of like five correspondence … As soon as we start to see we’ll get thirty now on this one, then we go something is up … if you get six thousand - okay there’s a bot.

These responses suggest that a high volume of emails is not always necessary to at least reach the MP and may be detrimental if the campaign suspects astroturfing or other types of foul play such as automated emails (bots).

Two staffers said the process was issue dependent, with more weight given to issues that are relevant to the riding association or the MP’s office. Three staffers said they observe trends in communication and use those to inform the MP of which issues are becoming more salient for their constituents, “usually there’s an issue that becomes popular and we get a lot of e-mails on
that specifically and then that’s the one we send over to him”. Two staffers noted that the type of communication helped them determine if the message was worth sending to their MP, with less weight given to campaign emails. One interviewee said, “if an e-mail is a campaign, so if it’s something we’re getting repeatedly, our support staff at the Liberal research bureau will create a party response to the issue. So it doesn’t necessarily need to be brought up to [name of MP], because there’s already party lines provided.”

This raises the complication that a letter can be effective either because it is actually seen by an MP and therefore has the chance to persuade them, or because it is added to a tally that informs the decisions of the MP or the party apparatus: “when it comes to e-mails we do keep track and … gauge whether or not they’re pro or they’re anti for an issue”. Another staffer noted that they “keep tallies on who calls in … who e-mails in about what, and all the offices do that, and [staff at the political party] keep track of it.”

### 5.3.4 Form of communication

Ten of the twelve staffers were able to comment on which type of communication was given more weight in decision-making. All staffers agreed that campaign emails (or form emails) were given either equal or lesser treatment compared to personalized emails, hand-written letters or phone calls. Five staffers described a hierarchy with campaign emails on the bottom. For instance, one mentioned that when they received personalized messages they tried to set up a phone call with the constituent while another described how hand-written letters receive personal responses from the MP. Both of these staffers observed that campaign emails only receive generic responses in their office.
Other staffers were very explicit in describing a hierarchy, saying for instance that “Hand-written letters are certainly more impactful than emails and form emails” while another noted that if a message comes through the MP’s website it “definitely weigh(s) more heavily than a blanket campaign letter”. One MP went so far as to identify four levels of impact with a personalized hand-written letter being the most impactful, followed by a form letter that is mailed, then a personalized email, and finally campaign emails. They went on to say “a hundred e-mails about one issue … like each person has written their own e-mail, that will make us think about it. But a hundred [hand-written] letters would really give you pause to think about what’s going on, and to try to figure out how you respond.”

Still, this was not a unanimous belief: two staffers maintained that all communications were treated equally while a third claimed that campaign emails had lower weight for the MPs, but equal weight when sending numbers to the political party apparatus. Two other staffers did not rank campaign emails as being less impactful but believed that the process of responding to a hand-written letter endowed it with more meaning.

When a letter comes in, someone has to physically open it and read it. An e-mail comes in and you get blasted with it… don’t want to say we don’t read them, we read all those, maybe really quickly … and then go to the next one.

5.3.5 Is communication on climate change saturated?

Interviewees were asked, “Compared to other issues, do you feel like you receive a lot of correspondence from constituents about climate change?” Responses to this question were mixed. Three interviewees said that they received a below average amount of communication on
this issue, for instance, “We don’t have a whole lot of personal people writing in their personal thoughts of climate change. We get a lot of form letters that somebody’s found a website that automatically sends an e-mail to their MP”. One interviewee said it was average and seven offices believed the amount of communication on climate change was above average. Some interviewees identified the difficulty of drawing boundaries around the issue, as climate change can exacerbate natural resource problems or be taken into consideration when approving new fossil fuel infrastructure like pipelines. One interviewee noted that because their constituency is in Alberta, which has a heavy oil and gas industry presence, they receive correspondence with “a bit more balance on the environment issues”, indicating that not all communication on the issue of climate change consists of a pro-climate message. Two interviewees also observed that climate can be more or less represented in constituent communication depending on current events and media focus.

5.4 Discussion

In order to pass the type of aggressive legislation needed to mitigate climate change, elected officials need strong signals that such action would be supported by their constituents. Individuals and climate campaigners seeking to motivate elected officials would therefore benefit from understanding which forms of communication are more persuasive. Mass communication campaign emails are a primary tool of contemporary climate action, but researchers believe that their efficacy may be declining (Cluverius, 2017). This study used an original, real-world experiment to test the responsiveness of elected officials to communication from their constituents, connected to a campaign.
In the experiment, Members of Canadian Parliament received generic, campaign emails from their constituents asking them to post a pro-climate message on social media accounts. Only one of the 181 MPs who received such a message posted the text suggested in the email to their Twitter account, and no statistical difference was detected in the frequency of pro-climate tweets of those who received messages compared to those who did not. This initial evidence suggests that campaign emails are only a marginally effective way of reaching out to Members of Parliament in Canada. Furthermore, follow-up interviews with MP staffers indicate that campaign emails are likely to be among the least effective ways for constituents to directly communicate with their MPs.

The lack of MP response to the constituent requests in this experiment is notable given that the low-cost, symbolic nature of the requested action: posting a pro-climate message on Twitter. Campaigns regularly seek more substantial action from elected officials, like requesting a vote against party lines. The request in this study demands a much lower level of persuasion by the constituents. The staffers who manage MPs Twitter accounts are often the same staffers who deal with messages from constituents, which further reduces obstacles to participation: some staffers who are given more latitude could take care of the constituent request independently. Furthermore, many MPs tweet dozens of times per day, so a single tweet on the topic of climate change would not need to constitute a large shift in messaging strategy. An alternative interpretation is that a social media request may seem less important in the eyes of the MP offices than constituent requests to vote a certain way on legislation. The perceived stakes associated with the campaign request may matter in addition to how easily the request can be satisfied.
MPs from the Conservative Party may have also been hesitant to send a signal that is at odds with the messaging strategy of their party, but they are an exception. Their reticence does not explain why only one of the 115 MPs from other parties who received emails from their constituents was willing to post the suggested message on Twitter. We also detected no difference between MPs who received at least one email requesting a pro-climate tweet, and those who did not in terms of pro-climate tweets posted to Twitter. Consistent with the (disputed) hypothesis that politicians in safe positions are less responsive to their voters (Griffin, 2006), we found evidence that Liberal MPs were responsive to constituent requests but only when controlling for the competitiveness of their district. Theoretically we would expect Liberal MPs to be more responsive on this issue than Conservative MPs, but we were unable to perform the same tests for the other parties because they hold fewer parliamentary seats. Future research could expand on our findings by testing on these other parties.

Our use of an experiment instead of surveys to determine the responsiveness of elected officials avoids the response bias and social desirability bias that would weaken the findings of a similar investigation performed with surveys alone. This method of investigation does however necessitate certain tradeoffs. First, studies on political elites are understandably restricted to a small sample size (we analyzed 335 MPs for this experiment). Similarly, performing a realistic experiment required us to partner with an actual organization, in this case Evidence for Democracy. We chose a non-partisan organization with the intent of reducing the tendency for right-leaning MPs to dismiss the persuasive communication outright. But given the partisan divide on some science-policy issues in Canada (Lachapelle et al., 2012), Evidence for
Democracy and its membership may not be viewed by MPs as non-partisan (Liberal received over twice as many emails per MP as Conservatives). Evidence for Democracy also has a smaller membership than other organizations, and the fact that the campaign centered on social media posts instead of more galvanizing topics in Canadian politics resulted in only 392 emails going out to MPs. This is not necessarily a flaw since more communications are not necessarily more effective, but it does limit the generalizability of our results to smaller campaigns. Finally, the campaign was timed to coincide with the Fridays for Future and the March for Science marches. Possibly due to this timing, MPs posted more pro-climate tweets per day in the control period, and by the time campaign communications had been relayed to them they may have been disinclined to tweet on the subject again.

Even with these limitations, the findings of the experiments and interviews, integrated together, provide evidence about the general effectiveness of individual political actions. If campaign emails sent within six months of an election are unable to persuade MP offices to make a token statement on social media, then they are unlikely to achieve larger changes such as an elected official voting against party lines. Such vote shifts also represent a rather ineffective way of influencing national politics: the Canadian political system is even less amenable to dissenting votes than other Westminster-style parliaments, and parties incentivize conformity by denying promotions and coveted committee positions to dissenters (Malloy, 2003). The interviews suggest that the greater political impact of communication from constituents, whether via campaign emails or more individually persuasive hand-written letters, may be on party or governing strategy rather than a vote in the legislature. Though follow-up research is needed to
understand if all parties operate in the same way, one interviewee described how every office in their party tallied delivers tallies of constituent communication to the central party.

This influence is evident in internal party negotiations about climate and energy policy decisions. For example, in Canada, MPs of the governing party (ostensibly informed by the preferences of their constituents) meet with the Prime Minister in weekly sessions where they have the opportunity to influence the government’s agenda (Malloy, 2004). The debate within the Liberal cabinet over whether to approve the Teck Frontier oilsands project serves as a recent example, with members of cabinet taking sides largely based on the preferences of their constituents (Leblanc and Walsh, 2020). This highlights some regional differences in the power of individual voters, where constituents represented by members of the governing party have greater influence over national decision-making. But, constituencies of other parties still command some leverage, especially in situations where the governing party retains only a plurality of seats in the legislature (as is the case for the current minority government in Canada). In such cases the governing party tends to be especially sensitive to public opinion and criticisms levelled by the opposition parties (Bourgault, 2011). Furthermore, there is evidence that representatives in party-centered systems may work to change the views of fellow party members when those views are in opposition with the preferences communicated by constituents (Öhberg and Naurin, 2016).

While persuading individual MPs or political parties through emails might not generate change that can be experimentally observed, there is evidence that such efforts are still worthwhile. This research points to a variety of new avenues for future work. Results from the interviews suggest that campaign emails may be more effective at informing party decisions than decisions
of individual MPs. It is possible that campaigns targeting a small number of swing votes on legislation would do better to use personalized emails, phone calls and hand-written letters, whereas efforts to change the priorities of party leadership could still rely on generic campaign emails. More generally, there is a need to understand how different forms and volumes of communication are viewed by subnational elected officials, and by officials in other governing systems. For instance, officials with a smaller number of constituents, like city councilors, may be considerably more responsive than national officials.

As political science makes greater use of field experiments, responsiveness can be measured by social media posts, whether an official sends a reply to constituent outreach (Butler et al., 2012), the quality of that reply (Richardson and John, 2012), the willingness to meet with a constituent (Kalla and Porter, 2019), and the willingness to co-sponsor new legislation or change a vote on tabled legislation. Additional experiments that match these dependent variables with different forms of persuasion (phone calls, petitions, and perhaps even protests) can provide insight into how citizens best engage with their representatives.

5.4.1 Recommendations

Interviews with campaign staffers showed that elected officials are not so saturated with communication on climate change that additional outreach from constituents would be ignored. And if there is still value for campaigners and individuals in reaching out to their representatives, then it is worthwhile to know the most effective ways of doing so.
While mass campaign emails remain more effective than no action at all, organizations seeking to maximize their impact on the political decision-making process should consider diversifying methods of contact. Phone banks, letter-writing parties, and personalized emails all have the potential to be more persuasive on a per-communication basis than campaign emails. Campaigners often seek to intervene in political decisions that arise suddenly, in which case online communications have an obvious advantage over hand-written letters or postcard campaigns, but phone calls would still be timely and possibly more effective. Personalized emails or letters also require more effort and may result in a lower volume of communication, but there could be diminishing returns to high volumes of repetitive communication if elected officials and their staff fail to see these as sincere efforts at outreach. Alternatively, recruiting activists to make more phone calls may generate its own set of obstacles, such as unwillingness on the part of socially anxious individuals to participate (Reid and Reid, 2007). In the short term, if large, organized protests are curtailed by increased social distancing (as a legacy of the COVID-19 pandemic), it will be especially important for members of the climate movement to understand how to better persuade elected officials using other means.

