Pro-environmental behaviour impacts and their relationship to insurance claim frequency through individual household and municipal-level analyses

by

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Author’s Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

The research within this thesis is presented in a manuscript style. The first paper entitled “Household pro-environmental behaviour impacts and their relationship to insurance claim frequency and severity”, within Chapter 2, has been submitted to the Journal of Environmental Psychology and I am the primary author of this study with editing and financial contributions from Dr. Jeffrey Wilson. The second paper entitled “Municipal pro-environmental behaviour relationship to insurance claim frequency”, within Chapter 3, has been submitted to Carbon Footprints and I am the primary author of this study with editing and financial contributions from Dr. Jeffrey Wilson.

Abstract

The primary objective of the research has been to determine the relationship between pro-environmental behaviour (PEB) and risk-mitigating behaviours. Chapter 2 approached the objective by comparing a direct measurement of individual household behaviours and motivations to insurance claim frequency scores. Chapter 3 approached the objective by measuring municipal actions based on milestones completed for carbon mitigation as an indirect proxy for pro-environmental behaviour at a municipal level. The milestone data was then compared to the same insurance claim frequency scores. The outcome of both studies did not identify a clear link between pro-environmental and risk-mitigating behaviour through behavioural spillover. Instead, Chapter 2 found that at a community level data resolution, age, income, education, or place of residence do not influence the PEBs of an individual. Also, Chapter 2 found that the intentions of an individual do not reflect their behaviour. Chapter 3 models did not show significant evidence of any relationship between the milestone data and the frequency of insurance claims for a municipality, indicating an absence of spillover. This study suggests that within the bounds of such a program, municipalities are experiencing either a lack of motivation for the initial behaviour or barriers to subsequent behaviours are too large. Considering both papers, in order to fully assess and understand the relationship between PEBs and risk-mitigating behaviour, additional research is necessary.

Acknowledgements

Dr. Jeffrey Wilson, my supervisor, has been an invaluable support throughout my entire master's degree. I would like to acknowledge and give my warmest thanks to him, whose guidance and advice carried me through all the stages of my research and writing. Also, in addition to providing funding support, the models applied in this study benefited from substantial input provided by the Cooperators Team, notably Tom Ewart and Sylvain Pannetier-Lebeuf. We greatly appreciate their support and commitment to the study.

Additionally, we would like to thank the Canadian Index of Wellbeing for providing access to the Nova Scotia quality of life survey results. Also, the International Council for Local Environmental Initiatives (ICLEI) for providing us with access to their programming data. Plus, we would like to thank the Smart Prosperity Institute.

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Land Acknowledgement

I acknowledge that the work I've done at the University of Waterloo is situated on the traditional territory of the Neutral, Anishinaabeg and Haudenosaunee peoples. The main campus is situated on the Haldimand Tract, the land granted to the Six Nations that includes six miles on each side of the Grand River. The work I have done remotely is in Regina, Saskatchewan, situated on the territories of the nêhiyawak, Anihšināpēk, Dakota, Lakota, and Nakoda, and the homeland of the Métis/Michif Nation. Regina is on Treaty 4 lands with a presence in Treaty 6.

The findings and analysis of this study are not universally applicable across Canada. Considering Canada's vast geography and culture, the scope of one study will always be insufficient to cover all aspects of the Canadian experience. Specifically, and important to note is the Indigenous relationships of Canada in the face of climate change. These relationships are Canadian-specific contexts intrinsic to understanding any climate change-related research within Canada. There are unique dynamics and challenges in understanding individuals and industries within Canada due to their inherent tie to the historical relationship with Indigenous people. Additionally, the governing system of Canada is a top-down process, causing many of the policies to be largely disconnected from communities directly affected by climate change, undermining and devaluating traditional adaptation capacities (Fayazi, Bisson, & Nicholas, 2020). Indigenous people in Canada experience pre-existing marginalization from the colonial legacy of Canadian governing systems that provide barriers to support for climate-related aid (Ford, et al., 2018; Abate & Kronk, 2013; Fayazi, Bisson, & Nicholas, 2020; Downing & Cuerrier, 2011). Many Indigenous groups hold a unique biophysical and cultural connection and dependency on the land, making an acute sensitivity to natural shifts due to climate change. The marginalization of Indigenous peoples extends to the Canadian economy situated on their lands, which has exacerbated their sensitivities to climate change and constitutes acute livelihood challenges.

Previous research has argued that climate adaptation aims to reduce vulnerabilities and build societal resilience (Nichol & Harford, 2016; Fayazi, Bisson, & Nicholas, 2020). Unfortunately, despite these intentions, climate adaptation response policies have perpetuated the marginalization through the exclusion of Indigenous voices and adapting strategies that persist in the devaluing of traditional knowledge and cultural values (Morchain, 2018; Scoville-Simonds, Jamali, & Hufty, 2020; Fayazi, Bisson, & Nicholas, 2020). Mainstream research and policy solutions have been pointed out as providing technical solutions, overlooking social context, cultures, and power relations

on the ground (Stern N. , 2008; Barbeau, 2017; Cameron, 2012; Bankoff, 2019; Morchain, 2018), and failing to consider how Indigenous communities perceive, understand, and respond to climate change (Feltmate, et al., 2018; Fayazi, Bisson, & Nicholas, 2020). Plus, the foundation Indigenous people have formed in the discussion of the environmental preservation of Canada is essential in recognizing. When analyzing municipal policy, acknowledgement of the basis of all Canadian legislature is grounded in othering indigenous groups. The policy or sustainability objectives might exist within a region. However, no matter how much consultation is done with Indigenous groups, Canadian municipal policy is done with the assumption that it is primary demographic is non-indigenous people. These are limitations of the research of this study, and the relationships with Indigenous people need to be acknowledged and discussed since this is essential in any Canadian discourse in the steps of reconciliation.

Chapter 1
Introduction and Study Overview

Climate change's effect on insurance premiums is an emerging research topic within Canada. The impacts of climate change have had significant variations across geography and social groups, causing a mixture of responses to the threat. Changes due to climate change impacts have been recorded as increased temperatures, permafrost receding, ice melt, precipitation pattern changes, snow cover decreasing, water availability reduction, sea level rise, and increased extreme weather events (The Government of Canada, 2008; Fayazi, Bisson, & Nicholas, 2020). Canada's aging infrastructure was primarily designed to anticipate historic, moderate weather events and smaller populations (McCaffery, 2022). Therefore, Canada is unprepared for the projected future impacts of climate change. The annual amount of money insurance companies have spent on climate change-related damages have quadrupled from the 1983 to 2008 average of $422 million to a $2 billion average between 2009 and 2020 (Rosanes, 2021). Damages to buildings and infrastructure are expected to increase as infrastructure ages and areas deemed high-risk spread across the country. Financial losses with average annual severe weather claims paid by insurers in Canada are expected to double to $5 billion by 2030 (Kovacs, 2020). These extreme losses have already spurred the insurance industry's transformation (Malloy & Sylvester, 2010), and the predicted losses over the next ten years and beyond are expected to continue to drive profound, transformative change (McCaffery, 2022). Along with increased insurance rates, insurance companies are predicted to withdraw property coverage in areas deemed too costly or avoid insuring certain risks altogether if circumstances do not change (Rosanes, 2021).

Canada is working to transition to a low-carbon future, with efforts since 2000 causing a decline in emissions by 20% (Kovacs, 2020). However, Canadian greenhouse gas emissions per capita are still among the highest in the world (McCaffery, 2022). The federal government has set 2030 and 2050 emission reduction targets, but 95% of emissions are not covered by provincial targets (Turcotte, 2021). Therefore, the impacts of climate change on the Canadian economy are expected to continue to be significant, especially at a community level (The Government of Canada, 2008). Impact modelling suggests that at moderate degrees of warming, economic impacts may be slightly positive in the short term, but further warming with the associated changes in the climate will overwhelm systems, causing net economic losses (Stern N. , 2008). For all sectors, climate change

means the increased risk of reaching critical thresholds where long-term future feedback and catastrophic events will be costly (Stern N. , 2008; Schneider, 2004), especially in the case of natural resource-reliant communities (Parry, Canziani, Palutikof, van der Linden, & Hanson, 2007). These primary impacts will cause strain on the production and demand for goods and services and cause increased costs associated with public safety, health, and welfare of populations.

Individuals and private households have been highlighted as key actors in mitigating the effects of climate change through pro-environmental behaviours (PEB). For example, in the United States, researchers have determined that through behavioural changes alone, CO2 emissions can be reduced by 20% within ten years (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009; Steinhorst, Klöckner, & Matthies, 2015). These proactive actions for limiting impacts on the environment are often adjacent to behaviours that reduce risk exposure to climate-related hazards. In many cases, like greywater collection and rain barrels, the pro-environmental behaviours are simultaneously risk-mitigating behaviours. The potentially close relationship between PEBs and risk-mitigating behaviours indicates a potential for individuals and private households to simultaneously contribute to climate change mitigation and alleviate financial strains on Canada and the insurance industry.

PEBs are subject to various internal and external influences that serve as motivators or barriers to action (Carrus, Bonaiuto, & Bonnes, 2005; Steg & Vlek, 2009; Gifford & Nilsson, 2014; Takahashi & Selfa, 2014; Kollmuss & Agyeman, 2002). These influences affect an individual's commitment toward completing the activity and the likelihood of doing subsequent PEBs or risk-mitigating behaviours. Studies have documented contradictory results regarding the robustness of internal and external influences (Silvi & Padilla, 2021). These conflicting results and limitations suggest a potential gap in research regarding analyzing the overlap and interconnectivity of internal and external influences and how they shape pro-environmental behaviours.