Climate campaigners have a unique opportunity during climate strikes and other protests to recruit mobilized individuals to contact their representatives. A survey of protestors attending the Fridays for Future rallies in 13 cities found that of the largest age group, teenagers, only 10% had ever contacted a government official (Wahlström et al., 2019). Each gathering features a large captive audience, who, though engaged in protesting, could be maximizing their impact by also writing short, hand-written letters to their MPs, or leaving a phone message at their MPs office. Based on our experimental results and the interviews conducted with MP staffers, these
interventions are expected to be more effective than campaign emails. Organizing group communication at a protest would ensure that multiple interventions not only occur at the same time, but also coincide with increased media attention. This would signal the kind of trend that MP staffers described as sufficient justification to notify their Member of Parliament, and is consistent with expert belief that the attention of political actors is influenced by recent events (Jones and Baumgartner, 2005). In addition to generating necessary pressure on politicians to act on climate change, organizing group communications of this sort would also better educate members of the public on how to communicate with their representatives, allowing for lasting civic engagement.
Chapter 6: Conclusion

Climate change represents the principal collective action problem of our time. Individuals can contribute to solving the problem, but without sufficient participation there is no guarantee that their contributions will amount to measurable change. On occasion we can observe individual actions scaling up to the global level; the choice to purchase large Sport Utility Vehicles instead of smaller, more efficient cars has been the second-largest contributor to the global increase in CO₂ emissions since 2010 (Cozzi and Petropoulos, 2019). If the decision to engage in an optional high-emitting activity matters can be scaled up across wealthy nations, then there may be opportunities for individuals to make choices that scale up for positive change. How do we identify these opportunities and decide where to place our effort?

Past research for my master’s degree and PhD comprehensive exam showed which lifestyle choices lead to the largest reductions in emissions on a per person basis (Wynes and Nicholas, 2017) and the interventions that could be used to reduce the greatest amount of emissions on a per intervention basis (Wynes et al., 2018). The first study was criticized for not evaluating how realistic it is for a large fraction of the population to take on these lifestyle changes and adhere to them with sufficient stringency (Stern and Wolske, 2017). Indeed, one lesson I derived from criticisms of the paper (Pedersen and Lam, 2018) is that the most effective actions on a per person basis (e.g. choosing smaller families) may be so weighed down with cultural and historical baggage, or so politically charged, that focusing on them is counterproductive. Some scholars believe the same principle applies to all lifestyle choices (see Introduction 1.2). Are there any lifestyle choices that merit attention? And if only political actions are useful, then
which deserve the most focus? Before addressing that question directly, I briefly discuss the findings of my dissertation research below to review some important considerations.

6.1 Summary of major findings

I began this dissertation by showing that individual lifestyle choices can be more effective when they set an example for others and lead to change beyond a single person. In Chapter 2, I show opportunities for individuals at public institutions to lead by example in reducing their emissions from air travel. Based on my analysis of the travel habits of 705 travelers at the University of British Columbia, I found that researchers who study topics related to sustainability currently display the same patterns of high-carbon mobility as their colleagues. Initially these Green researchers could take simple steps like finding alternatives to trips that are easily avoidable, in order to shift academia from a culture of prolific air travel to a culture of necessary air travel. Although the regressions used to analyze the relationship between academic travel and productivity cannot prove causation, the presence of a large number of “easily avoidable” or discretionary trips suggests that academics could at least somewhat reduce their air travel without fear of reducing their academic productivity.

As academia continues to grapple with high-carbon forms of transport in a carbon-constrained world, my research raises questions of distributional equity not unlike those addressed by international climate negotiations. Are early career researchers entitled to a larger share of an institution’s air travel than their senior colleagues? Would restrictions on conference air travel privilege wealthier institutions or academics from developed nations? Which forms of air travel are more necessary, and should researchers who use air travel for those purposes (field work, for
instance) be given more latitude to travel frequently than their colleagues? We categorize some
trips as “easily avoidable” but different academics could have different perceptions of which
flights are discretionary and which are not. If academia chooses to reduce demand for air travel,
those differences in perceptions could become stumbling blocks to progress.

In Chapter 3, I report the findings of a survey evaluating the carbon numeracy of 965 members
of the North American public. The results show one possible reason why many individuals, even
those who are concerned about climate change, continue to travel extensively by air; emissions
from air travel are consistently underestimated compared to other lifestyle choices. Correcting
similar misperceptions of which lifestyle choices matter for the climate may help motivated
individuals focus their efforts in more effectual ways. More generally, people with strong
environmental identities do not have lower emissions than the rest of the public, partially
because the pro-environmental behaviours they adopt tend to be low-impact or symbolic (Moser
and Kleinhüchelkotten, 2018). People with strong environmental identities put low effort into
reducing their air travel, which has a large climate impact, while placing substantial effort into
purchasing organic food, which has a negligible climate impact (Moser and Kleinhüchelkotten,
2018). The results of my surveys are consistent with this tendency: people underestimate the
emissions associated with meat consumption and air travel, while overestimating the emissions
associated with more symbolic actions like eating organic food or food without packaging. Even
participants who were concerned about climate change were largely unable to perform tradeoffs
between different actions, which would partially explain why people sometimes believe that a
token action can compensate for the rest of their carbon footprint. So long as a segment of the
public centers its identity on green living, it may be worth persuading this group to focus on high-impact lifestyle choices.

My surveys revealed another potential misconception: when asked an open-ended question about the most effective ways an individual can reduce emissions, very few people suggest political actions. In Chapter 4, I attempted to quantify the emissions responsibility of voting, so as to make at least one political action comparable to lifestyle choices. The 2019 Canadian federal election made for an ideal case study to investigate this question because there were substantial differences in projected emissions for the two most likely outcomes. Our analysis of this case showed that if one assigned equal responsibility for the emissions outcome to all voters, each voter would be responsible for 6.7 tCO$_2$e – about the same as an individual passenger’s responsibility for crossing the Pacific four times (e.g., two return flights from Los Angeles to Beijing). Based on this, and a quick analysis of the US 2016 presidential election I concluded that voting in climate-relevant elections can be associated with more emissions than many lifestyle decisions. If individuals are focused on lifestyle actions, and if political actions are more effective per individual than lifestyle choices, then this would have important ramifications for the ongoing debate between climate thinkers on which actions to emphasize.

However, out of all political actions, I was only able to quantify the emissions responsibility of voting (see Chapter 4 for this brief text, originally prepared as a short-format journal article). Although I explored calculations for other actions, I found the number of assumptions necessary to be prohibitive. Even in the case of voting, my calculations were focused on responsibility and not efficacy (though see Appendix A for an attempt to quantify the efficacy of voting, which
does offer some support for the idea that emissions reduced by voting is greater than those reduced by lifestyle choices).

Instead of quantifying the efficacy of each political action, I suggest that it is more feasible to compare political actions to one another in a rough hierarchy. In Chapter 5 I extended our understanding of which political actions are more effective than others by measuring the efficacy of campaign emails in changing the communication behaviour of elected officials on climate change. Using a novel experiment, members of a non-partisan organization sent generic campaign emails to their elected officials, requesting that the officials make a pro-climate post to their social media accounts. Our preliminary findings suggest that campaign emails are still marginally effective, but other modes may be more persuasive on a per communication basis. Individuals seeking to enhance their communications with elected officials should coordinate with friends or groups so that officials receive larger numbers of messages at the same time. Ideally these messages should also be personalized, using phone calls or hand-written letters where possible.

6.2 Recommendations for climate educators and advocates

I have shown that certain actions (living car free, eating a plant-based diet, and avoiding air travel) are among the most effective steps an individual can take to reduce lifestyle-based emissions. These actions have the potential for transformative change, are not easily addressed through technological developments, and are well-suited for individuals across the developed world but especially for adolescents establishing their patterns of living (Wynes and Nicholas,
While focusing on low-impact actions like recycling is probably not an effective climate communication strategy, different audiences do require different messages.

In communications with wealthy homeowners, there is value in encouraging home weatherization (Stern, 2020), installing heat pumps, producing renewable electricity (Ivanova et al., 2020) and so forth. I have given this type of action less attention partially because it is less visible and less likely to form a part of someone’s environmental identity, but mostly because it is not widely applicable. When speaking to an audience with agency over these decisions, they should be mentioned. But here I wish to consider whether any lifestyle actions merit particular focus. This assumes a zero-sum situation, where more focus on one behaviour reduces time or energy that could be spent on another. In some situations, communicators may be able to take a nuanced approach, acknowledging that certain actions (e.g. recycling, changing lightbulbs) are positive, but other actions are much more positive. Yet this still leaves us with the question of which actions belong in that second, elevated category.

Trusted experts can encourage some individuals to adopt either lifestyle changes or political actions to mitigate climate change (Cologna and Siegrist, 2020). So which behaviours should be recommended? Which behaviours should be modelled by experts? And is it worthwhile supporting movements, with time or finances, that promote particular lifestyle changes?

In this dissertation I have confirmed that individuals underestimate the emissions associated with eating a plant-based diet and with air travel but are more accurate in their estimations involving personal vehicles. They also tend to overlook political actions when thinking of the most
effective ways that they can reduce emissions. This can help answer the question of what actions communicators and educators should focus on in messaging: those that the public has not heard or fully processed.

Less effort could be spent reaffirming the fact that personal vehicles contribute to climate change since individuals already understand that driving is a major source of emissions. Still, there may be value in repeating information that is already understood, and informing audiences of the other negative externalities associated with personal vehicles may also help to change policies or behaviours (Fujii, 2007). But there are limits to human agency in this domain. Unlike air travel which can be highly discretionary (Higham et al., 2014), or meat consumption which is frequently done in excess (Wang and Beydoun, 2009), personal vehicle usage is often forced on individuals by structural and political forces (Mattioli et al., 2020). There is value in societal leaders decreasing their meat consumption and air travel to raise awareness and change social norms, partly because widespread adoption might help make regulation of those industries more feasible. Additionally, personal costs to those actions are comparatively low: plant-based diets are healthier (Tilman and Clark, 2014), and my research suggests that professionals can lead by reducing air travel without harming their careers. But it may be less fair to ask climate leaders to risk their lives biking on unsafe roads to inculcate car-free culture in cities where infrastructure is lacking.

Emissions reductions from personal vehicles are probably best achieved by encouraging the uptake of zero-emissions vehicles, or by changing the incentives and structures that promote personal vehicles so individuals can adopt car-free alternatives when they are safe and widely
available (Buehler and Pucher, 2012; Pucher et al., 2010; Prins et al., 2016). Individuals interested in engaging in climate politics, especially at a local level, would do well to advocate for such changes. Meanwhile, if a reader believes that climate advocates should continue pursuing lifestyle change for themselves and others, this dissertation affirms the decision to focus on reducing air travel and meat consumption, especially in educational efforts and modelling by climate leaders.

Returning to the question of which political actions are more effective in achieving structural or policy change, I have used a bottom-up, somewhat reductionist approach to begin answering this question. Another approach would be to determine which societal changes are necessary, and which social movement tactics are most likely to be successful in establishing those changes. Whereas my approach assumes an individual is already engaged and recommends the best way to participate, a top-down approach might be concerned less with the efficacy of an individual action and more with the actions that are most likely to grow a social movement.

In the Introduction (1.1.2.2), I referenced some of the prominent social movements that are driving political action on climate change, including the divestment movement, school strikes, and the push for a Green New Deal. Much of the sociological research on these movements is retrospective, but could still be useful for grassroots organizations as they seek to improve on their practice. For instance, research on the success of the divestment movement in changing structures of discourse (Schifeling and Hoffman, 2017) could be taken into consideration by organizations like the Sunrise Movement who are also pushing not just for singular changes in policy, but also for a broad reimagining of societal structures.
In some cases, there is evidence of climate organizers incorporating research findings into their strategy. Research on the efficacy of resistance campaigns, relying on a worldwide database of movements, found that non-violent resistance campaigns are more effective than their violent counterparts, largely because they are more inclusive than violent forms of resistance (Chenoweth et al., 2011). This conclusion inspired the campaign tactics adopted by the founders of Extinction Rebellion (Berglund, 2019). The bottom up approach that I take here, informed by my background and research skills, can hopefully complement the work of sociologists and campaigners in their strategies and decision-making.

Based on the high values we calculated for the emissions responsibility of voting in climate-relevant elections, voting is likely to be among the most effective ways to create change on a per person basis. But citizens can only vote every so often - how can they be engaged to maximum effect the rest of the year? One possibility is that voting is so disproportionately effective that campaigns and individuals should focus on increasing the pro-climate votes of other people, through donations, conversations and canvassing. This is consistent with an approach to lifestyle actions discussed in Section 1.2 where lifestyle actions become more powerful when they serve to inspire or inform others.

The alternative to focusing on elections is to change the decision-making of politicians who are already in office. This could include attending protests, writing letters to the editor, signing petitions, or contacting elected officials. In terms of contacting elected officials, my preliminary results indicate that personalized communications are likely to be more persuasive than generic
modes of communication, like campaign emails. Climate advocates can therefore recommend to their audiences that they not only contact officials but send personalized messages when they do. But we still have little idea how communications with elected officials compare with other political actions (though see Hooghe and Marien, 2012 for some indication of how elected officials perceive different actions). In the following section I examine some of the next steps for my research, detailing ideas for how to expand on this question of the efficacy of political actions.

6.3 Future steps

When I began this dissertation, the central goal was to determine the most effective political actions an individual could take to reduce greenhouse gas emissions and, if possible, compare those actions to lifestyle choices. Although I have managed to collect a good deal of peripheral evidence, I have by no means established a clear hierarchy of political actions. It is my belief that answering this question in a satisfactory way would require many subsequent experiments, and I delineate some of my ideas for that in the next section.

But much of my research also concerned lifestyle change – the role climate advocates could play in leading by example, the way institutions could help people in making better decisions, and the limitations of lifestyle change. I showed through my surveys that not only do people have weak understanding of their own carbon footprints, but that it may never be feasible for individuals to manage their carbon footprints to the level where they are able to make accurate tradeoffs between actions. Rather than perfecting how we educate the public on lifestyles and climate change, I conclude that we need to acknowledge these limitations, and focus on supporting better
choices. That includes institutions encouraging low-carbon choices, whether by providing emissions feedback soon after workplace decisions have been made or by adding carbon labels to products at the point of purchase. But we also need research to better understand whether lifestyle choices have a positive or a negative role to play in social movements, including those that push for policy change.

Below I gather some of my thoughts on promising avenues for future work, including a few suggested methodologies for answering the questions raised above. Based on my findings from Chapter 4, I describe some of the steps we can take to better understand citizens who are prioritizing climate change when they vote. Next I turn to the problem of understanding the relative efficacy of political actions, showing how my research in Chapter 5 could be expanded upon and improved in the future. Because I have worked more on aviation in the past, and because the results of Chapter 3 suggest that the climate impact of aviation is misunderstood by members of the public, out of the high-impact lifestyle choices, I concentrate on air travel.

6.3.1 Understanding climate voters

My findings suggest that encouraging voters to select pro-climate candidates and policies could greatly enhance climate mitigation efforts. And while there is evidence that a growing portion of the electorate is influenced by climate change in their voting choices, there is less understanding of how these voters make their decisions. For instance, recent polling of the United States Democratic Party Primary shows that voters who list climate change as their top priority prefer different candidates than climate experts, despite the presence of substantive policy differences between the various candidate platforms (Aton, 2020). In Canada, one might wonder how voters
whose top priority is climate choose between multiple parties with varying strategies and levels of ambition on climate mitigation. Future researchers might also try to discern how these voters weigh considerations such as party, rhetoric, endorsements and stated platforms when selecting their preferred candidate. Methodological approaches could be borrowed from studies on voter information gathering strategies (Lau and Redlawsk, 2001; Redlawsk, 2004; Stevenson and Vavreck, 2000) or by using conjoint experiments to simultaneously test many different stimuli (Stenhouse and Heinrich, 2019). This research could be extended using some of the survey techniques I employed in this dissertation to understand if climate voters are able to assess the efficacy of different policies (e.g. can voters differentiate policies with the potential to reduce emissions substantially, like a price on carbon, from policies with no chance of reducing emissions, like a ban on single use plastics).

I have already begun some preliminary research in this field. Since voters are known to use heuristics (mental shortcuts) to reduce the cognitive demands of processing information (Lau and Redlawsk, 1997), one cannot expect all voters to perform detailed research on every candidate. Voters who are concerned about climate change may want to know which candidates have the best voting records on climate issues or receive the fewest campaign donations from fossil fuel companies. Yet that information may not always be available or might be too difficult for a lay person to collect and interpret. I therefore intend to test whether a candidate’s pro-climate messaging on social media is a more reliable indicator of their climate credentials than other readily available heuristics, such as their party affiliation. By collecting this data both for the United States and the United Kingdom I should be able to show with some level of
generalizability whether voters can rely on statements made by candidates, or whether some candidates use their rhetoric to unjustifiably position themselves as climate leaders.

6.3.2 Ranking the most effective political actions

Research using field experiments for political science is expanding, and most of the work done so far focuses on voters rather than decision-makers. While surveys would quickly inundate decision-makers with additional responsibilities, field experiments can be performed in conjunction with organizations already conducting campaigns. In such partnerships, organizations benefit from academic expertise in designing conditions that shed more light on campaign tactics, and researchers get access to results with greater external validity. Political scientists who study institutions often lack the behavioural research background, and so disciplinary barriers have resulted in underutilization of this approach (Grose, 2014). Because of this, many interesting questions remain unanswered.

Additional experiments of this sort could help to elaborate the hierarchy of most effective political actions or show whether such a hierarchy exists at all (i.e. certain political actions may be more effective only in certain settings). Understanding how federal officials respond to constituents is not the same as understanding how provincial or local officials might respond. Replicating my results at different political levels would be valuable, but an experiment that compared the responsiveness of local officials to provincial or national officials using the exact same treatment would be even more useful.
My research question on the efficacy of campaign emails could be tested with an improved version of the same experiment. One such experimental design, which was discussed with the partner organization but found infeasible for that particular time, would be to randomly assign elected officials to different treatments: one where they received a generic campaign email, one where they received a personalized email, and another where they received a hand-written letter. This would test the theory that costlier displays of voter effort are given more weight in the decision-making of elected officials. Such an approach could be generalized in ways beyond straightforward communications, by for instance comparing how elected officials respond to receiving a digital versus a paper petition. Finally, rather than narrowly re-testing for the same outcome (posts to social media), other variables could be selected, such as asking officials to pledge a pro-climate action. That specific case would have the benefit of allowing researchers to observe both the pledge as a variable, and the follow-through on that pledge.

A good deal of investigation on many of these matters may have already been performed by political organizations. Academics exploring these questions may therefore inadvertently repeat research that was never published. There is a need for more partnerships between organizations and academics, and more organizations that can act as knowledge brokers, such as the Climate Advocacy Lab, who ensure that learning is shared between university researchers and practitioners (www.climateadvocacylab.com).

6.3.3 Encouraging individuals to fly less

Research on interventions and policies that can motivate sustainable decisions regarding air travel is scarce. First, there are dozens of studies evaluating the efficacy of behavioural
interventions to increase recycling and household energy conservation, but no studies have evaluated interventions to reduce demand for air travel (Wynes et al., 2018). Workplaces could provide personalized feedback to employees about their air travel choices or appoint sustainability group leaders to encourage and model green travel behaviours in business departments. I designed an experiment to test the former approach, where frequent flyers at the University of British Columbia would be randomized into a control group and a treatment group, with emails sent to the treatment group summarizing the number of trips they took and the quantity of emissions associated with those trips during the preceding six months. The emails would also include links to campus resources that could be used to reduce the need to travel (videoconferencing resources available in their faculty etc.). To this end I worked with an undergraduate research assistant to design a handbook on climate change and air travel, as well as various stand-alone infographics that could also be used to inform faculty (http://videoconferencing.arts.ubc.ca). Emails containing feedback and links to this information could be sent every six months and we could track whether the treatment group reduced travel compared to the control. Despite receiving support from relevant stakeholders on campus, we were unable to go forward with the experiment due to bureaucratic constraints, but it would be straightforward enough for others to implement in the future.

Similarly, in the public, researchers could evaluate the efficacy of providing carbon labels at the point of purchase on travel aggregator websites like Google Flights or Kayak, so that consumers can select more fuel-efficient aircraft or even select more carbon friendly modes of transit (high-speed rail versus flight). Further investigation might also uncover whether the “technological myths” that have been used to defer action on reducing emissions from air travel (Peeters et al.,
have also had a psychological impact on the willingness of consumers to fly less. In conjunction with some colleagues, I designed resources aimed at inoculating the public against common misconceptions such as “electric aircraft will allow us to fly without worrying about carbon emissions”. These resources (http://greentravel.arts.ubc.ca), or ones like them, could be tested as inoculation strategies, consistent with best practice on preventing climate misinformation (Cook et al., 2017; van der Linden et al., 2017).

The social movement of flygskam is also in need of more study. Early framing of the movement by the airline industry translated the Swedish term as “flight shaming”, which has an external, nagging connotation, as opposed to the original “flight shame”, which is meant as an internal, self-monitoring term of conscience. Does this framing make a difference on how those who are introduced to the movement perceive its aims?

Universities operating under the living lab approach are perfectly positioned to answer many such questions about air travel. Faculty represent a large group of frequent business flyers with autonomy over their mobility decisions. By greatly restricting air travel, the COVID-19 pandemic may also act as a natural experiment for business air travel. Faculty and universities around the world will have been simultaneously subject to a very similar stimulus, but not all will have responded in a similar way. Will departments that invested more heavily in technological upgrades and IT personnel see reductions in future air travel? Furthermore, since faculty are more accessible to researchers than other business travelers, they may able to offer insights about which travel norms will stick and which are temporary. People may feel less comfortable traveling frequently or attending larger conferences, even after a vaccine is
developed. Technologies which before were viewed as difficult or insufficient may now be viewed as adequate alternatives.

Thinking beyond the pandemic, interventions designed to reduce passenger kilometers, whether they be carbon labels, personalized feedback or departmental leaders, could be tested first on campuses. My research in Chapter 2 shows that such research would be low risk, since there is no evidence that reducing air travel would harm individual faculty members’ career prospects. And yet, individuals have been identified as a major obstacle to institutional sustainability progress, especially due to a lack of incentive structure. Our finding that the mobility habits of Green researchers are indistinguishable from their colleagues represents a missed opportunity of modelling sustainable behaviour, and a potential barrier to institutional change. This links two aspects of my thesis by demonstrating that it is difficult to achieve institutional change (which could help change society beyond the institution) without making change at the individual level.

6.4 Final thoughts

Whether through social movements, lifestyle choices or political action, climate change will be tackled by the concerted efforts of many individuals. Sometimes those efforts will look like a senior professor explaining to their undergraduate students why they have chosen to no longer participate in conferences that can only be attended via air travel. Other times it will look like a politician designing ambitious climate policy. It may be a constituent writing a hand-written letter to their public official or a voter choosing a climate leader in the ballot box. In this dissertation I have tried to enhance our understanding of how such individuals, and the institutions that they interact with, can best contribute to tackling the issue of climate change.
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Appendix A

A.1 Emissions responsibility versus emissions efficacy

Individuals may have a greater responsibility for the climate impact of their vote than for the climate impact of their consumer choices (Chapter 4), but that does not necessarily indicate that their vote *causes* more emissions than their consumer behavior. To draw a parallel, governments assign responsibility for emissions to business air travel passengers based on the fraction of space the passengers occupy on an aircraft (BEIS, 2016). But if those passengers opted to stay home they would actually reduce emissions by a lesser, marginal amount that could be calculated by measuring the additional fuel saved by not carrying their persons and luggage, and weighing the price signal of their ticket purchase, which would have incentivized future flights (Bigazzi, 2019). This second, marginal approach to estimating air travel emissions is similar to asking, “what are the emissions created by this entire flight, and what is the probability that my ticket happens to be the one that causes an additional flight to be scheduled?” How would our thinking about elections change if we approached the problem from this instrumentalist perspective? The question would then become “what are the emissions associated with a certain election outcome, and what is the probability that my vote will be decisive in determining that outcome? By synthesizing evidence from political science and carbon accounting I offer some arguments to the question of whether it is rational for an environmentalist, especially a climate voter, to vote.