A recent study by Silvi and Padilla (2021) notes that studies that account for the integrative influence of both internal and external influence are rare. They describe pro-environmental research as being studied as one of two potential frames. The first framing is pro-environmental behaviour as the result of internal moral deliberation without acknowledgement of an individual’s external context (Heberlein, 1981; Black, Stern, & Elworth, 1985; Hopper & Nielsen, 1991; Grodzinska-Jurczak, 2003; Bamberg & Moser, 2007; Sidique, Joshi, & Lupi, 2010; Liobikienė, Mandravickaitė, & Bernatonienė, 2016). The second research framing is that pro-environmental behaviour is the

automatic response to an external stimulus regardless of an individual's values (Jacobs & Bailey, 1983; Palmer & Walls, 1997; Linderhof, Kooreman, Allers, & Wiersma, 2001; Ferrara & Missios, 2005). These assumptions neglect heterogeneity across individuals' values, responsibilities, knowledge, relationships, and finances, which will influence a wide variety of potential behavioural outcomes (Silvi & Padilla, 2021).

There is a need to examine the potential interconnections between PEB influences. Overall, existing literature fails to make connections from socio-demographic factors, institutions, or location to internal influences. Also, no studies consider how one's internal value system or motivations can shape their external world and how that connects to pro-environmental behaviour. These gaps in research indicate a need for more integrated frameworks to be applied in the pro-environmental behaviour analysis (Jackson, 2005; Van der Bergh, 2008; Turaga, Howarth, & Borsuk, 2010; Kirakozian, 2016; Silvi & Padilla, 2021).

Behavioural spillover theory is the process of performing one behaviour resulting in subsequent behaviours, such as recycling behaviours spilling over into composting behaviours (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009; Steinhorst, Klöckner, & Matthies, 2015). The framework was developed by Truelove, Carrico, Weber, Raimi, and Vandenbergh (2014). Spillover theory assumes that the extent of an initial behaviour leading to subsequent similar behaviours depends on the reasons behind doing the initial behaviour and the level of acknowledgement an individual gives to the initial behaviour (Truelove, Carrico, Weber, Raimi, & Vandenbergh, 2014). Additionally, the framework moderates the spillover process by bounding the process with the characteristics and interrelationships between the behaviours. Through applying the spillover theory framework, the understanding of behaviour processes is broken down into decision modes, causal attribution, characteristics, interrelationships, and difficulty of the behaviours. Therefore, understanding the execution of PEBs should not be perceived as the result of complete individual analysis; rather is sensitive to the domain of an array of socio-spatial analyses (Agovino, Crociata, & Luigi Sacco, 2016). While the concept of spillover is a commonly explored research area, this process is a relatively new framework and has limited application. The potential context of behavioural spillover theory is demonstrated within the pro-environmental and risk-mitigating behaviour system in Figure 1-1: Spillover theory framework.

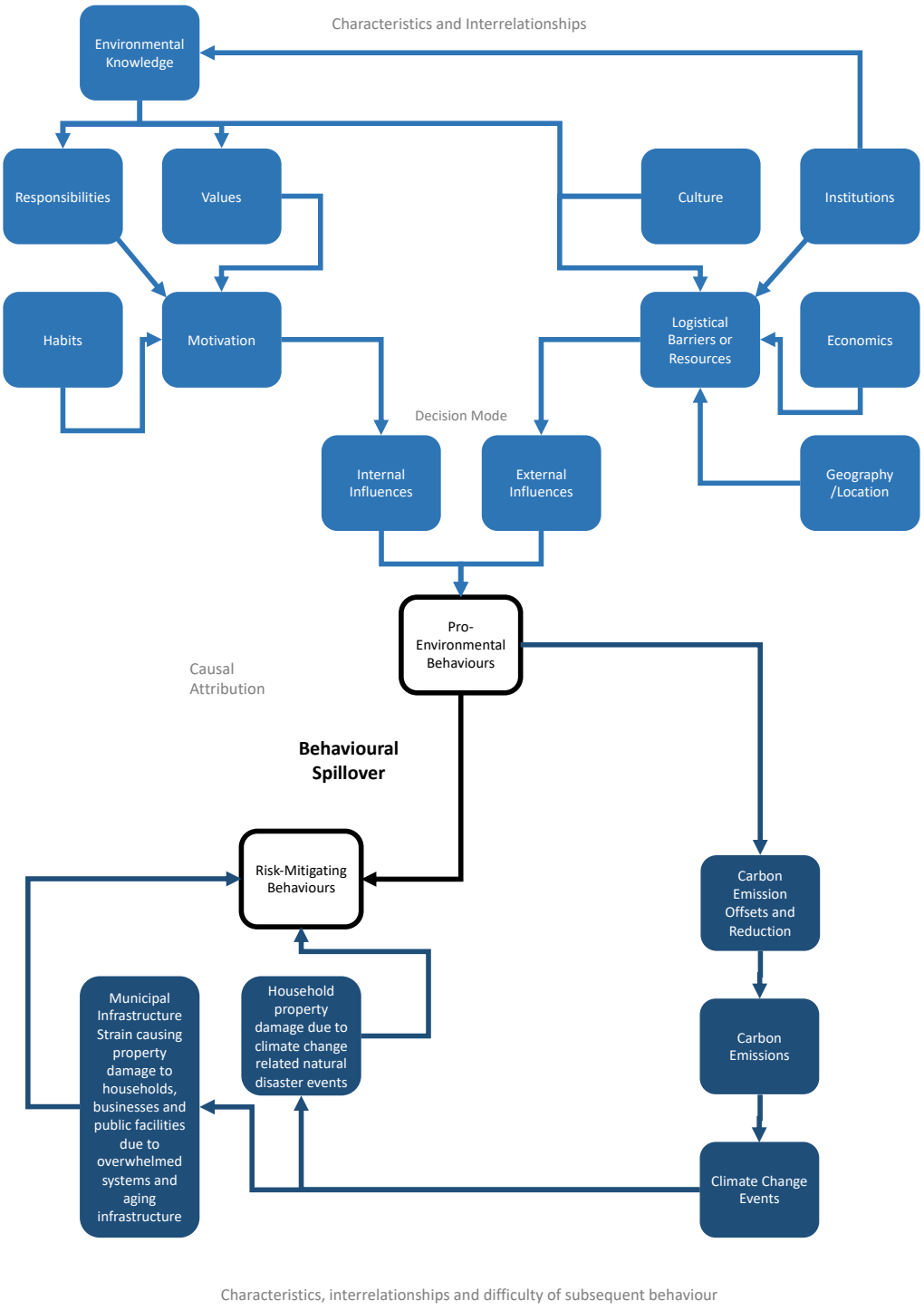

Figure 1-1: Spillover theory framework

The decision mode is the mind frame- or mode- an individual holds when deciding to adopt an initial behaviour. The mode can be based on analytic processing (calculation-based), emotions or values (affect-based), and perceived obligation due to internalized social norms (rule-and-role). As seen in Figure 1-1: Spillover theory framework, calculation-based modes fit within external influences and will be the result of more logistical barriers or resources; affect-based is the result of more internal motivations and rule-and-role connects to both internal and external influences. Individuals who perform behaviours driven by positive calculations or affect modes are more likely to exhibit positive spillover because the initial decision will reinforce and strengthen the participants' role (Truelove, Carrico, Weber, Raimi, & Vandenbergh, 2014). The reverse of this is true, with negative calculations or affect modes leading to negative spillover. Additionally, multiple decision modes can be executed in parallel, and the less deliberation put into behaviour, the more accessible for a behaviour to be modified.

Causal attribution is an internal process that makes up the final push in spillover occurring. It takes place after an initial behaviour when an individual assigns an understanding of an action being driven internally or externally. In Figure 1-1: Spillover theory framework, the internal influences are formed by motivations and external influences are formed by logistical barriers and resources. Upon reflection, if an individual considers their initial behaviour to be internally motivated with the right resources available, they will often aim to achieve consistency through additional similar behaviours. However, if an initial behaviour is not driven by enough internal motivations or barriers are too large, the need for consistency is less prevalent and often will not result in the spillover of additional activities (Truelove, Carrico, Weber, Raimi, & Vandenbergh, 2014).

The characteristics and interrelationships encapsulate an individual's behavioural system and have profound implications for whether spillover is observed (Truelove, Carrico, Weber, Raimi, & Vandenbergh, 2014). Figure 1-1: Spillover theory framework demonstrates their existence around an individual's internal motivations, and external barriers and resources. Characteristics form the details of the entire behavioural system and provide the nuance that exists when an individual experiences their decision mode and causal attribution. The interrelationships acknowledge the integrated nature of internal and external influences, connecting socio-demographic factors, institutions, and location to internal influences. Additionally, interrelationships integrate the indirect influence of PEBs on risk-mitigating behaviours through carbon emission impacts.

The perceived difficulty of a subsequent behaviour provides context to the likelihood of more behaviours occurring during causal attribution. The perceived difficulty is made up of characteristics, and interrelationships and takes place alongside the causal attribution process. Despite the best motivations or intentions, a challenging behaviour ultimately inhibits subsequent behaviours.

The primary gap in research pertaining to this study exists when connecting pro-environmental behaviour spillover into risk-mitigating behaviours and the subsequent potential impacts this could have on insurance rates. Behavioural spillover theory offers a mechanism for significant impact by enabling policy and program makers to catalyze broad lifestyle changes from one behaviour to another (Nash et al., 2017). Currently, no studies have been identified noting this link and the potential benefits for Canadian policymakers and insurance companies.

To make this connection, the study is broken into two phases of research. The first phase, Chapter 2, uses Nova Scotia Quality of Life survey data from the Canadian Index of Wellbeing to analyze at a household and individual level. The second phase, Chapter 3, uses milestone achievement data tracked by the International Council for Local Environmental Initiatives (ICLEI) to analyze at a municipal level. The results and their connection to pro-environmental behaviour spillover is discussed in Chapter 4.

1.1 Research Objectives and Questions

The research within this study aims to bridge gaps in research between pro-environmental and risk-mitigating behaviours through the behaviour spillover theory framework. Exploration of these relationships and the behaviours' motivations, barriers and resources can enable policymakers and insurance companies to understand how to effectively promote more sustainable lifestyles (Silvi & Padilla, 2021).

Therefore, the objective of the research within this thesis is to determine the relationship between pro-environmental behaviour and risk-mitigating behaviours. Also, to address the following research questions:

1. What variables drive pro-environmental behaviour?
2. Do internal or external influences of pro-environmental behaviour correlate with household insurance claims (or state risk mitigating behaviours)
3. Do local municipal environmental policies correlate with insurance claims in a region?

4. Are external influences an effective measurement tool for comparing risk-mitigating behaviour on insurance claim frequency/severity?
5. Are internal or external influences stronger in initiating pro-environmental behaviour?
6. Is there a relationship between pro-environmental behaviour and risk-mitigating behaviour due to spillover?

This study is broken into two phases, where the connection between pro-environmental behaviour and risk-mitigating behaviour is explored at a household and municipal level.

1.2 Literature Review

Research topics within the literature relevant to the relationship between pro-environmental behaviour and risk-mitigating behaviour are pro-environmental behaviour and the application of behavioural spillover theory to pro-environmental behaviour. PEB is the action of an individual consciously aiming to minimize consumption, waste generation and impact on the planet. While risk-mitigating behaviours are the avoidance or reduction of behaviours that directly increase the chance of damage or destruction to ones-self or property. The focus on these terms in the literature review and research of this study is the general overlap in these behaviours enabling a justifiable connection for a relationship to be found. For example, many PEBs, such as rainwater collection, are also behaviours that could prevent property damage such as basement flooding.

Other research topics focused on influencing individuals to perform environmentally friendly behaviours, such as community based social marketing, encompass strategies to reduce barriers and increase adoption of behaviours (Smith, Lynes, & Wolfe, 2019). These topics are not focused on within this study due to their connection to risk-mitigating behaviours being indirect through a process rather than describing a direct set of comparable behaviours.

1.2.1 Pro-Environmental Behaviour (PEB)

Pro-environmental behaviour is the action of an individual consciously aiming to minimize consumption, waste generation reduction, and recycling (Kollmuss & Agyeman, 2002; Wang & Mangmeechai, 2021). These activities cover behaviours that "harm the environment as little as possible or even benefit the environment" (Steg & Vlek, 2009; Steinhorst, Klöckner, & Matthies, 2015; Kollmuss & Agyeman, 2002). Pro-environmental actions can consist of conscious and proactive behaviours to be more environmentally friendly - such as energy conservation (Sparks &

Shepherd, 1992), or culturally standard behaviours - such as recycling (Whitmarsh & O'Neill, 2010). These actions can be done to minimize the health risk to self, others, next generations, other species, and whole ecosystems (Bamberg & Moser, 2007).

In 1981, Liere and Dunlap published their study analyzing the different measurement types of environmental concerns and the consistency of measurement methods and results (Liere & Dunlap, 1981). Their study dove into the growing concern for the environment and the emerging research which applied behavioural studies to environmentally friendly behaviour. Prior studies had applied behaviour studies to environmental concerns through the analysis of electricity conservation (Slavin, Wodarski, & Blackburn, 1981) or water conservation (Geller, Scott, Erickson, & Buttram, 1983). Also, in 1981, Fietkau and Kessel published a paper using sociological and psychological factors for explaining the presence of environmentally conscious behaviours. Their analysis focused on the attitudes and values of individuals, including a model of potential variables that can directly or indirectly influence an individual to behave with environmental preservation in mind. These were the first found instances of pro-environmental behaviour before the term "pro-environmental behaviour" was established. Before the 1980s, behavioural studies used potentially acting environmentally friendly as examples in their research but were not a focal point (Tajfel & Turner, 1979).

Hines, Hungerford, and Tomera formalized the topic of pro-environmental behaviour in 1986 through a model of environmental behaviour built from a list of 128 primary studies which assessed variables associated with environmentally friendly behaviour (Hines, Hungerford, & Tomera, 1986-87; Bamberg & Moser, 2007). Their work analyzed the intentions behind behaviour and objective situational factors as determinates in a person acting "pro-environmentally." The study assessed this by focusing on the association between five "psychosocial variables," attitude, locus of control/self-efficacy, moral responsibility, behavioural intention, and pro-environmental behaviour. Hines, Hungerford, and Tomera (1986) formalized the groundwork for subsequent research to expand on for the next 20 years.

Initially, research focused heavily on the influence of internal motivations on pro-environmental behaviour. Refer to Table 1-1: Pro-environmental behaviour research topics and studies that covered them row one for a compiled list of studies discussing this topic.

Table 1-1: Pro-environmental behaviour research topics and studies that covered them

#	PEB Topic	Studies Covering the Topic	
1	Influence of internal motivations on pro-environmental behaviour	Borden & Francis, 1978 Wilkie, 1990 Preuss, 1991 Grob, 1991 Diekmann & Preisendoerfer, 1992 Eagly & Chaiken, 1993 Stern & Dietz, 1994 Fuhrer, Kaiser, Seiler, & Maggi, 1995 Staats, Wit, & Midden, 1996 Espey, Espey, & Shaw, 1997	Fliegenschnee & Schelakovsky, 1998 Moisander, 1998 Chawla, 1998/99 Michelsen, McGuckin, & Stumpf, 1999 Lehman, 1999 Kaiser, Woelfing, & Fuhrer, 1999 Schultzs & Zelezny, 1999 Schultz, 2002 Kollmuss & Agyeman, 2002 Clark, Kotchen, & Moore, 2003
2	Motivation to action gap	Sheeran & Orbell, 1999 Blake, 1999	Kollmuss & Agyeman, 2002 Gollwitzer & Sheeran, 2006
3	The role of external influence before the early 2000s	Tajfel & Turner, 1979 Liere & Dunlap, 1981 Burn & Oskamp, 1986 Cialdini, Reno, & Kallgren, 1990 Coleman, 1990 Ajzen, 1991 Putnam, 1993 Danielson, Hoban, Van Houtven, & Whitehead, 1995 Schultz, Oskamp, & Mainieri, 1995 Ackermann, 1997 Putnam, 2000	Jamison, 2001 Steg, Vlek, & Slotegraaf, 2001 Kollmuss & Agyeman, 2002 Kemmelmeier, Król, & Kim, 2002 Gosken, Adaman, & Zenginobuz, 2002 Domina & Koch, 2002 Felder & Schleiniger, 2002 Greunz, 2003 Bamberg & Schmidt, 2003 Dupont, 2004 Torgler & García-Valiñas, 2005 Jackson, 2005
4	The role of external influence after the early 2000s	Alsmadi, 2007 Ajzen & Albarracín, 2007 Engel, Pagiola, & Wunder, 2008 Hage, Söderholm, & Berglund, 2009 Brécard, Hlaimi, Lucas, Perraudeau, & Salladarré, 2009 Amutenya, Shackleton, & Whittington-Jones, 2009 Sidique, Joshi, & Lupi, 2010 Feygina, Jost, & Goldsmith, 2010 Scannell & Gifford, 2010 Filippini, 2011 Saphores, Ogunseitan, & Shapiro, 2012 Markowitz, Lewis, Goldberg, Ashton, & Lee, 2012 Basile, Capello, & Caragliu, 2012 Laidley, 2013 Valkering, Beumer, de Kraker, & Ruelle, 2013	Takahashi & Selfa, 2014 Clark, 2014 Botetzagias, Dima, & Malesios, 2015 López-Mosquera, Lera-López, & Sánchez, 2015 Han, 2015 Kyriacou, Muinelo-Gallo, & Roca-Sagalés, 2015 Crociata, Agovino, & Sacco, 2015 Steinhorst, Klöckner, & Matthies, 2015 Imas, Sado, & Samek, 2016 Agovino, Crociata, & Luigi Sacco, 2016 Zhang, Zhang, Yu, & Ren, 2016 De Quidt, 2017 Ifegbesan & Rampedi, 2018 Jagers, Harring, & Matti, 2018 Li, Zhao, Ma, Shao, & Zhang, 2019

		Graham-Rowe, Jessop, & Sparks, 2014	Ghesla, Grieder, Schmitz, & Stadelmann, 2019 Silvi & Padilla, 2021
5	Internal and external motivations connectivity	Fife-Schaw, Sheeran, & Norman, 2007 Welsch & Kühling, 2010 De Bruin, et al., 2012 Fan, et al., 2013 Liiu & Bai, 2014 Dixit & Badgaiyan, 2016	Fielding, et al., 2016 Zhang, Zhang, Yu, & Ren, 2016 Hanss, Böhm, Doran, & Homburg, 2016 Li, Zhao, Ma, Shao, & Zhang, 2019 Wang & Mangmeechai, 2021
6	Internal and external connectivity in motivation to action gap	Van der Bergh, 2008 Sidique, Joshi, & Lupi, 2010 Turaga, Howarth, & Borsuk, 2010 Miafodzyeva & Brandt, 2013 Van der Werff, Steg, & Keizer, 2013 Kirakozian, 2016	Liobikienė, Mandravickaitė, & Bernatonienė, 2016 Agovino, Crociata, & Luigi Sacco, 2016 Li, Zhao, Ma, Shao, & Zhang, 2019 Silvi & Padilla, 2021

(Compiled by author)

Then, in the early 2000s, research expanded and acknowledged a motivation-to-action gap, See row two of Table 1-1: Pro-environmental behaviour research topics and studies that covered them, referencing studies where the motivations and desires of an individual to act pro-environmentally did not line up with their actual actions. In many studies this is also referred to as the intention-action gap. The terms “intention” and “motivation” independently portrays different internal functions. Intention describes the desired outcome of an individual’s behaviour and motivation is the factors that push an individual to do a behaviour. However, in studies that use them to discuss the -action gap, they both describe the same phenomenon. Therefore, the terms “intention” and “motivation” will be used interchangeably within this literature review. The consistency of studies finding the -action gap caused a pivot in the research to focus more intently on the role of external influence. Row three of Table 1-1: Pro-environmental behaviour research topics and studies that covered them references studies acknowledging the role of external influence before the research pivot. Row four of Table 1-1: Pro-environmental behaviour research topics and studies that covered them then outlines the studies that then focused on external influences in explaining the intention-action gap.