A.2 The rationality of voting

There has been considerable debate as to why citizens spend time and energy in order to cast a vote that results in very little personal benefit. Voters may incur costs to cast a ballot because of
a sense of civic duty (Blais et al., 2004), because of pride and social norms (Gerber and Rogers, 2009; Panagopoulos, 2010) or because of a desire for self-expression (Brennan and Hamlin, 1998). Setting these motives aside, scholars are undecided as to whether even self-interested citizens can rationally engage in the act of voting (Dowding, 2005).

Often a financial test is used to help evaluate whether the choice is rational (Edlin et al., 2008; Usher, 2014). The idea makes use of the expected value calculation. In gambling if the expected value of a game is positive, then it is rational for a gambler to play because over a large number of attempts, the gambler can expect to gain money. Lotteries are an interesting example of expected value in gambling because, though the odds of winning are astronomically low, the payoff is also quite substantial. We can use the same math to evaluate whether participation in a lottery is advisable, generally finding that it is not (Matheson, 2001). Elections are similar to lotteries in that the likelihood of one person’s vote “making a difference” by serving as the deciding vote is also quite low but the payoff of an election could be quite high. For instance, if the person casting a deciding vote held a financial stake in the outcome of the election, or if the voter is an altruist who is motivated by the greater good, then the perceived benefit may exceed the costs.

Based on this logic, scholars have argued that voting is a rational act for those voters who are not trying to maximize selfish gains, but instead wish to increase social well-being. In larger elections where a voter is less likely to cast a pivotal vote, there is greater potential for social good that can compensate for these lowered odds (Edlin et al., 2007). The same relationship might be true for climate mitigation – the larger the number of voters, the larger the potential
difference in terms of greenhouse gas emissions. Since it is possible to estimate both a range of probabilities for a pivotal election, and a range of potential outcomes for the difference in emissions attributable to an election, we can test whether an ardent environmentalist is rationally justified in voting.

Let us assume that there is a group of voters who are willing to vote altruistically, and whose sole aim in voting is to mitigate climate change. Such voters may engage in actions that have climate costs, such as driving to a voting booth, hoping that the costs will be paid off in the event that they cast a deciding vote which results in more ambitious climate legislation. We can adapt an expected value calculation to see whether it is a rational choice for a voter to drive to the polling station in order to cast such a vote. A basic model of this expected utility calculation can be described by:

\[ R = (BP) - C \]  

where \( R \) represents the reward gained from voting, \( B \) represents the benefit gained by the preferred candidate winning, \( P \) represents the probability of casting a deciding vote and \( C \) represents the cost of voting (Riker and Ordeshook, 1968). For a climate voter seeking to maximize emissions reductions, \( R \) would represent the balance of emissions, where a positive value would justify the act of voting, \( B \) would represent the benefit in terms of the expected emissions reduced through the policies of the preferred candidate winning, \( P \) is the probability of casting a decisive vote, and \( C \) is the cost, in emissions, of casting a vote. Next I look at how we can estimate \( P \).
A.3  Estimating the likelihood of a pivotal election

Most actual estimates of $P$ have focused on the United States, either at the national or the state level (Gelman et al., 2012; Mulligan and Hunter, 2003; Gelman et al., 1998) but methods for calculating this probability vary. If a forecast based on opinion polling data is available, one can use that data to estimate the likelihood that the election will be decided by a single vote. In such a prediction, the lower the predicted margin of victory for any candidate, the greater the chance of a pivotal election (Fischer, 1999). Assuming that even a good forecast will have a standard error of 2% of the vote, an upper bound for $P$, in very close, generic elections (where the two candidates are forecast to receive an equal share of votes) has been estimated at $20/n$, where $n$ is the number of voters (Gelman et al., 1998). Since most elections have much larger margins between candidates, we can expect most probabilities to be substantially lower.

In fact, researchers have looked at historical records to give an indication of how often pivotal votes occur. One analysis found that of 16577 US elections, only one was decided by a single vote (Mulligan and Hunter, 2003). That same analysis found that in 40036 US state elections, two elections were tied and seven were decided by only one vote (Mulligan and Hunter, 2003). These databases can be used to crudely approximate the probability of a pivotal vote by taking the empirical frequency, $x/N$, where $x$ is the number of elections that the winner’s vote tally exceeds the loser’s by no more than a single vote, and $N$ is the number of elections in the database. Because the number of pivotal elections is so rare, researchers can improve on these estimates by incorporating additional data such as the frequency of close but not pivotal elections (Mulligan and Hunter, 2003). Using such methods, the probability of a pivotal election is
estimated to be proportionate to the size of the electorate according to $n^{-1}$ (Mulligan and Hunter, 2003) or more precisely, $n^{-0.9}$ (Gelman et al., 2004). As might be expected, the larger the electorate, the less likelihood there is of a single individual casting a decisive vote.

In order for an environmentalist to rationally cast a ballot in hopes of lowering net greenhouse gas emissions, the cost of casting a ballot (in terms of greenhouse gas emissions) must be lower than the probability of casting a decisive ballot multiplied by the expected emissions reduced by the preferred candidate winning. Setting the reward, R to 0, replacing P with a conservative probability of $n^{-1}$ and rearranging (1) we have

$$0 \leq (B \times n^{-1}) - C$$

(2)

$$C \leq B/n$$

(3)

Even in a rural riding, it would be reasonable to expect a voter to be within 10 miles of a voting precinct (Gimpel and Schuknecht, 2003). Taking a few vehicles that exemplify a range of fuel efficiencies and multiplying their fuel efficiencies by the 10-mile range we see that C (the cost in emissions) is relatively small.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Emissions per kilometer (gCO$_2$ekm$^{-1}$)</th>
<th>C (Emissions to voting center in kgCO$_2$e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesla Model S Canada mix</td>
<td>25.9</td>
<td>0.42</td>
</tr>
<tr>
<td>Typical vehicle</td>
<td>215.83</td>
<td>3.47</td>
</tr>
<tr>
<td>Cadillac Escalade</td>
<td>333.1</td>
<td>5.36</td>
</tr>
</tbody>
</table>
We can then take an electorate size equal to \( n \) and solve to find the amount of emissions that would need to be reduced by the preferred candidate’s victory and subsequent policies in order to make the act of voting rational for our climate voter. We find that the scale of the emissions required by each increasing size of hypothetical electorate are easily achievable (Table 10). For instance, a single (rather inefficient) cash for clunkers program in the province of British Columbia was estimated to reduce emissions by 92000 tCO\(_2\) (Antweiler and Gulati, 2015). That program alone would justify a drive to the polling station in a Cadillac Escalade if the electorate was 17 million individuals. In actuality, British Columbia’s electorate was only about 1.7 million at the time of the policy’s implementation, and a provincial leader with ambitious climate goals could be expected to enact more than a single policy. In Chapter 4 we estimated the difference in emissions between the two most likely outcomes for the 2019 Canadian federal election was 192 MtCO\(_2\)e. Table 10 shows that the emissions difference necessary to make participation rational for a climate voter would be, at most, 0.098 MtCO\(_2\)e.

### Table 10: Emissions reductions needed to justify voting

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Number of voters in most recent general election</th>
<th>Necessary emissions reductions from preferred candidate (tCO(_2)e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlottetown, PEI</td>
<td>14578</td>
<td>6-78</td>
</tr>
<tr>
<td>Vancouver, BC</td>
<td>176450</td>
<td>74-946</td>
</tr>
<tr>
<td>British Columbia</td>
<td>1986374</td>
<td>834-10647</td>
</tr>
<tr>
<td>Canada</td>
<td>18351260</td>
<td>7708-98363</td>
</tr>
<tr>
<td>United States</td>
<td>140114503</td>
<td>58848-751014</td>
</tr>
</tbody>
</table>

Not every election will offer a clear range of choices to our hypothetical climate voter. The leading candidates may have identical climate policies, or a set of policies whose emissions cannot be easily projected or even guessed. Still, there are many instances where voters can
choose between a candidate with rigorous climate policies and a candidate without. In such instances it is likely that even driving an inefficient vehicle to cast a vote for a climate leader would be a rational action.

### A.4 Is politics an efficient climate investment?

Since the likelihood of a pivotal vote is so low, any instrumentalist approach to elections for individuals is somewhat abstract, but campaigners seeking to swing an election operate under a different set of considerations. For instance, researchers estimated that persuading only 500 voters in New Mexico to change candidates had a one in six thousand chance of swinging the entire US national election in 2008 (Gelman et al., 2012). Large volunteer efforts, get out the vote drives, and donations to political campaigns can meaningfully alter the outcome of an election, and therefore result in substantial changes for policy and the climate. Previously we looked at the chance of a pivotal election to help us understand what scale of emissions would be necessary to make voting rational. But we can also use certain elections as case studies to draw conclusions about the other variables in the rationality equation.

In Chapter 4, we estimated that the re-election of the Liberal Party resulted in savings of 192 MtCO$_2$e compared to the next most likely alternative. Let us imagine a climate philanthropist deciding on how to optimally allocate funding. Would it be worthwhile to fund the campaigns of politicians who propose strong climate policies, or would the funding be better spent on some other mitigation project? Table 11 shows the cost of 192 Mt of emissions using carbon prices from a variety of different sectors, including the cost of offsets, a carbon tax, a cap and trade scheme and modelled estimates of the cost of the impacts of carbon emissions on society.
Table 11: Different measures of cost per tonne of CO₂

<table>
<thead>
<tr>
<th>Approach</th>
<th>Cost per tonne (USD)</th>
<th>Cost of 192 MtCO₂ (in billion USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offsetters General Portfolio</td>
<td>14.26</td>
<td>2.74</td>
</tr>
<tr>
<td>Canada carbon tax</td>
<td>21.42</td>
<td>4.11</td>
</tr>
<tr>
<td>EU ETS</td>
<td>27.39</td>
<td>5.26</td>
</tr>
<tr>
<td>US social cost of carbon</td>
<td>42</td>
<td>8.06</td>
</tr>
</tbody>
</table>

The carbon prices in Table 11 are both well below the minimum requirement for 2020 of $40-80 that economists believe would be consistent with the Paris Agreement targets (Stiglitz et al., 2017). Furthermore, the maximum spending limit on all political parties combined for the 2019 Canadian federal election was $172 million, about 1/15th of the cost of the carbon emissions outcome by the lowest measure\(^1\). While spending huge sums on an election does not guarantee a victory, there is evidence that candidates who spend more increase the likelihood of their re-election (Gerber, 2004).

### A.5 Implications

While these back-of-the-envelope calculations are subject to considerable uncertainty, even if my estimates are off by an order of magnitude their implications could still be meaningful. The results suggest that it is rational for climate aware citizens to vote, but also that climate donors are justified in targeting political campaigns as more efficient investments.

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\(^1\) Candidates espousing environmental values during political campaigns have recently been criticized for flying private jets between campaign stops (Lippman, 2019; Blanchfield, 2019). Given the huge scale of emissions at stake, the candidates would only need to believe that the use of these jets increased the odds of winning the election ever so slightly for their use to be justified.
The advantage of generating change through political campaigns instead of projects that directly reduce emissions is already qualitatively justified. First, changes wrought by government policy can go beyond calculable reductions in greenhouse gas emissions. Government policies which stimulated market growth of photovoltaics were responsible for worldwide reductions in the cost of solar energy (Kavlak et al., 2018), allowing for further growth of that market and more emissions reductions than what were achieved through the original policy. Targeting elections where agreed upon social tipping elements such as fossil fuel or renewable subsidies are at play could likewise increase the likelihood of achieving transformational change (Otto et al., 2020). This would be consistent with at least some of the strategies of prominent climate philanthropists, such as billionaire Tom Steyer who has bankrolled various pro-climate political campaigns (Nisbet, 2014).