No additional metanalysis within the field was conducted until 2007, when Bamberg and Moser (2007) compiled the updated research with modern statistical methods. Their conclusion focused on the need for more integrative internal and external influence analysis within the field (Bamberg & Moser, 2007). Since then, several studies have looked to connect internal and external motivations, see row five of Table 1-1: Pro-environmental behaviour research topics and studies that covered them. Additional studies use these connections to explain the gap between an individual’s motivation

and actual pro-environmental behaviours; see row six of Table 1-1: Pro-environmental behaviour research topics and studies that covered them.

1.2.1.1 Influences on Pro-Environmental Behaviour

Many factors play essential roles in an individual behaving pro-environmentally and are presented in Figure 1-2: The breakdown of influences on pro-environmental behaviour (Carrus, Bonaiuto, & Bonnes, 2005; Steg & Vlek, 2009; Gifford & Nilsson, 2014; Takahashi & Selfa, 2014). Influences on pro-environmental behaviour have been studied due to their ability to shape an individual's actions toward the desired outcome. By thoroughly understanding the mechanisms influencing an individual's actions, behaviours can be targeted effectively and efficiently. Research by environmental psychologists has focused on harnessing altruistic motivations (De Young, 1986). Economists have discussed the extent monetary influences hold on an individual performing pro-environmental behaviour through incentives (Curlee, 1986). Additional research discusses convenience through infrastructure and influencing social norms. All these discussion areas can be categorized into the influences of an individual's internal and external motivations on acting pro-environmentally.

Conversely, influences on pro-environmental behaviour work both as catalysts to action and barriers. Blake (1999) breaks down barriers taking the forms of individuality, responsibility, and practicality (Blake, 1999). Individual barriers are internalized attitudes and temperaments towards a behaviour. These barriers can vary from day to day. Responsibility barriers can be internal and external to an individual, referring to internalized moral responsibilities or external motivations, such as job expectations or family needs. Practical barriers take the form of external social and institutional constraints that can prevent individuals from acting pro-environmentally, regardless of their attitudes or intentions (Blake, 1999; Kollmuss & Agyeman, 2002). An individual's responses to barriers are discussed through a low-cost/high-cost model (Diekmann & Preisendoerfer, 1992), which frames a decision to perform a behaviour being made by weighing the costs and choosing the perceived least costly option. Cost, in this context, does not entirely refer to the financial cost; rather, in a broader sense, it includes the time, effort and moral motivation needed to undertake pro-environmental behaviours (Kollmuss & Agyeman, 2002). For example, a large majority of individuals value environmental preservation but hold skepticism surrounding the potential for individual behaviour to

sufficiently mitigate the problems we face, reducing the moral motivation behind acting pro-environmentally (Crompton, 2008; Jackson, 2009; Nilsson, Bergquist, & Schultz, 2017).

There are significant challenges when understanding the influences on pro-environmental behaviour due to the complexity and interconnectivity of an individual's psyche. Specific challenges arise in temporal discrepancies when the data is inconsistent due to the attitude changes between data collection periods (Kollmuss & Agyeman, 2002). Attitude-behaviour measurement is another challenge for researchers. In surveys or questionnaires, measured attitudes related to pro-environmental behaviour are much broader than the measured actions, leading to discrepancies in results and challenges in determining relationships (Newhouse, 1991).

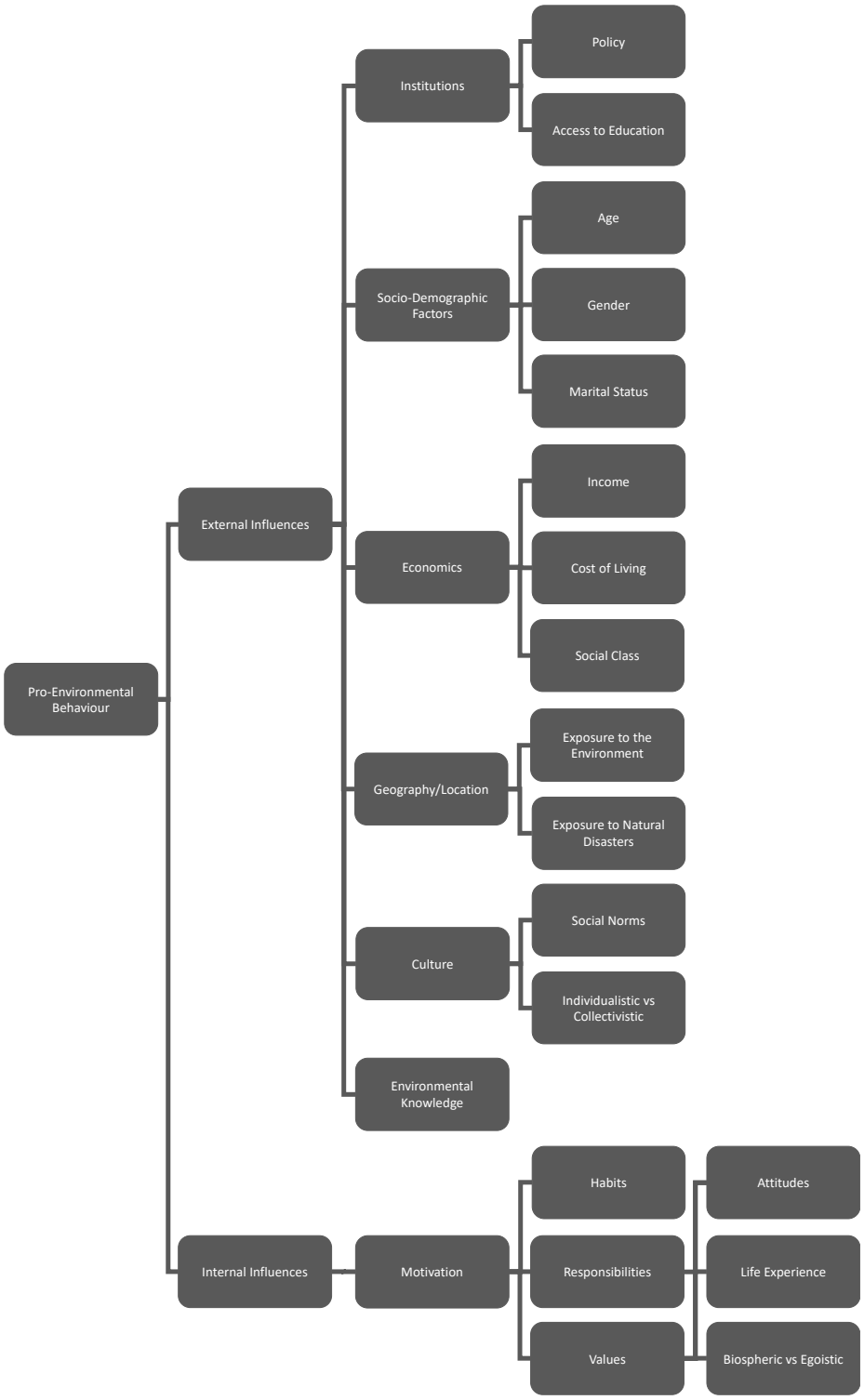

Figure 1-2: The breakdown of influences on pro-environmental behaviour

1.2.1.2 Internal Influences

Individuals can act pro-environmentally based on strong environmental values or other internal motivations (Dean, Lindsay, Fielding, & Smith, 2016). The internal influences of pro-environmental behaviour consist of environmental knowledge, motivation, and values. No single internal motivation formulates an individual's desire to behave pro-environmentally, rather a combination of childhood experiences in nature, experiences of environmental destruction, environmental values held by families or communities, role models and education (Kollmuss & Agyeman, 2002). Unfortunately, while individuals may have the strongest intentions to act pro-environmentally, there is a gap between their intention and actual action found within research.

1.2.1.2.1 Environmental Knowledge

The influence of environmental knowledge on pro-environmental behaviour consists of conflicting discourse. Kollmuss and Agyeman (2002) note the lack of knowledge within communities being a barrier to individuals acting pro-environmentally (Kollmuss & Agyeman, 2002). However, other papers state that environmental education, regardless of quality, will not motivate individuals to act pro-environmentally (Slavin, Wodarski, & Blackburn, 1981; Geller, Scott, Erickson, & Buttram, 1983; Preuss, 1991; Diekmann & Preisendoerfer, 1992; Staats, Wit, & Midden, 1996; Espey, Espey, & Shaw, 1997; Fliegenschnee & Schelakovsky, 1998; Michelsen, McGuckin, & Stumpf, 1999; Schultz, 2002; Bolderdijk, Steg, Geller, Lehman, & Postmes, 2012; Schultz, 2014; Agovino, Crociata, & Luigi Sacco, 2016). Only a small fraction of pro-environmental behaviour can be linked to environmental knowledge and awareness. Flieganschnee and Schelakovsky (1998) found that at least 80% of pro-environmental behaviour motives depend on situational or internal factors. Some studies state otherwise (Grob, 1991; Kaiser, Woelfing, & Fuhrer, 1999), but their conclusions are based on subjective situations that do not lend well to generalizations (Kollmuss & Agyeman, 2002).

1.2.1.2.2 Motivation and Values

Motivation is the reason behind an individual's behaviour. These reasons are shaped by overt or hidden, conscious or unconscious values, responsibilities, and attitudes (Wilkie, 1990; Moisander, 1998; Kollmuss & Agyeman, 2002). Most of an individual's intrinsic motivation behind behaviour is shaped by their values (Kollmuss & Agyeman, 2002; Silvi & Padilla, 2021). Values can be biospheric, a desire for the preservation of others or the environment, or they can be egoistic, a desire for the preservation of oneself. These values are neither good nor bad but are focused differently

(Wang, Van der Werff, Bouman, Harder, & Steg, 2021). An individual's extrinsic motivations are shaped by their needs and responsibilities. These responsibilities consist of job, familial and basic needs obligations. These motivations pose the most substantial barriers and influence pro-environmental behaviour through financial or time constraints (Kollmuss & Agyeman, 2002). More commonly, individuals are working to satisfy their needs and responsibilities. Therefore, acting pro-environmentally is not always possible (Borden & Francis, 1978). Many pro-environmental behaviours require some level of sacrifice, either financially or through time consumption, which poses a barrier to acting pro-environmentally due to circumstances (Söderholm, 2011).

If an individual is in a state where their needs are met, biospheric versus egoistic values can indirectly predict a range of pro-environmental behaviours (Schultz & Zelezny, 1999; De Groott & Steg, 2010; Wang, Van der Werff, Bouman, Harder, & Steg, 2021). In the case of an individual's needs already being met, biospheric values indicate a prioritization and effort put into bettering the community and environment, which often coincides with pro-environmental behaviour (Wang, Van der Werff, Bouman, Harder, & Steg, 2021). Those with prioritized biocentric values- a prioritization to preserve the environment- often have profound life experiences that form a personal connection to the environment (Clark, Kotchen, & Moore, 2003). Egoistic values advocate self-interest and personal comfort. These values indicate that an individual will be more reluctant to perform pro-environmental behaviours since they can be costly and take effort (Wang, Van der Werff, Bouman, Harder, & Steg, 2021).

Attitude reflects the degree of value individuals place on a given behaviour (Eagly & Chaiken, 1993; Graham-Rowe, Jessop, & Sparks, 2014; Li, Zhao, Ma, Shao, & Zhang, 2019). They do not determine a behaviour directly; instead, they determine the intention/motivation or valued outcome of one's action (Kollmuss & Agyeman, 2002). Attitudes alone have been found to have a low impact on an individual acting pro-environmentally (Newhouse, 1991). Instead, one's values and responsibilities shape their attitude when determining to do a pro-environmental behaviour.

1.2.1.3 Motivation Versus Action Gap

The motivation versus action gap was first explicitly acknowledged in pro-environmental behaviour studies by Sheeran and Orbell in 1999, where they found a clear gap between individuals' intentions and actions (Sheeran & Orbell, 1999). This gap suggests that focusing research on an individual's intentions does not produce consistent results with reality (Gollwitzer & Sheeran, 2006). Likewise,

focusing on influencing pro-environmental behaviour through internal motivations does not guarantee a subsequent behaviour change (Fife-Schaw, Sheeran, & Norman, 2007; Wang & Mangmeechai, 2021). In practice, intentions have been found to only explain around 20% to 30% of the variance in behaviour (De Bruin, et al., 2012). Many other studies have acknowledged and discussed this gap (Liiu & Bai, 2014; Dixit & Badgaiyan, 2016; Fielding, et al., 2016; Zhang, Zhang, Yu, & Ren, 2016; Hans, Böhm, Doran, & Homburg, 2016). These studies have suggested that the motivation-behaviour gap is due to situational factors. Therefore, intentions or motivations mediate between infrastructural, relational, or cultural factors and actual behaviour (Fielding, et al., 2016).

1.2.1.4 External Influences

As discussed, an individual may face external, societal, or structural influences/barriers to acting environmentally conscious regardless of personal preference. These external influences are socio-demographic factors, economic influences, cultural influences, policy, and infrastructure.

1.2.1.4.1 Socio-Demographic Factors

Relationships between pro-environmental behaviour and socio-demographic factors vary between studies. Much of the research has found trends between age, gender, and education (Kollmuss & Agyeman, 2002; Ifegbesan & Rampedi, 2018; Brécard, Hlaimi, Lucas, Perraudeau, & Salladarré, 2009; Saphores, Ogunseitan, & Shapiro, 2012; Botetzagias, Dima, & Malesios, 2015; López-Mosquera, Lera-López, & Sánchez, 2015). General conclusions about the trends between age, gender and education are that women and highly educated young people are more likely to be aware of possible damage caused by neglect of the environment. Marital status is also discussed as having a potential relationship with pro-environmental behaviour, but the results were varied across studies. Overall, studies acknowledge that many results contradict one another (Ifegbesan & Rampedi, 2018; Li, Zhao, Ma, Shao, & Zhang, 2019).

1.2.1.4.2 Economics

Economic influences on pro-environmental behaviour of income, social class, and cost of living are widely discussed within the literature. The discussion surrounding it is varied, but most studies agree that these factors are significant predictors of pro-environmental attitudes at a societal level (Kemmelmeier, Król, & Kim, 2002; Laidley, 2013; Kollmuss & Agyeman, 2002). Financial and temporal capital can ease the burden of acting pro-environmentally. Therefore, financial and temporal

constraints significantly adversely affect pro-environmental behaviours such as purchasing green products, retrofits, recycling, and composting (Cialdini, Reno, & Kallgren, 1990; Silvi & Padilla, 2021). Some research has found that when people choose green products, they will only choose the environmentally conscious item if the payback is very short (Kollmuss & Agyeman, 2002). Alternatively, financial or temporal constraints have been shown to have a positive relationship with water and energy conservation and green travel. The positive relationship is due to a desire to save money and a lack of access to personal vehicles (Cialdini, Reno, & Kallgren, 1990; Silvi & Padilla, 2021). From a biospheric values perspective, Laidley (2013) states that environmentally conscious individuals tend to belong to the middle- or upper-middle-classes. On the other hand, studies have found that the highest-income earners negatively relate to pro-environmental behaviour and act the least environmentally conscious (Ifegbesan & Rampedi, 2018). Feygina, Jost, and Goldsmith (2010) find that from this class, environmental denial is persistent due to a desire to preserve the current economic and political system that benefits them (Feygina, Jost, & Goldsmith, 2010; Jagers, Harring, & Matti, 2018). Using economic factors exclusively to predict pro-environmental behaviour is ineffective due to the intertwining of motivation with social, infrastructural, and psychological factors (Kollmuss & Agyeman, 2002).

1.2.1.4.3 Geography and Location

The location of residence for an individual and their surrounding geography influence behaviour through exposure to environmental problems, attachment to location, geographic segregation, and dependency on natural resources. Regional identity is formed from an individual's relationship with their surrounding community and environment. The level of exposure to the natural environment in a location and the surrounding geography will influence the level of environmental connection one will experience in this identity (Ifegbesan & Rampedi, 2018). Regional identity has been identified as a significant predictor for individuals supporting protected areas. Some studies have discussed the differences in regional identity between rural and urban dwellers, stating that rural residents have a better place identity than urban dwellers (Ifegbesan & Rampedi, 2018). Additionally, Gosken, Adaman, and Zenginobuz (2002) discuss the proximity of people to environmental problems affecting their willingness to invest financially and temporally in solutions (Gosken, Adaman, & Zenginobuz, 2002; Ifegbesan & Rampedi, 2018). If someone holds a positive regional identity, they are motivated to protect it from environmental harm (Scannell & Gifford, 2010; Takahashi & Selfa, 2014; Han, 2015). On the other hand, if a region is highly dependent on natural resources for its local economy,

individuals indicate resistance to pro-environmental behaviours and conservation efforts in favour of economic preservation (Ifegbesan & Rampedi, 2018).

1.2.1.4.4 Culture

Croiata, Agovino and Sacco (2015) distinctly addressed culture as a significant factor influencing an individual's pro-environmental behaviour (Crociata, Agovino, & Sacco, 2015). Prior to this, culture and social norms were discussed as a component of internal motivations within sociology (Burn & Oskamp, 1986) or a topic within civic virtue research (Putnam, 2000), rather than culture being an external influence, acting as a resource or barrier to motivations for pro-environmental behaviour (Kollmuss & Agyeman, 2002). Pro-sociality is a topic acknowledging the local, contextual complexity of culture influencing behaviour (Clark T. N., 2014; Agovino, Crociata, & Luigi Sacco, 2016). It considers the fact that many groups can influence individuals through social learning (Greunz, 2003; Basile, Capello, & Caragliu, 2012). The norms that stick depend on a complex array of factors, such as information dissemination, ideas, practices, beliefs, traditions, and values, both in the short and long term (Tajfel & Turner, 1979; Agovino, Crociata, & Luigi Sacco, 2016).

When pro-sociality is applied to pro-environmental behaviours, the cumulative effect of neighbours influencing one another creates a structure of clusters where behaviours stick. In a study by Agovina, Crociata and Luigi Sacco (2016), they found that 95% of people who recycled reported that their friends and neighbours recycle (Agovino, Crociata, & Luigi Sacco, 2016). These dynamics can motivate pro-environmental behaviour within an individual even if they do not hold strong biospheric values or motivations; rather, they act pro-environmentally due to the social norm rather than a moral obligation (Kollmuss & Agyeman, 2002). Social norms are shared rules of conduct within a society's culture partly sustained by approval and disapproval (Elster, 1989). Norms are formed through cultural traditions and family customs- which subsequently can influence and shape an individual's motivations, values, attitudes, and knowledge (Kollmuss & Agyeman, 2002). Often, the internalization of social norms is driven by an individual's desire to fit in with others, avoid social disapproval, and seek social esteem (Schwartz, 1977; Pretty, 2003; Klöckner & Oppedal, 2011; Halvorsen, 2012; Lakhan, 2015; Li, Zhao, Ma, Shao, & Zhang, 2019). Therefore, if a dominant culture is concerned with environmental preservation, pro-environmental behaviour is more likely to occur (Kollmuss & Agyeman, 2002). Conversely, in communities where poor pro-environmental behaviours persist, pro-sociality indicates that these behaviours are locked in and more difficult to

influence change (Agovino, Crociata, & Luigi Sacco, 2016). Agovina, Crociata and Luigi Sacco (2016) also discuss the topic of buffer zones, where pro-sociality has less influence due to a lack of distinct clusters within the population.