While qualitative arguments have already been made for the superiority of reducing emissions through electoral means, I have provided a quantitative justification. Philanthropists could possibly refine my approach further by using research on the cost of securing additional votes through get out of the vote campaigns to inform strategic decisions (Green and Gerber, 2019). My findings here justify a similar conclusion for consumers and individual donors seeking to reduce emissions, since their combined donations would scale to the level of philanthropy. A consumer wanting to offset their emissions from a flight, for instance, is likely justified in donating to political campaigns rather than tree planting efforts. Any one donation to a political campaign may result in no measurable change (e.g. if the campaign is unsuccessful for instance) but the collective results of many small donors lending to many pro-climate campaigns would be
more effective than an offset project with higher certainty of success per donation, but lower efficacy per dollar.
Appendix B

B.1 Comparison of the two samples, figures and analysis

Figure 13: The 25 most common responses to an open-ended question about the single most effective action the participant could take to reduce greenhouse gases. Color indicates self-reported political orientation.
<table>
<thead>
<tr>
<th>Action code</th>
<th>Student Sample</th>
<th>Online Sample</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green energy</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Contact elected official</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Efficient appliances</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Join an organization</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Travel less</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Ecolabel products</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Plant a tree</td>
<td>2</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Deny climate change</td>
<td>1</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Have smaller families</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Minimize waste</td>
<td>11</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Reduce air travel</td>
<td>8</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Raise awareness</td>
<td>11</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Vote</td>
<td>8</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Install renewables</td>
<td>7</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>Consume less</td>
<td>11</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Live car free</td>
<td>13</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td>Plant-based diet</td>
<td>21</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>Conserve energy</td>
<td>11</td>
<td>31</td>
<td>42</td>
</tr>
<tr>
<td>Eat less meat</td>
<td>20</td>
<td>23</td>
<td>43</td>
</tr>
<tr>
<td>Recycle</td>
<td>9</td>
<td>37</td>
<td>46</td>
</tr>
<tr>
<td>Government</td>
<td>32</td>
<td>24</td>
<td>56</td>
</tr>
<tr>
<td>Other</td>
<td>28</td>
<td>30</td>
<td>58</td>
</tr>
<tr>
<td>Reduce GHGs</td>
<td>37</td>
<td>45</td>
<td>82</td>
</tr>
<tr>
<td>Bike/walk/take transit</td>
<td>72</td>
<td>51</td>
<td>123</td>
</tr>
<tr>
<td>Drive less</td>
<td>90</td>
<td>185</td>
<td>275</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>414</strong></td>
<td><strong>551</strong></td>
<td><strong>965</strong></td>
</tr>
</tbody>
</table>
**Figure 14**: Online versus student sample for ranking question. Proportion of participants that ranked each of the 15 actions as low (dark blue), moderate (medium blue) or high impact (light blue). Note that not all percentage values in the figure add to 100% due to rounding.
Table 13: Hierarchical regression of trade-off accuracy (average error) on four trade-off questions, undergraduate student sample

<table>
<thead>
<tr>
<th>Model</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic numeracy</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03**</td>
<td>-0.02**</td>
<td>-0.02*</td>
<td>-0.02*</td>
<td>-0.02*</td>
</tr>
<tr>
<td></td>
<td>(-0.05, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.003)</td>
<td>(-0.04, -0.003)</td>
<td>(-0.04, -0.003)</td>
</tr>
<tr>
<td>Rank score</td>
<td>-0.03***</td>
<td>-0.03**</td>
<td>-0.02**</td>
<td>-0.02**</td>
<td>-0.02**</td>
<td>-0.02**</td>
<td>-0.02**</td>
</tr>
<tr>
<td></td>
<td>(-0.05, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
</tr>
<tr>
<td>Climate score</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(-0.01, 0.002)</td>
<td>(-0.01, 0.002)</td>
<td>(-0.02, 0.002)</td>
<td>(-0.02, 0.001)</td>
<td>(-0.01, 0.003)</td>
<td>(-0.01, 0.003)</td>
<td>(-0.01, 0.003)</td>
</tr>
<tr>
<td>Year of program</td>
<td>-0.04**</td>
<td>-0.03**</td>
<td>-0.03*</td>
<td>-0.03*</td>
<td>-0.03*</td>
<td>-0.03*</td>
<td>-0.03*</td>
</tr>
<tr>
<td></td>
<td>(-0.07, -0.01)</td>
<td>(-0.06, -0.01)</td>
<td>(-0.06, -0.03)</td>
<td>(-0.06, -0.03)</td>
<td>(-0.06, -0.04)</td>
<td>(-0.06, -0.04)</td>
<td>(-0.06, -0.04)</td>
</tr>
<tr>
<td>Age</td>
<td>0.01</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(-0.003, 0.01)</td>
<td>(-0.004, 0.01)</td>
<td>(-0.004, 0.01)</td>
<td>(-0.004, 0.01)</td>
<td>(-0.004, 0.01)</td>
<td>(-0.004, 0.01)</td>
<td>(-0.004, 0.01)</td>
</tr>
<tr>
<td>Gender (Female)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(-0.03, 0.09)</td>
<td>(-0.03, 0.09)</td>
<td>(-0.03, 0.09)</td>
<td>(-0.03, 0.09)</td>
<td>(-0.03, 0.09)</td>
<td>(-0.03, 0.09)</td>
<td>(-0.03, 0.09)</td>
</tr>
<tr>
<td>Political orientation</td>
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<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(-0.03, 0.01)</td>
<td>(-0.03, 0.01)</td>
<td>(-0.03, 0.01)</td>
<td>(-0.03, 0.01)</td>
<td>(-0.03, 0.01)</td>
<td>(-0.03, 0.01)</td>
<td>(-0.03, 0.01)</td>
</tr>
<tr>
<td>Observations¹</td>
<td>414</td>
<td>414</td>
<td>414</td>
<td>413</td>
<td>413</td>
<td>408</td>
<td>408</td>
</tr>
<tr>
<td>R²</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Note: 90% confidence intervals in parentheses. *p<.1, **p<0.05, ***p<0.01

¹Models 4-7 have fewer observations due to the removal of participants who selected gender responses other than male or female, and participants who did not complete questions on year of program.

Observations: 414
Table 14: Hierarchical regression of trade-off accuracy (average error) on four trade-off questions, online sample

<table>
<thead>
<tr>
<th>Model</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic numeracy</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>-0.04***</td>
</tr>
<tr>
<td></td>
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<td>(-0.05, -0.03)</td>
<td>(-0.05, -0.02)</td>
<td>(-0.05, -0.02)</td>
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<td>(-0.05, -0.02)</td>
<td>(-0.05, -0.02)</td>
<td>(-0.05, -0.02)</td>
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<tr>
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<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
<td>-0.03***</td>
</tr>
<tr>
<td></td>
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<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
<td>(-0.04, -0.01)</td>
</tr>
<tr>
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<td>-0.001</td>
<td>-0.001</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
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<td>(-0.01, 0.003)</td>
<td>(-0.005, 0.003)</td>
<td>(-0.005, 0.005)</td>
<td>(-0.004, 0.005)</td>
<td>(-0.004, 0.005)</td>
<td>(-0.004, 0.005)</td>
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<td>Age</td>
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<td>0.001</td>
<td>0.001</td>
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<td>(-0.001, 0.003)</td>
<td>(-0.001, 0.003)</td>
<td>(-0.001, 0.003)</td>
<td>(-0.001, 0.003)</td>
<td>(-0.001, 0.003)</td>
</tr>
<tr>
<td>Gender (Female)</td>
<td>0.004</td>
<td>0.005</td>
<td>0.002</td>
<td>0.002</td>
<td>-0.04, 0.05</td>
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<td>-0.04, 0.05</td>
<td>-0.04, 0.05</td>
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<tr>
<td></td>
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<td>(-0.04, 0.05)</td>
<td>(-0.04, 0.05)</td>
<td>(-0.04, 0.05)</td>
<td>(-0.04, 0.05)</td>
<td>(-0.04, 0.05)</td>
</tr>
<tr>
<td>Political orientation</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.02, 0.01</td>
<td>-0.02, 0.01</td>
<td>-0.02, 0.01</td>
<td>-0.02, 0.01</td>
</tr>
<tr>
<td>(1=Extremely liberal,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7=Extremely conservative)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
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<td>-0.004</td>
<td>-0.01, 0.004</td>
<td>-0.01, 0.004</td>
</tr>
<tr>
<td>(1= &lt;$10,000, 12 = &gt;$150 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-0.01, 0.004)</td>
<td>(-0.01, 0.004)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education (1= Less than high school, 8=Professional/doctoral degree)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-0.02, 0.02)</td>
</tr>
<tr>
<td>Observations†</td>
<td>551</td>
<td>551</td>
<td>551</td>
<td>551</td>
<td>548</td>
<td>546</td>
<td>546</td>
<td>544</td>
</tr>
<tr>
<td>R²</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.06</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Note: 90% confidence intervals in parentheses. *p<.1, **p<0.05, ***p<0.01
†Models 5-8 have fewer observations due to the removal of participants who selected gender responses other than male or female, and participants who did not complete questions on political orientation or education.
B.2 Methods and results from the pilot study

Methods
The pilot survey was distributed in three classes at the University of British Columbia in January of 2017. 178 students completed the survey. The survey began with a set of questions intended to elicit level of participant concern for climate change. Next, participants were asked an open-ended question regarding the most effective action they could take to reduce climate change. Third, the participants were asked “Please rank these actions from most effective (1) to least effective (15) at reducing climate change”. The listed actions were the same as the 15 actions provided in the main study, except for two differences: students were not asked about hybrid vehicles and instead asked about the efficacy of turning down the thermostat by 1 degree for one winter, and they were not asked about food with no packaging and were instead asked about the efficacy of eating only organic food for one year. The survey concluded with a series of demographic questions. Unlike in the main study, there were no tradeoff questions and no corresponding control questions.

Results
Six students chose to not provide their gender and eight students chose to not provide their political orientation. Of those who did provide this information, 65% were female, 74% described themselves as liberal (scores 5-7), 6% described themselves as conservative (scores 1-3) and 20% as moderates (score 4).

We found significant differences in ranking between the different actions according to the Kruskal–Wallis test (H(14)= 396.95, p<.001). We used the Dunn test for multiple comparisons of groups with p-values adjusted with the Benjamini-Hochberg method to identify significant differences between actions (summarized by letter groupings in Figure 15).

Despite this ranking approach differing from the methodology used in the main study to assess understanding of the relative efficacy of fifteen actions, results roughly conformed to the findings from the main study. On average, participants considered switching from an SUV to public transit to be the most effective action, whereas not buying GMO food for a year was considered the least effective (see Figure 15 and Figure 16). Furthermore, eating a vegan diet and avoiding one trans-Pacific flight (which are both high-impact) received significantly lower rankings than recycling (which is moderate-impact).
Figure 15: Perceived ranking of 15 actions, sorted from the action that is perceived to be most effective at the top to least effective at the bottom. Error bars indicate one standard error. Actions sharing a letter are not significantly different from one another (alpha = 0.05).

Figure 16: Histograms of survey participants who assigned each action a given rank. Actions are arranged by average perceived rank with the action perceived to be most effective in the top left and the action perceived to be least effective in the bottom right.
B.3 Supplementary Methods

Full Survey Questions

Q1 What do you believe is the single most effective action you can take to reduce greenhouse gas emissions that contribute to climate change?