The strength of pro-sociality is dependent on whether nations are collectivistic or individualistic. In collectivistic cultures, individuals prioritize the social norm in their decision making (Triandis, 1988; Wang, Van der Werff, Bouman, Harder, & Steg, 2021). Individualistic cultures are when people do not hold the collective perspective in as high of regard. These cultures can still be impacted by cultural norms but have less importance in an individual's decision-making and behaviours (Wang, Van der Werff, Bouman, Harder, & Steg, 2021). Individualistic and collectivistic distinctions provide a foundational understanding of the relationship between culture and pro-environmental behaviour.

1.2.1.4.5 Policy or Infrastructure

Policy and governmental infrastructure are often effective mechanisms that policymakers and civil servants utilize to provide more convenience in acting pro-environmentally and incentivizing individuals to change their behaviours. Many barriers to pro-environmental behaviour are more influential than an individual's personal beliefs, and governments often have the power to remove or reduce the significance of those barriers (Schultz, Oskamp, & Mainieri, 1995; Steg, Vlek, & Slotegraaf, 2001; Kollmuss & Agyeman, 2002; Bamberg & Schmidt, 2003; Jackson, 2005). Policies, programs and infrastructure implemented aim to target convenience, environmental knowledge, economics, and culture for enacting specific behaviour changes in the population, the associated studies targeting these are presented in Table 1-2: Pro-environmental policy intervention research topics and studies that covered them.

Table 1-2: Pro-environmental policy intervention research topics and studies that covered them

PEB Policy Intervention Topics	Studies Covering the Topic
Convenience	Domina & Koch, 2002 Zhang, Zhang, Yu, & Ren, 2016 Hage, Söderholm, & Berglund, 2009 Miafodzyeva & Brandt, 2013 Saphores, Ogunseitan, & Shapiro, 2012

	Amutenya, Shackleton, & Whittington-Jones, 2009 Li, Zhao, Ma, Shao, & Zhang, 2019 Steinhorst, Klöckner, & Matthies, 2015 Silvi & Padilla, 2021 Imas, Sado, & Samek, 2016 De Quidt, 2017 Ghesla, Grieder, Schmitz, & Stadelmann, 2019 Pigou, 1920 Engel, Pagiola, & Wunder, 2008 Felder & Schleiniger, 2002 Stephan & Paterson, 2012
Environmental knowledge	Kollmuss & Agyeman, 2002 Chawla, 1998/99 Preuss, 1991
Economics	Andor, Gerster, Peters, & Schmidt, 2017 Ghesla, Grieder, Schmitz, & Stadelmann, 2019 Ackermann, 1997 Kollmuss & Agyeman, 2002 Filippini, 2011 Silvi & Padilla, 2021
Culture	Jamison, 2001 Valkering, Beumer, de Kraker, & Ruelle, 2013 Agovino, Crociata, & Luigi Sacco, 2016

(Compiled by author)

Convenience is utilized in policy by providing infrastructure and programming that eases the burden of pro-environmental behaviour. For example, rather than asking homeowners to compost their organic materials a region will provide a green bin pickup service. Environmental knowledge is promoted through outreach such as educational campaigning, visiting schools, and running events. Economics is addressed through financial incentives or penalty programs. Addressing culture through policy is more abstract, but these changes have succeeded in grassroots advocacy programs. Typically, these movements result from dissatisfaction within a community and are led by local

advocacy groups or Non-governmental Organizations. The role of the government in this context is their response to these movements and encouragement for activism, and appropriate responses improve social trust, institutional trust and social networks- which in turn improves compliance within the community (Coleman, 1990; Putnam, 1993; Li, Zhao, Ma, Shao, & Zhang, 2019). Stronger support and compliance for public policy within a community reduce the government's cost and effort for monitoring and enforcing programs (March & Olsen, 2004; Jagers, Harring, & Matti, 2018). Policymakers and program designers successfully promote sustainable lifestyles when they clearly understand the determinants of pro-environmental behaviour within their unique context (Silvi & Padilla, 2021).

1.2.1.4.5.1 Targeting Convenience

Convenience-based programs are the implementation of infrastructure that eases the effort for an individual to behave pro-environmentally. For recycling and composting, convenience is considered a top priority in infrastructure development (Domina & Koch, 2002; Zhang, Zhang, Yu, & Ren, 2016). These programs create convenience for recycling, yard waste, and compost pickup schedules and decrease the convenience of garbage pickup schedules (Hage, Söderholm, & Berglund, 2009; Miafodzyeva & Brandt, 2013; Saphores, Ogunseitan, & Shapiro, 2012). Additionally, these programs work to implement available facilities that accommodate the desired scheduling (Amutenya, Shackleton, & Whittington-Jones, 2009; Steinhorst, Klöckner, & Matthies, 2015; Zhang, Zhang, Yu, & Ren, 2016; Li, Zhao, Ma, Shao, & Zhang, 2019). Other convenience-based programs include public transportation. Individuals will find it more convenient to take public transportation over personal vehicles in a well-done system. In this case, a person does not even need to be motivated by biospheric values; instead, they can choose this pro-environmental behaviour based on convenience alone (Kollmuss & Agyeman, 2002).

1.2.1.4.5.2 Targeting Environmental Knowledge

Despite research determining the ineffectiveness of educational campaigns, many governments and environmental Non-governmental Organizations are basing communication campaigns on increasing environmental awareness and knowledge (Kollmuss & Agyeman, 2002). The ineffectiveness of educational campaigns to promote pro-environmental behaviour is due to the indirect nature of the topic. Direct experiences have a more decisive influence on behaviour due to emotional involvement shaping beliefs, values, and attitudes toward the environment (Chawla, 1998; Chawla, 1999).

Environmental degradation, which drives the need for pro-environmental behaviour, is a gradual and complex process that often cannot be experienced directly (Preuss, 1991). Therefore, any education campaign will be constrained by the indirect dissemination of knowledge (Kollmuss & Agyeman, 2002).

While research has highlighted the ineffectiveness of educational campaigns in influencing pro-environmental behaviours (Kollmuss & Agyeman, 2002), environmental communication is still essential in garnering support and trust from communities. In a study by Kronrod et al. (2023), they state that communication is key for individuals to adopt pro-environmental behaviorus, but can only be effective if the messaging is tailored to the audiences level of knowledge. Therefore, communicators need to consider segmenting the population by education level in communication dissemination (Kronrod, Tchetchik, Grinstein, Turgeman, & Blass, 2023).

1.2.1.4.5.3 Targeting Economics

A complex but standard method for enacting behavioural change is incentives. Adequately designed incentives provide an alternative behaviour that avoids specific barriers or prevents continued undesired behaviours by creating barriers (Ghesla, Grieder, Schmitz, & Stadelmann, 2019). Incentives are either framed as gain-based, rebates, or loss-based, taxes. Gain-based incentives are viewed as favourable by the public because they are enabled to perform actions, they have not previously been able to do. These methods have been shown to improve the pro-environmental behaviours of individuals, but they face limitations and cannot alone provide long-term substantial behavioural change (Silvi & Padilla, 2021). In respect to gain-based incentives, participation is limited to individuals who already have a desire to act pro-environmentally but are limited by finances- which, while still positive, neglects a significant portion of the population. Plus, bureaucratic processes can drag down the process of implementing these programs when looking to allocate money to incentive programs (Stephan & Paterson, 2012; Ghesla, Grieder, Schmitz, & Stadelmann, 2019). Loss-based incentives are polarising since they prevent individuals from performing behaviours they would otherwise prefer to do. For example, if policymakers want individuals to reduce their energy consumption, they introduce surge pricing at certain times of the day (Pigou, 1920). There is hesitancy to implement loss-framed incentives, such as taxes, due to the historical dislike the public feels toward them (Engel, Pagiola, & Wunder, 2008; Felder & Schleiniger, 2002).

The discourse surrounding loss-framed incentives is not always substantiated in all applications. Multiple studies have found that in comparing loss-framed and gain-framed incentives, there were no higher attrition rates observed in participants randomly assigned to the loss-frame (Imas, Sado, & Samek, 2016; De Quidt, 2017; Ghesla, Grieder, Schmitz, & Stadelmann, 2019). These results are subjective to the application of the incentives. Studies by Filippini (2011), Ghesla, Grieder, Schmitz and Stadelmann (2019), and Silvi and Padilla (2021) found that loss-framed incentives are the most successful tool in reducing electricity consumption. The households in their studies were highly responsive to off-peak and high-peak energy prices and adapted their energy use accordingly (Filippini, 2011; Silvi & Padilla, 2021; Ghesla, Grieder, Schmitz, & Stadelmann, 2019). Additionally, gasoline taxes effectively encourage green transportation over personal vehicle use in locations where robust public transportation exists (Von Weizaecker & Jesinghaus, 1992; Kollmuss & Agyeman, 2002). On the other hand, water tariffs implemented did not significantly impact conservation behaviours (OECD, 2009; Silvi & Padilla, 2021). Also, gasoline taxes in locations with limited public transportation, only served to increase financial strain and unrest. In a paper by Kollmuss and Agyeman (2002), they discuss the discrepancy in the effectiveness of disposable bag fees. Their discussion notes the ineffectiveness of a disposable bag fee program implemented by Ackermann (1997). The authors compare those results to another program where the disposable bag fee program caused supermarkets to redesign and reduce their packaging to a minimum level causing a significant per capita reduction of garbage waste (Kollmuss & Agyeman, 2002). These findings note the importance of highly tailored programming to a specific region and culture. The acceptance of loss-framed incentives and the effectiveness of gain-based incentives are highly dependent on the public's perceived value of those programs.

1.2.1.4.5.4 Targeting Culture

Social movements have been considered a powerful tool for governments to drive social and cultural perspectives on environmental preservation (Jamison, 2001). Stemming from dissatisfaction within a community and led by local advocacy groups or Non-governmental Organisations, these movements are an opportunity for social good rather than a political challenge. While the policy and infrastructure are not directly involved at the beginning of these movements, they have the power to support and encourage them. From an infrastructure perspective, providing space, resources and availability for discourse and planning are essential. Once these have been provided, collaborative opportunities between public-private partnerships are opened for integrative aspects of other

socioeconomic inequality (Valkering, Beumer, de Kraker, & Ruelle, 2013). These relationships and collaboration cause the exchange of co-produced pro-socially useful knowledge and practices (Agovino, Crociata, & Luigi Sacco, 2016). Then leadership responses and policy actions instill individuals with trust, further enabling cultural shifts in values (Coleman, 1990; Putnam, 1993; Li, Zhao, Ma, Shao, & Zhang, 2019).

1.2.1.5 Interconnectivity of Influence

To date, a robust body of research discusses internal and external influences on pro-environmental behaviour. Figure 1-2: The breakdown of influences on pro-environmental behaviour shows the categorization of internal and external influences on pro-environmental behaviour. The effectiveness of internal versus external influences varies from study to study, and many conclusions contradict one another. This is possibly due to the lack of discussion surrounding the interconnectivity between influences. There is room to expand on Figure 1-2: The breakdown of influences on pro-environmental behaviour to integrate potential interconnections between the various influences. In aiming to produce a more integrated framework, the primary interconnections between influences are vital to identify. Discussing how an individual's external environment influences internal motivations is a strong starting point. Some of the papers outlined note how the various external factors discussed can impact an individual's internal motivations and values. Policy (Wang & Mangmeechai, 2021; Silvi & Padilla, 2021), culture (Wang, Van der Werff, Bouman, Harder, & Steg, 2021), and social norms (Hage, Söderholm, & Berglund, 2009; Söderholm, 2011; Li, Zhao, Ma, Shao, & Zhang, 2019) are the predominate external factors discussed in connection to internal motivations and values.

The discussion of policy influencing an individual's internal motivations and values consists of perceived policy effectiveness. In cases where policy is considered influential, an individual's behavioural intentions, implementation intentions, and pro-environmental behaviours were more receptive to internalizing the rationale behind an intervention (Wang & Mangmeechai, 2021; Silvi & Padilla, 2021). Cultural values shaping an individual's motivation and values are discussed from the perspective of group identity. Wang, van der Werff, Bouman, Harder, and Steg (2021) propose that perceived group biospheric values can represent the individuals' pre-existing values, and group values can then strengthen and reinforce those personal values (Wang, Van der Werff, Bouman, Harder, & Steg, 2021). These findings assume that a group's biospheric values are related to pro-environmental behaviour, but this relationship was only present within collectivistic groups (Wang, Van der Werff,

Bouman, Harder, & Steg, 2021). Social norms impacting an individual's motivations and values have the most robust discussion within the literature. Papers by Hage, Söderholm, and Berglund (2009), Söderholm (2011), and Li, Zhao, Ma, Shao, and Zhang (2019), discussed the internalization of social norms by an individual. Hage, Söderholm, and Berglund (2009) termed this internalization as 'norm activation' and discuss them as significant predictors of recycling behaviour intentions. Li, Zhao, Ma, Shao, and Zhang (2019) reiterate this concept by discussing the potential indirect impact social norms have on recycling behaviour. Söderholm (2011) then focuses more intently on using policy relevant to preexisting social norms to promote a moral obligation in policy participation.

1.2.1.6 Models of Analysis

Within the research discourse, many different models of analysis have been proposed and employed. Fietkau and Kessel (1981) first applied sociological and psychological factors to explain the mechanisms behind an individual behaving pro-environmentally. Their focus was on the individual's attitudes and values, and they found that positive reinforcement was influential in encouraging continued ecological behaviours (Fietkau & Kessel, 1981). Then, Hines, Hungerford, and Tomera (1986) published their Model of Responsible Environmental Behavior, which was based on the Theory of Planned Behaviour (TPB) by Ajzen and Fishbein (1980). The Theory of Planned Behaviour is based on behaviours being guided by rational evaluations of behavioural consequences through the assumption that people are motivated to avoid punishments and to seek rewards (Bamberg & Moser, 2007). The Model of Responsible Environmental Behavior was the launching point for subsequent researchers to integrate TPB into their research frameworks (Bamberg & Moser, 2007; Nguyen, Nguyen, & Hoang, 2019; Wang & Mangmeechai, 2021). Additional models for analysis include norm activation models (Schwartz, 1977; Harland, Staats, & Wilke, 1999; Bamberg & Moser, 2007; Söderholm, 2011). Norm activation models are the process of integrating moral norms into an individual's values. Harland, Staats, and Wilke (1999) found moral norm inclusion to raise the proportion of explained variance of intention by 1–10% (Harland, Staats, & Wilke, 1999; Bamberg & Moser, 2007). Brueckner (2003) proposed integrating spillover theory with a resource flow model (Agovino, Crociata, & Luigi Sacco, 2016). Spillover considers the possibility of one behaviour catalyzing subsequent similar behaviours. The use of spillover in a resource flow model allowed researchers to account for the flow of behaviours of an individual. In two studies by Anselin (2002), they used a neighbouring agent model to determine if an agent will recycle after the recycling behaviour of other neighbouring agents is taken into account (Anselin, 2002b; Anselin, 2002a).

1.2.2 Pro-Environmental Behaviour Spillover

Behavioural spillover is a causal effect one behaviour can have on completing another related behaviour (Nash, et al., 2017; Galizzi & Whitmarsh, 2019). Pro-environmental spillover is the process of one pro-environmental behaviour initiating subsequent pro-environmental behaviours and is extensively explored within the literature (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009; Steinhorst, Klöckner, & Matthies, 2015). For example, if individuals start to recycle, they are more likely to begin composting if their region offers both blue and green bin pickup (Thøgersen & Ölander, 2003). Much of pro-environmental research is limited by only considering the effects of an intervention on targeted pro-environmental behaviours. This narrow approach misses out on examining the effects of non-targeted behaviours, and behavioural spillover enables research to explore those outcomes (Maki, et al., 2019). Academically, pro-environmental spillover provides a deeper context to the complex behavioural ecology of an individual's lifestyle changes by examining holistic relationships between behaviours (Geller E. S., 2001; Schatzki, 2010; Galizzi & Whitmarsh, 2019). Behavioural spillover is not only valuable in the context of research, but it also provides unique and essential insights for policy. From the policy perspective, behavioural spillover potentially shows the methodology of changing behaviours cost-effectively with little regulation (Galizzi & Whitmarsh, 2019). Studies such as Sintov et al. (2019), Liu et al. (2021) and Xu et al. (2018) - found evidence of spillover between composting, recycling, energy conservation and water-saving (Sintov, Geislar, & White, 2019; Xu, Zhang, & Ling, 2018; Liu, Kua, & Lu, 2021).

Spillover is a process that can result in positive or negative secondary effects on non-targeted behaviours (Carrico, 2021). Positive and negative behavioural spillover is an area of social sciences research commonly applied to pro-environmental behaviour research (Nash, et al., 2017; Manika, Antonetti, Papagiannidis, & Guo, 2021). Positive spillover is the influential mechanism researchers and policymakers are focused on when discussing catalyzing spillover. Research has demonstrated that one particular pro-environmental behaviour can increase the likelihood of an individual performing other kinds of pro-environmental behaviour (Bratt, 1999; Stern, Dietz, Abel, Guagnano, & Kalof, 1999; Thøgersen & Ölander, 2003; Thøgersen, 2004; Steinhorst, Klöckner, & Matthies, 2015). Negative spillover is the form of spillover resulting in any additional undesired behaviours. Negative spillover can result in one undesired activity causing additional undesired behaviours (Nilsson, Bergquist, & Schultz, 2017). Alternatively, negative spillover can be the effect of a positive behaviour causing a 'licencing effect' on an individual, where a person permits themselves to do

something “bad” because they have already done something good (Merritt, Effron, & Monin, 2010; Maki, et al., 2019; Nilsson, Bergquist, & Schultz, 2017).

The outcome of positive spillover desired by researchers and practitioners is strongly contingent on circumstances (Thøgersen & Crompton, 2009). Catalyzing and measuring pro-environmental behavioural spillover has proven to be challenging in studies with varying results (Galizzi & Whitmarsh, 2019). Studies agree that the framing of an initial pro-environmental behaviour is significant in triggering spillover (Cornelissen, Dewitte, Warlop, & Yzerbyt, 2007; Cornelissen, Pandelaere, Warlop, & Dewitte, 2008; Evans, et al., 2013). Interventions by Evans et al. (2013), and Steinhorst, Klöckner, and Matthies (2015) found that promoting pro-environmental behaviour monetarily limits positive spillover effects (Evans, et al., 2013; Steinhorst, Klöckner, & Matthies, 2015). Instead, Steinhorst, Klöckner, and Matthies (2015) found that framing pro-environmental behaviour through environmental conservation produced positive spillover in the case of an individual having climate-friendly intentions. Additional research has also noted that the greater the similarity of the activities, the more substantial the likelihood of behavioural spillover (Thøgersen, 2004).

Analyzing spillover has been done by using cognitive dissonance theory (Festinger, 1957; Gawronski, 2012; Thøgersen & Crompton, 2009; Nilsson, Bergquist, & Schultz, 2017), and self-perception theory (Bem, 1972; Cornelissen, Dewitte, Warlop, & Yzerbyt, 2007; Nilsson, Bergquist, & Schultz, 2017). Cognitive dissonance theory assumes that behaviours that are inconsistent with an individual’s cognitions or behaviours will lead to discomfort, which motivates strategies to alleviate those feelings of discomfort (Festinger, 1957; Gawronski, 2012). The theory is applied by assuming that people want to avoid the unpleasant feeling of behaving inconsistently across different pro-environmental behaviours. Although, the process has been shown to be inconsistent due to an individual’s ability to mitigate the feelings of discomfort through other means, such as changing their attitudes (Thøgersen & Crompton, 2009; Nilsson, Bergquist, & Schultz, 2017). Self-perception theory predicts an individual to use their prior behaviour when forming attitudes, values, and norms (Bem, 1972). When applied to pro-environmental behaviour, individuals who described their past behaviours as pro-environmental were more likely to have a stronger moral obligation to perform subsequent pro-environmental behaviours (Cornelissen, Pandelaere, Warlop, & Dewitte, 2008).