Q2 Please categorize these actions as high, medium or low impact in terms of reducing greenhouse gases. Each high impact action accounts for more than 5% of the average North American's annual carbon footprint. Each medium impact action accounts for 1-5% of an average North American's annual carbon footprint. Each low impact action accounts for less than 1% of an average North American's annual carbon footprint.
<table>
<thead>
<tr>
<th>Action</th>
<th>Low Impact</th>
<th>Medium Impact</th>
<th>High Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't litter for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Avoid one trans-Pacific flight</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Switch from an SUV to public transit for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Recycle as much as possible for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Waste no extra food for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Don't buy GMO food for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Switch from a midsize car to a midsize hybrid car for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Vote for a political party that is proposing a carbon tax</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Eat a vegan diet for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Use canvas bags instead of plastic shopping bags for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Vote in favour of a nuclear power plant</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Buy only unpackaged food for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Buy only local food for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Wash your laundry in cold water for one year</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Q3 Someone takes a trip that requires driving 100 miles in a standard, midsize car. If they switch from a standard, midsize car to a midsize hybrid car, how many miles can they now drive while still producing the same amount of greenhouse gases as they did on their trip in the standard car? Please give your best guess.

Q4 Eating meat and flying in a plane both result in greenhouse gas emissions. A person taking a one-way, economy flight from New York to London might try and make up for their emissions by giving up quarter-pound hamburgers. How many quarter-pound hamburgers would they need to give up to offset this flight? Please give your best guess.

Q5 Hang drying clothing instead of using a dryer saves electricity, which reduces greenhouse gas emissions. If someone chooses to hang dry one load of laundry, how long can they leave an LED light bulb switched on and still produce the same amount of greenhouse gases as if they had used the dryer? Please give your best guess.

Q6 Someone decides to reduce greenhouse gas emissions by switching to a vegetarian diet for one year. Another person tries to save the same amount of greenhouse gases by purchasing only unpackaged foods. How long would it take for the second person to save the same amount of greenhouse gases as the first one? Please give your best guess.

Q7 Recent research on decision making shows that choices are affected by context. Differences in how people feel, their previous knowledge and experience, and their environment can affect choices. To help us understand how people make decisions, we are interested in how you are currently feeling. In addition to emotions, we are interested in whether you are paying attention to the instructions. This is a test to see whether you actually take the time to read the instructions. If you do not follow the instructions, we won’t be able to use your data. To show that you have
read the instructions, please ignore the question below about how you are feeling and instead check only the "none of the above" option as your answer.

- Interested
- Distressed
- Excited
- Upset
- Strong
- Guilty
- Scared
- Hostile
- Enthusiastic
- Proud
- Irritable
- Alert
- Ashamed
- Inspired
- Nervous
- Determined
- Attentive
- Jittery
- Active
- Afraid
- None of the above

**Skip logic: If participant does not answer “None of the above”: End of Survey: Failed attention check message**

Thank you for taking our survey.

You are seeing this message because you are not eligible to complete the study. This may be because you failed to answer a question that checked to see if you read and understood the instructions.

Q8 We have provided more information to this question. Someone takes a trip that requires driving 100 miles in a standard, midsize car (fuel efficiency: 3 gallons/100 miles). If they switch to a midsize hybrid car (fuel efficiency: 2 gallons/100 miles), how many miles can they now drive while still producing the same amount of greenhouse gases as they did on their trip in the standard car? Please give your best guess.

Q9 We have provided more information to this question. Hang drying clothing instead of using a dryer saves electricity, which reduces greenhouse gas emissions. If someone chooses to hang dry their clothes for one load (thereby saving 3400Wh), how long can they leave an LED light bulb
switched on (10W per hour) and still produce the same amount of greenhouse gases as if they had used the dryer? Please give your best guess.

Q10 We have provided more information to this question. Someone decides to switch to a vegetarian diet for one year (thereby saving 1100kg of greenhouse gases). Another person tries to save the amount of greenhouse gases by purchasing only unpackaged foods (which reduces greenhouse gases by 100kg a year). How long would it take for the second person to save the same amount of greenhouse gases as the first one? Please give your best guess.

Q11 We have provided more information to this question. Eating meat and flying in a plane both result in greenhouse gas emissions. A person taking a one-way, economy flight from New York to London (which produces 800kg of carbon dioxide) might try and make up for their emissions by giving up quarter-pound hamburgers (which produces 2kg of carbon dioxide per hamburger). How many hamburgers would they need to give up to offset this flight? Please give your best guess.

Q12 You are in a race and you overtake the runner who is in third place. What position are you in now?

Q13 What number should come next in this series? 3,5,8,12,17, 20, 21, 22, 23, 24

Q14 You are planning to rent an apartment for $800 per month. How many cups of coffee ($2 per cup) would you have to give up to pay for one month’s rent? Please give your best guess.

Q15 A scientist finds a very old tree and calculates that it is 3400 years old. How many decades (1 decade = 10 years) has this tree been alive? Please give your best guess.

Q16 A local grocery store has two cashiers who can service 100 customers in an hour. They hire a third cashier. How many customers can they now service in one hour? Please give your best guess.

Q17 Two people are climbing a mountain. The first person started early and is already waiting at the top (1100 meters in height). The second person is climbing at a speed of 100 meters an hour. How many hours will it take for the second person to join the first at the top of the mountain? Please give your best guess.
Q18 Please indicate how strongly you agree or disagree with each of the following statements.

<table>
<thead>
<tr>
<th>Human activities</th>
<th>Completely agree</th>
<th>Agree</th>
<th>Somewhat agree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat disagree</th>
<th>Disagree</th>
<th>Completely disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humans are responsible for climate change</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Humans do not need to change their lifestyles to address climate change</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that my actions contribute to climate change</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that I need to change my lifestyle to address climate change</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q19 What percent of climate scientists think that climate change is caused mostly by human activities? Please write a number between 0 and 100 without decimals.
Q20 You're almost done with the. Please answer the following questions about yourself and your situation.

Q21 What is your year of birth?

Q22 What is your gender?
○ Male
○ Female
○ Other
○ Prefer not to say

Q23 What year are you in? (UNDERGRADUATE SAMPLE ONLY)
○ 1st Year
○ 2nd Year
○ 3rd Year
○ 4th Year

Q24 What course are you in? (UNDERGRADUATE SAMPLE ONLY)

Q25 What faculty are you in? (UNDERGRADUATE SAMPLE ONLY)
○ Audiology and Speech Sciences
○ Business, Sauder School of
○ Community and Regional Planning
○ Continuing Studies
○ Dentistry
○ Education
○ Forestry
○ Graduate and Postdoctoral Studies
○ Journalism
○ Kinesiology
○ Land and Food Systems
○ Law, Peter A. Allard School of
○ Library, Archival and Information Studies
○ Medicine
○ Music
○ Nursing
○ Pharmaceutical Sciences
○ Population and Public Health
○ Science
○ Social Work
○ UBC Vantage College
○ Vancouver School of Economics
○ Other
Q23 What city do you currently live in? (ONLINE SAMPLE ONLY)

Q24 What is the highest level of school you have completed or the highest degree you have received? (ONLINE SAMPLE ONLY)

- Less than high school degree
- High school graduate (high school diploma or equivalent including GED)
- Some college but no degree
- Associate degree in college (2-year)
- Bachelor's degree in college (4-year)
- Master's degree
- Doctoral degree
- Professional degree (JD, MD)

Q25 Please indicate your total annual personal income before taxes. (ONLINE SAMPLE ONLY)

- Less than $10,000
- $10,000 to $19,999
- $20,000 to $29,999
- $30,000 to $39,999
- $40,000 to $49,999
- $50,000 to $59,999
- $60,000 to $69,999
- $70,000 to $79,999
- $80,000 to $89,999
- $90,000 to $99,999
- $100,000 to $149,999
- $150,000 or more

Q26 How would you describe your political orientation?

- Extremely liberal
- Liberal
- Slightly liberal
- Moderate
- Slightly conservative
- Conservative
- Extremely conservative

Q26 How would you describe your political orientation?

- Extremely liberal
- Liberal
- Slightly liberal
- Moderate
- Slightly conservative
- Conservative
- Extremely conservative
Q27 What party did you vote for in the last election federal or national election?

Q28 Thank you for completing the survey! Do you have any additional thoughts about climate change, or any comments about the survey that you would like to share with us?

B.4 Supplementary Calculations

Hamburger versus flight

“Eating meat and flying in a plane both result in greenhouse gas emissions. A person taking a one-way, economy flight from New York to London might try and make up for their emissions by giving up quarter-pound hamburgers. How many quarter-pound hamburgers would they need to give up to offset this flight? Please give your best guess.”

We use data from North American research (Beauchemin et al., 2010) to find 22 kgCO$_2$e/kg of carcass. Other studies have found similar results, although values do vary based on methodology and especially with country studied; Peters et al. (2010), based on data from other sources (Vergé et al., 2008), conclude that beef in Canada has a CF of 19.6 kg of CO$_2$e per kg of carcass weight. These studies do not include transport and are based on carcass weight and we therefore take them as a conservative lower bound. Others (Heller et al., 2013) estimate beef at 29 kgCO$_2$e/kg which represents a typical value for a life cycle assessment of beef in a western nations (see also, for example, research (Hoolohan et al., 2013) which places the estimate at 25 kgCO$_2$e/kg of beef). Although some life cycle assessments calculate extremely high values for the footprint of beef (if for instance land use change impacts from mangrove deforestation is included in the LCA of tropical beef production (Boone Kauffman et al., 2017)), we do not consider these values to be representative of what the average North American consumer should be expected to consider.

We specify a “quarter-pound” hamburger which works out to 0.113 kg of beef. The carbon footprint therefore ranges from a low value of 2.21 kgCO$_2$e (based on the Canadian CF of 19.6kg of CO$_2$e per kg of carcass weight) to a higher value of 3.3 kgCO$_2$e (based on the highest life cycle assessment value of 29 kgCO$_2$e/kg of meat), per meat in the burger depending on which life cycle assessment study is used.


Therefore 146–410 hamburgers are equivalent with one flight. CENTRAL ESTIMATE: 278 hamburgers.
Hang dry clothing vs turning off light bulb

“Hang drying clothing instead of using a dryer saves electricity, which reduces greenhouse gas emissions. If someone chooses to hang dry one load of laundry, how long can they leave an LED light bulb switched on and still produce the same amount of greenhouse gases as if they had used the dryer? Please give your best guess.”

3.4 kWh are saved by hang drying clothing instead of using a typical modern dryer (Attari et al., 2010). Wynes and Nicholas (2017) calculate the emissions value associated with these savings at 210 kgCO₂e per person per year or 1.9 kgCO₂e per use, which is the value shown in the caption in Figure 7 (but is not necessary for the ratio calculation here).

For a 75W-99 W equivalent (reasonable for a hallway light) LEDs range from 9.6-12.5 W (http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.search-recherche&appliance=LAMP_CFL)

3.4kWh/0.0096 kW = 354 hours (for a dim, efficient LED)
3.4kWh/0.0125 kW = 272 hours (for a bright, less efficient LED)

You could leave an LED light on for 272-354 hours and have the same carbon footprint as hang drying one load of laundry.

CENTRAL ESTIMATE: 313 hours

Drive hybrid versus drive conventional car

“Someone takes a trip that requires driving 100 miles. If they switch from a standard, midsize car to a midsize hybrid car, how far can they drive while still producing the same amount of greenhouse gases? Please give your best guess.”

Five popular mid-size vehicles (http://www.autofocus.ca/news-events/canadian-car-and-truck-sales/cars-the-30-best-selling-in-canada) and five mid-size hybrid vehicles were selected for comparison. Where two different carbon intensities were given (i.e. for different number of cylinders in engine) we chose smallest value.
The lowest possible shift would be from a Honda civic (153 gCO₂/km) to a Toyota Camry/Hyundai Sonata hybrid (both 137 gCO₂/km). A person making such a shift could drive 112 miles while producing the same amount of emissions (25 kgCO₂e) as they previously did while driving 100 miles (note that because this is a ratio of efficiency, the same would be true for kilometers, e.g. someone driving 100 km in the typical midsize vehicle could then drive 112 km in a hybrid vehicle while producing the same emissions).

The greatest possible shift would be from a Toyota Camry (199 gCO₂/km) to a Toyota Prius (105 gCO₂/km). A person making such a shift could drive 190 miles while producing the same amount of emissions (32 kgCO₂e) as they previously did while driving 100 miles.


You could drive 112-190 miles if you switch to a hybrid vehicle.

CENTRAL ESTIMATE: 151 miles

Vegan vs unpackaged foods

“Someone decides to reduce greenhouse gas emissions by switching to a vegetarian diet for one year. Another person tries to save the same amount of greenhouse gases by purchasing only unpackaged foods. How long would it take for the second person to save the same amount of greenhouse gases as the first one? Please give your best guess.”

Hoolohan et al. quantify the emissions attributable to the average consumer for both meat consumption and food packaging (Hoolohan et al., 2013).

On a daily basis they suggest 3.05 kgCO₂e saved by not eating meat and 0.29 kgCO₂e by not buying any packaging (this equates to 1113 kgCO₂e per year from a meat-free diet). Because the estimate for packaging is suggested as a maximum possible value we estimate a lower range as 10% below this value: 0.26-0.29 kgCO₂e.

It would therefore take 10.52-11.73 years with a central estimate of 11.125 years.

For the range of uncertainty we round generously to include 10-12 years since a person estimating is unlikely to pick 11 exactly.
B.5 Additional analyses

How political orientation affected open-ended responses
Differences can be observed between participants with different political orientations on the open-ended question responses. For instance, no conservative described voting as the most effective action and few selected eating a plant-based diet or eating less meat. We collapsed the open-ended responses into two categories, e.g. those where participants selected eating a plant-based diet/less meat, and those where they did not, in order to conduct logistic regression. Political orientation was found to be a significant predictor (p=.003) of choosing a plant-based diet or eating less meat as the most effective action in the open-ended question, even when controlling for gender (p=.347) and age (p=.883).

Testing for differences between the two survey samples
We also collapsed the open-ended responses into two categories to look for differences between the online sample and the student sample using chi-squared tests. There were significant differences between the student sample and the online sample in the “Drive less” category, ($\chi^2(2)=16.25, p<.001$), and the “Recycle” category ($\chi^2(2)=10.74, p=.001$) but not for the combined “Eat less meat” and “Plant-based diet” categories ($\chi^2(2)=2.48, p=.115$).

We found no difference between the undergraduate students’ absolute log error scores (M=0.85) and the online participants’ (M=0.88), (t=-1.11, 95% CI [-0.074, 0.021], p=.27). Breaking this down further we found minimal differences between the absolute log error scores on the four estimation questions for these two groups. Differences were not significant for the hybrid tradeoff question (t=-1.64, 95% CI [-0.085, 0.008], p=.10), the LED tradeoff question (t=-0.39, 95% CI [-0.134, 0.089], p=.69), or the hamburger tradeoff question (t=1.06, 95% CI [-0.134, 0.146], p=.29) and were marginally significant for the vegetarian tradeoff question (t=-1.68, 95% CI [-0.169, 0.013], p=.09). In the case of the vegetarian tradeoff question, the undergraduate students had lower error (M=1.04) than the online participants (M=1.12). Note that in additional linear regression models that were tested, the sample (student versus online) was not a significant predictor of accuracy when rank score and numeracy were accounted for.

There was a significant difference (p=.029) in rank score (the number of correctly ranked actions) between the student sample (M=4.184) and the online sample (M=3.967), although this amounts to a small practical effect (on average students were able to correctly rank 0.2 questions more than online participants out of 13 questions).

Testing for differences in accuracy between estimations and controls
We conducted pairwise chi-square tests to investigate whether participants were more accurate at making tradeoffs if they were given numerical inputs and when they answered questions requiring the same mathematical process but outside of a climate context. We found in all cases that participants made significantly more accurate estimates when given numerical inputs, and that their responses to non-climate questions were significantly more accurate than their estimates to climate questions with numerical inputs.
Miles of driving hybrid vs 100 miles in conventional car: Climate estimate (22.6% accurate) compared to control estimate with mathematical inputs (46.2% accurate), ($\chi^2(1)=119.35$, $p<.001$).
Control estimate with mathematical inputs (46.2% accurate) compared to non-climate control question (83.2% correct), ($\chi^2(1)=289.19$, $p<.001$).

Numbers of hamburgers vs one trans-Atlantic flight: Climate estimate (17.4% accurate) compared to control estimate with mathematical inputs (82.6% accurate), ($\chi^2(1)=819.98$, $p<.001$).
Control estimate with mathematical inputs (82.6% accurate) compared to non-climate control question (95.5% correct), ($\chi^2(1)=83.14$, $p<.001$).

Hours of LED usage vs one load of hang-dried laundry: Climate estimate (2.6% accurate) compared to control estimate with mathematical inputs (71.0% accurate), ($\chi^2(1)=880.92$, $p<.001$).
Control estimate with mathematical inputs (71.0% accurate) compared to non-climate control question (91.0% correct), ($\chi^2(1)=125.33$, $p<.001$).

Years of unpackaged food vs one year vegetarian food: Climate estimate (2.6% accurate) compared to control estimate with mathematical inputs (68.2% accurate), ($\chi^2(1)=881.77$, $p<.001$).
Control estimate with mathematical inputs (68.2% accurate) compared to non-climate control question (85.1% correct), ($\chi^2(1)=76.88$, $p<.001$).
Appendix C

C.1 Materials and Methods

Methods for Figure 8

Each country’s democracy score downloaded from: https://www.eiu.com/topic/democracy-index

Data on number of registered and actual voters downloaded from IDEA (Institute for Democracy and Electoral Assistance): https://www.idea.int/data-tools/data/voter-turnout

In the case of Spain and Japan, the data on the most recent elections (2019 and 2017 respectively) were unavailable. We sourced this data from: http://www.electionguide.org/countries/id/109/

Emissions data including LULUCF was downloaded from UFCCC for year 2017 from: https://di.unfccc.int/time_series

2017 population values used to calculate per capita emissions were downloaded from the World Bank: https://data.worldbank.org/indicator/SP.POP.TOTL?end=2017&start=2017

Methods for Figure 9


The projection from Jaccard (2019) above uses a rounded 2015 baseline federal emission value of 700 MtCO$_2$e. The reported 2015 emissions value is 715 MtCO$_2$e. We have scaled the emissions projection as follows:

New projection = old projection * (reported baseline/Jaccard’s rounded baseline)

Calculations for the US 2016 Presidential Election

Presidential election results by state from: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/42MVDX
As mentioned in the text, the emissions attributable to the 2016 US Presidential election is subject to considerable uncertainty. We include the emissions reductions which would have been expected for only the year 2025 from implementation of the Clean Power Plan. Other regulations could also have been included, such as the Obama era methane regulations, which would have resulted in higher values for responsibility per voter.

The electoral college system results in differences in the voting power of individuals between states. To find the emissions per winning voter in a state, we take a conservative emissions total (200 MtCO$_2$e) and apportion it to the 304 electoral college votes given to Donald Trump (note that there were two faithless electors who defected from Trump). To find the emissions per winning voter in a state, we take the emissions per electoral college vote, multiply it by the number of electoral college votes awarded to Trump in that state, and then divide by the number of individual Trump voters in that state.

In the case of finding the emissions per registered voter in the US Presidential election, we take the 200 MtCO$_2$e and divide them amongst the states according to the fraction of electoral college votes held by each state (regardless of which candidate the state’s electoral votes went towards). The emissions per state are then divided by the number of registered voters per state. North Dakota does not require voter registration. We approximated registered voters for North Dakota using total actual voters, but since we only report the median value of 0.9 tCO$_2$e per registered voter (which was not from North Dakota), this has no impact on our reported findings.
**Figure 16**: Emissions per winning voter in winning ridings of the 2019 Canadian federal election. Each blue bar represents one of 217 electoral districts. Two electoral districts and selected information are highlighted in the graph.
<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Total voters</th>
<th>Registered voters</th>
<th>2017 GHG (tCO₂e)</th>
<th>Democracy score</th>
<th>2017 population</th>
<th>GHG per capita (tCO₂e)</th>
<th>GHG per registered voter (tCO₂e)</th>
<th>GHG per voter (tCO₂e)</th>
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<tbody>
<tr>
<td>United States</td>
<td>2016</td>
<td>140114503</td>
<td>214109367</td>
<td>5742622750</td>
<td>7.96</td>
<td>325147121</td>
<td>17.7</td>
<td>26.8</td>
<td>41.0</td>
</tr>
<tr>
<td>Canada</td>
<td>2019</td>
<td>18351260</td>
<td>27126166</td>
<td>692026540</td>
<td>9.15</td>
<td>36540268</td>
<td>18.9</td>
<td>25.5</td>
<td>37.7</td>
</tr>
<tr>
<td>Australia</td>
<td>2019</td>
<td>15088616</td>
<td>16419543</td>
<td>534695450</td>
<td>9.09</td>
<td>24601860</td>
<td>21.7</td>
<td>32.6</td>
<td>35.4</td>
</tr>
<tr>
<td>Japan</td>
<td>2017</td>
<td>56947831</td>
<td>106091229</td>
<td>1232172770</td>
<td>7.99</td>
<td>126785797</td>
<td>9.7</td>
<td>11.6</td>
<td>21.6</td>
</tr>
<tr>
<td>Poland</td>
<td>2019</td>
<td>18678457</td>
<td>30253556</td>
<td>379935260</td>
<td>6.67</td>
<td>37974826</td>
<td>10.0</td>
<td>12.6</td>
<td>20.3</td>
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<tr>
<td>Germany</td>
<td>2017</td>
<td>46976341</td>
<td>61688485</td>
<td>891426250</td>
<td>8.68</td>
<td>82657002</td>
<td>10.8</td>
<td>14.5</td>
<td>19.0</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2019</td>
<td>32026221</td>
<td>47587254</td>
<td>464453440</td>
<td>8.53</td>
<td>66058859</td>
<td>7.0</td>
<td>9.8</td>
<td>14.5</td>
</tr>
<tr>
<td>France</td>
<td>2017</td>
<td>35467172</td>
<td>47568588</td>
<td>439420410</td>
<td>7.8</td>
<td>66865144</td>
<td>6.6</td>
<td>9.2</td>
<td>12.4</td>
</tr>
<tr>
<td>Spain*</td>
<td>2019</td>
<td>24831865</td>
<td>35338068</td>
<td>301903060</td>
<td>8.08</td>
<td>46593236</td>
<td>6.5</td>
<td>8.5</td>
<td>12.2</td>
</tr>
<tr>
<td>Italy</td>
<td>2018</td>
<td>33916460</td>
<td>46505499</td>
<td>409328960</td>
<td>7.71</td>
<td>60536709</td>
<td>6.8</td>
<td>8.8</td>
<td>12.1</td>
</tr>
</tbody>
</table>

*Election data based on the *November* 2019 Spanish general election
Appendix D

D.1 Letter to Member of Parliament

Dear [MP name],

I am writing to you today as a concerned constituent. Today is March for Science, a global movement that started in 2016 to champion science and evidence-based decision-making for the public good.

For March for Science this year I’m writing to you about one of the most important science-based issues we are facing - climate change.

Scientists across Canada are celebrating March for Science by supporting the youth climate strike. Students and young people around the world are demonstrating for a viable future and a livable climate by following the lead of Swedish student activist Greta Thunberg and striking from school on Fridays.

I’m asking you to join them and show your support for this movement. Here is a tweet that I am hoping you will share today to show your support.

Tweet 1: Science tells us that climate change poses a significant public health threat, from increased asthma & heat stroke to the spread of disease due to extreme weather. Thanks to all the youth who voiced their concern #Fridays4Future #MarchforScience

Tweet 2: Science tells us that climate change stands to dramatically alter Canada’s ecosystems, putting our cherished landscapes and iconic wildlife species at risk. Thanks to all the youth who voiced their concern #Fridays4Future #MarchforScience

Thank you,
[Your name]
Bonjour [nom du M.P.],

Je vous écris en tant que membre de votre circonscription pour exprimer mes préoccupations. Aujourd’hui a lieu la Marche pour les sciences, un mouvement mondial qui a commencé en 2016 et qui vise à soutenir les sciences ainsi que la prise de décisions fondée sur des données probantes dans le but de servir l’intérêt général.

Dans le cadre de la Marche pour les sciences de cette année, je vous écris au sujet d’un des enjeux scientifiques les plus importants auxquels nous sommes confrontés : le changement climatique.

Les scientifiques à travers le Canada célèbrent actuellement la Marche pour les sciences en soutenant la grève des jeunes pour le climat. Les élèves et les étudiants du monde entier manifestent pour un futur viable et un climat vivable en suivant les pas de l’adolescente militante suédoise, Greta Thunberg et sa grève scolaire chaque vendredi.

Je vous demande de vous joindre à eux pour montrer votre adhésion à ce mouvement. Voici un tweet que j’espère vous partagerez aujourd’hui en témoignage de votre soutien.

Tweet 1 : Le changement climatique est une menace pour la santé publique, que ce soit l’augmentation du taux d’asthme et des maladies liées aux phénomènes climatiques extrêmes. Merci à tous les jeunes qui ont décidé de faire entendre leur voix #Fridays4Future #MarchforScience

Tweet 2 : Le changement climatique remodelera les écosystèmes canadiens en mettant en péril nos paysages et la sauvegarde de nos espèces sauvages emblématiques. Merci à tous les jeunes qui ont décidé de faire entendre leur voix #Fridays4Future #MarchforScience

Je vous remercie de votre attention et de votre soutien.

[Votre nom]
D.2 Instructions for coding tweets

code1: pro_climate
Tweets that encourage action or awareness about climate change (could include links to stories about climate change causing wildfires, coral reef death, public health emergencies etc.)
Example: tweet mentions the carbon-tax AND how it will stop pollution
Example: tweet mentions pipelines AND how they will increase emissions
Tweets that associate positive words with climate action such as "climate leader", and negative words with fossil fuels and greenhouse gas emissions such as "fossil fuel addiction" also likely belong in this category. Tweets that tout a party or leader's plan as positive fall in this category IF the plan purports to reduce emissions, e.g. "Our party's plan will reduce emissions more effectively than the other party's plan"

Code2: anti_climate
Tweets that deny the existence or severity of climate change or discourage action. Tweets that discourage action could include popular tropes that are demotivating toward climate action, such as "Canada is only responsible for 3% of global greenhouse gases" or "Climate activist X is a hypocrite for eating beef/getting on a plane/owning a large house"

Code3: neutral
Includes false positives, e.g. talking about the economic climate or greenhouses that grow tomatoes. Also includes neutral mentions (zero inferred positive or negative sentiment).
Examples could include mentioning the carbon tax rebate but no further mention of climate change or cutting pollution. Mentioning a pipeline and even referring to oil spills and health of the environment, but NOT mentioning climate or increased emissions etc.

Note on hashtags: treat these as a way to determine if the tweet is relevant to climate change. If a tweet has a message calling for action but no climate content, for instance, then it is neutral. But if it has a hashtag (e.g. "ClimateActionNow") then it becomes pro_climate

Note on links: Links are only to be opened if the framing or direction of the tweet is uncertain and interpretation of the tweet relies on the content of the link. Example, "Check out this video so you understand what to think about climate change: URL"
D.3 Interview Consent Form

Consent Form for Study: “Elected officials and social media”

Who is conducting the study?
Principal Investigator: Dr. Simon D Donner, Department of Geography, University of British Columbia, 604-822-6959
Coinvestigator: Seth Wynes, PhD student, Department of Geography, University of British Columbia

Academic Consultant: Dr. John Kotcher, Department of Communication, George Mason University

Why are we doing this study?
You are being invited to take part in this research because you have first-hand experience on how elected officials use social media to communicate with their constituents. We want to understand how elected officials interact with people in their ridings, especially regarding environmental issues like climate change. This study will help inform voters who want to participate more effectively in Canadian democracy.

How is the study done?
We will ask you some short questions about your experience responding to constituents who participate in campaigns or contact you through other means. This interview should only take about ten minutes to complete during a single phone call.

How will the results be communicated?
The results of this study will be reported in a PhD thesis and may also be published in an academic journal. If you would like to be provided with the results of the study once it is finished, please express this during the interview or by email and a copy will be emailed to you when available.

Is there any way this study could harm you?
We do not think there is anything in this study that could harm you. The questions asked are not personal, but are about your experiences at work communicating with constituents. You do not have to answer any question if you do not want to.

Are there benefits to participating in this study?
We do not think that participating will help you personally. However, others may benefit in the future from what we learn (including Canadian citizens).
How will your privacy be maintained?
Your identity and the identity of your Member of Parliament will be kept confidential. We will make an audio recording of the interview and then write a transcription of what was said. Once we have transcribed the audio (within a few months of conducting the interview) we will delete the original audio files. Transcriptions will be stored for at least five years in password protected files on an encrypted computer in a locked room at the university.
When we publish our results, we will not release information that could be used to identify you.

Who can you contact if you have questions?

If you have questions or concerns about the questions we are asking you, please feel free to contact the Principal Investigator, Dr. Simon Donner. His phone number is included at the top of this form.

Who can you contact if you have concerns about the study?

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598

Participant Consent
We recognize that you are a busy professional, and so to save you time we will be asking for your oral consent when we conduct the interview. Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason.
D.4 Analysis of zero-inflated negative binomial regression

Here we present the analysis of the zero-inflated negative binomial regression. This is the full ZINB model with all predictor variables in R code:

```r
zeroinfl(postNPro ~ NEmail + ReElection + EmailTreat + Gender + offset(log(postNTweets)) | prescore + postNTweets,
          data = dat, dist = "negbin", EM=TRUE)
```

Where:
- `postNPro` represents the count of pro-climate tweets in the experimental period
- `NEmail` represents the count of emails sent to a Member of Parliament (note that in the model results presented in Table 17 this is instead a binary outcome variable)
- `ReElection` represents the likelihood of re-election on a seven-point scale
- `EmailTreat` represents the two different email treatments (public health versus environmental frame)
- `postNTweets` represents the number of tweets posted by the MP in the experimental period
- `prescore` represents the fraction of tweets that were pro-climate during the control period

Note that the model contains a log link term that accounts for the number of opportunities an MP had to make a pro-climate tweet during the experimental period. Since the log of zero is undefined we excluded those MPs who posted zero tweets during the experimental period in the analysis below. We also ran the analysis with those same MPs included but added 0.1 to the log of the number of their total tweets during the experimental period. There were no meaningful differences between these two analyses. Additionally, neither email treatment nor gender were significant predictors in the models, though the results of including them are presented here for interest’s sake. However, when we report statistics in the main text they are from model (1) or, when district competition is specified, model (2) of the various tables.
Table 16: Results from the zero-inflated negative binomial models

<table>
<thead>
<tr>
<th></th>
<th>Dependent variable:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of pro-climate tweets in the experimental period</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Number of emails</td>
<td>0.037</td>
<td>0.056*</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>Likelihood of re-election</td>
<td>-0.216***</td>
<td>-0.215***</td>
</tr>
<tr>
<td></td>
<td>(0.071)</td>
<td>(0.071)</td>
</tr>
<tr>
<td>Email treatment</td>
<td></td>
<td>0.116</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.212)</td>
</tr>
<tr>
<td>Gender (Male)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-2.935***</td>
<td>-2.103***</td>
</tr>
<tr>
<td></td>
<td>(0.122)</td>
<td>(0.302)</td>
</tr>
<tr>
<td>Observations</td>
<td>280</td>
<td>280</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-329.043</td>
<td>-324.411</td>
</tr>
</tbody>
</table>

Note: Standard errors in parenthesis, *p<0.1 **p<0.05 ***p<0.01
Table 17: Results from the second set of zero-inflated negative binomial models

<table>
<thead>
<tr>
<th></th>
<th>Dependent variable:</th>
<th>Number of pro-climate tweets in the experimental period</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Received email (Y)</td>
<td>0.174</td>
<td>0.297</td>
<td>0.304</td>
<td>0.268</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.213)</td>
<td>(0.214)</td>
<td>(0.219)</td>
<td>(0.217)</td>
<td></td>
</tr>
<tr>
<td>Likelihood of re-election</td>
<td></td>
<td>-0.201***</td>
<td>-0.201***</td>
<td>-0.227***</td>
<td></td>
</tr>
<tr>
<td>(0-6 where 6 = safe district)</td>
<td></td>
<td>(0.072)</td>
<td>(0.072)</td>
<td>(0.073)</td>
<td></td>
</tr>
<tr>
<td>Email treatment</td>
<td></td>
<td>0.029</td>
<td>0.049</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(public health)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender (Male)</td>
<td>-0.422*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.219)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-2.956***</td>
<td>-2.215***</td>
<td>-2.263***</td>
<td>-1.915***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.164)</td>
<td>(0.314)</td>
<td>(0.474)</td>
<td>(0.503)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-329.896</td>
<td>-325.993</td>
<td>-325.984</td>
<td>-324.111</td>
<td></td>
</tr>
</tbody>
</table>

Note: Standard errors in parenthesis, *p<0.1 **p<0.05 ***p<0.01
Table 18: Results from the zero-inflated negative binomial models Liberal Party only

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable:</strong></td>
<td>Number of pro-climate tweets in the experimental period</td>
<td>Number of pro-climate tweets in the experimental period</td>
<td>Number of pro-climate tweets in the experimental period</td>
<td>Number of pro-climate tweets in the experimental period</td>
</tr>
<tr>
<td><strong>Number of emails</strong></td>
<td>0.046*</td>
<td>0.060**</td>
<td>0.056**</td>
<td>0.058**</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.025)</td>
<td>(0.026)</td>
<td>(0.027)</td>
</tr>
<tr>
<td><strong>Likelihood of Re-election (0-6 where 6 = safe district)</strong></td>
<td>-0.224***</td>
<td>-0.217***</td>
<td>-0.215***</td>
<td>-0.215***</td>
</tr>
<tr>
<td></td>
<td>(0.082)</td>
<td>(0.082)</td>
<td>(0.082)</td>
<td>(0.083)</td>
</tr>
<tr>
<td><strong>Email treatment (public health)</strong></td>
<td>-0.140</td>
<td>-0.137</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.249)</td>
<td>(0.249)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender (Male)</strong></td>
<td>0.049</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.269)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>-3.136***</td>
<td>-2.202***</td>
<td>-2.160***</td>
<td>-2.206***</td>
</tr>
<tr>
<td></td>
<td>(0.150)</td>
<td>(0.374)</td>
<td>(0.380)</td>
<td>(0.456)</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>153</td>
<td>153</td>
<td>153</td>
<td>153</td>
</tr>
</tbody>
</table>

*Note:* Standard errors in parenthesis, *p*<0.1 **p*<0.05 ***p*<0.01
Table 19: Results from the zero-inflated negative binomial models Liberal Party only

<table>
<thead>
<tr>
<th></th>
<th>Dependent variable:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of pro-climate tweets in the experimental period</td>
<td>(1)</td>
</tr>
<tr>
<td>Received Email (Y)</td>
<td>0.408</td>
<td>0.468*</td>
</tr>
<tr>
<td></td>
<td>(0.258)</td>
<td>(0.253)</td>
</tr>
<tr>
<td>Likelihood of Re-election</td>
<td>-0.193**</td>
<td>-0.182**</td>
</tr>
<tr>
<td>(0-6 where 6 = safe district)</td>
<td>(0.085)</td>
<td>(0.084)</td>
</tr>
<tr>
<td>Email treatment</td>
<td>-0.308</td>
<td>-0.302</td>
</tr>
<tr>
<td>(public health)</td>
<td></td>
<td>(0.247)</td>
</tr>
<tr>
<td>Gender (Male)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-3.254***</td>
<td>-2.451***</td>
</tr>
<tr>
<td></td>
<td>(0.210)</td>
<td>(0.412)</td>
</tr>
<tr>
<td>Observations</td>
<td>153</td>
<td>153</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-200.625</td>
<td>-198.043</td>
</tr>
</tbody>
</table>

*Note:* Standard errors in parenthesis, *p<0.1**p<0.05***p<0.01