Chapter 2
Household pro-environmental behaviour impacts and their relationship to insurance claim frequency and severity

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Abstract: Insurance companies are considering a rate reduction for homeowners displaying pro-environmental behaviours. To justify the decision, the link between pro-environmental behaviour and risk-mitigating behaviour needs to be validated statistically and affirmed within the broader academic research. This study investigates if pro-environmental behaviours spillover into risk-mitigating behaviours using regression and multivariable analysis of a dataset linking environmental behaviours with insurance claims. The analysis failed to identify a clear link between pro-environmental and risk-mitigating behaviours. Instead, a need to reframe our understanding of pro-environmental behaviour mechanisms was revealed. The analysis found that at a community level data resolution, the age, income, education, or place of residence do not influence the PEBs of an individual. Plus, the intentions of an individual do not reflect the reality of their behaviour. Therefore, focusing on influencing pro-environmental behaviour through internal motivations does not guarantee a subsequent behaviour change either. Considering both results, evaluating the PEB of an individual through isolating external or internal influences will not produce results reflective of reality. Rather, intentions or motivations mediate between infrastructural, relational, or cultural barriers/resources and actual behaviour. The paper then makes six recommendations for future research to integrate and expand on these findings.

Keywords: pro-environmental behaviour, insurance claims, spillover, multi-regression analysis, household behaviour

2.1 Introduction

Climate change's effect on insurance premiums is an emerging research topic. Regarding flood risk alone, home insurance premiums for Canadians increased from 20% to 25% between 2015 and 2019 (Bakos, Feltmate, Chopik, & Evans, 2022). Homeowners are financially vulnerable as insurance rates will continue to rise with increased risk of exposure to climate change impacts (Chopik, 2019). The annual amount of money insurance companies spent on climate change-related damages has quadrupled from the 1983 to 2008 average of $422 million to a $2 billion average between 2009 and 2020 (Rosanes, 2021). These extreme losses have already spurred the insurance industry's transformation (Malloy & Sylvester, 2010). The predicted increase in losses over the next ten years and beyond is expected to continue to drive profound, transformative change in Canada's insurance industry (McCaffery, 2022). Canada's aging infrastructure was primarily designed to anticipate historic, moderate weather events and smaller populations (McCaffery, 2022). Therefore, Canada is unprepared for the projected future impacts of climate change. Damages to buildings and infrastructure are expected to increase as infrastructure ages and areas deemed high-risk spread across the country. Financial losses with average annual severe weather claims paid by insurers in Canada are expected to double from $2.1 billion in 2020 to $5 billion in 2030 (Kovacs, 2020). Along with increased insurance rates, insurance companies are predicted to withdraw property coverage in areas deemed too costly or avoid insuring certain risks altogether if circumstances do not change (Rosanes, 2021).

Individuals and private households have been recognized as essential players in mitigating the effects of climate change through environmentally conscious behaviours, known as pro-environmental behaviours (PEB) (Oskamp, 2000). For example, in the United States, researchers have determined that through behavioural changes alone, CO2 emissions can be reduced by 20% within ten years (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009; Steinhorst, Klöckner, & Matthies, 2015). On a personal level, individuals and private households can take proactive actions to reduce risk exposure to climate-related hazards, especially regarding flood prevention and storm preparation. Insurance companies are looking at reducing rates to those displaying pro-environmental behaviours. However, the link between pro-environmental behaviour and risk-mitigating behaviour has not been established statistically or within the current research.

Pro-environmental behaviours are subject to various influences that serve as motivators or barriers (Carrus, Bonaiuto, & Bonnes, 2005; Steg & Vlek, 2009; Gifford & Nilsson, 2014; Takahashi & Selfa, 2014; Kollmuss & Agyeman, 2002). These influences affect an individual's commitment toward completing the activity and the likelihood of doing subsequent PEBs or risk-mitigating behaviours. Behavioural spillover theory is the process of performing one behaviour resulting in subsequent behaviours, such as recycling behaviours spilling over into composting behaviours (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009; Steinhorst, Klöckner, & Matthies, 2015). Behavioural spillover theory offers a mechanism for significant impact by catalyzing broad lifestyle changes from one behaviour to another (Nash et al., 2017). Therefore, understanding the execution of PEBs should not be perceived as the result of complete individual analysis; rather is sensitive to the domain of an array of socio-spatial analyses (Agovino, Crociata, & Luigi Sacco, 2016). However, a gap in research exists connecting pro-environmental behaviour spillover into risk-mitigating behaviours and the subsequent potential impacts this could have on insurance rates. The research within this study aims to bridge that gap by determining the relationship between pro-environmental behaviour and risk-mitigating behaviours through understanding the determinants and relationships of behaviours. Results offer policymakers and insurance companies important insights to promote more sustainable lifestyles (Silvi & Padilla, 2021).

2.2 Research Objectives and Questions

This study investigates if pro-environmental behaviours spill over into risk-mitigating behaviours. Considering that studies found evidence of behavioural spillover between composting, recycling, energy conservation and water-saving (Sintov, Geisler, & White, 2019; Xu, Zhang, & Ling, 2018; Liu, Kua, & Lu, 2021), we hypothesize similar pro-environmental behaviours spilling over into risk-mitigating behaviours at a household level. Currently, no studies have been identified examining the relationship between pro-environmental and risk-mitigating behaviours and the potential benefits for insurance companies. Supporting research questions include:

7. What variables drive pro-environmental behaviour?
8. Do internal or external influences of pro-environmental behaviour correlate with household insurance claims?
9. Is there a relationship between pro-environmental behaviour and risk-mitigating behaviour due to behavioural spillover?

2.3 Literature Review

Environmental degradation can be addressed in part through human behaviour and the transition to pro-environmental behaviours (Oskamp, 2000). Pro-environmental behaviour is the action of an individual consciously aiming to minimize their environmental impacts (Kollmuss & Agyeman, 2002; Wang & Mangmeechai, 2021). These activities cover behaviours that "harm the environment as little as possible or even benefit the environment" (Steg & Vlek, 2009; Steinhorst, Klöckner, & Matthies, 2015; Kollmuss & Agyeman, 2002). Pro-environmental actions can consist of conscious and proactive behaviours to be more environmentally friendly, such as energy conservation (Sparks & Shepherd, 1992), or culturally standard behaviours, such as recycling (Whitmarsh & O'Neill, 2010). These actions can be done to minimize the health risk to self, others, next generations, other species, and whole ecosystems (Bamberg & Moser, 2007).

In 1981, Liere and Dunlap published their study analyzing the different measurement types of environmental concerns and the consistency of measurement methods and results (Liere & Dunlap, 1981). Their study addressed growing concern for the environment and the emerging research which applied behavioural studies to environmentally friendly behaviour. Studies around this time applied behaviour studies to environmental concerns through the analysis of electricity conservation (Slavin, Wodarski, & Blackburn, 1981) or water conservation (Geller, Scott, Erickson, & Buttram, 1983). Also, in 1981, Fietkau and Kessel published a paper using sociological and psychological factors to explain the presence of environmentally conscious behaviours. Their analysis focused on the attitudes and values of individuals, including a model of potential variables that can directly or indirectly influence an individual to behave with environmental preservation in mind. Before the 1980s, behavioural studies considered acting environmentally friendly as examples in their research, but it was never the focal point (Tajfel & Turner, 1979).

Hines, Hungerford, and Tomera formalized the topic of pro-environmental behaviour in 1986 through a model of environmental behaviour built from a list of 128 primary studies which assessed variables associated with environmentally friendly behaviour (Hines, Hungerford, & Tomera, 1986-87; Bamberg & Moser, 2007). Their work analyzed the intentions behind behaviour and objective situational factors as determinates in a person acting “pro-environmentally.” The study assessed this by focusing on the association between five “psychosocial variables,” attitude, locus of control/self-efficacy, moral responsibility, behavioural intention, and pro-environmental behaviour. Hines,

Hungerford, and Tomera (1986) formalized the groundwork for subsequent research to expand on for the next 20 years.

Initially, research focused heavily on the influence of internal motivations on pro-environmental behaviour, presented in row one of Table 2-1: Pro-environmental behaviour research topics and studies that covered them for a compiled list of studies discussing this topic. Then, in the early 2000s, research expanded and acknowledged a motivation-to-action gap consistently occurring, see row two of Table 2-1: Pro-environmental behaviour research topics and studies that covered them, where the motivations and desires of an individual to act pro-environmentally did not align with their actual actions. The consistency of this finding caused a pivot to focus more intently on the role of external influence within research; see row three of Table 2-1: Pro-environmental behaviour research topics and studies that covered them. External influences were acknowledged previously in research; see row three of Table 2-1: Pro-environmental behaviour research topics and studies that covered them. However, focusing on external influences became more prominent in explaining the intention-action gap.

No additional metanalysis within the field was conducted until 2007 when Bamberg and Moser (2007) compiled the updated research with modern statistical methods. Their conclusion focused on the need for more integrative internal and external influence analysis within the field (Bamberg & Moser, 2007). Since then, several studies have looked to connect internal and external motivations, see row four of Table 2-1: Pro-environmental behaviour research topics and studies that covered them. Additional studies use these connections to explain the gap between an individual's motivation and actual pro-environmental behaviours, see row five of Table 2-1.

Table 2-1: Pro-environmental behaviour research topics and studies that covered them

#	PEB Topic	Studies Covering the Topic	
1	Influence of internal motivations on pro-environmental behaviour	Borden & Francis, 1978 Wilkie, 1990 Preuss, 1991 Grob, 1991 Diekmann & Preisendoerfer, 1992 Eagly & Chaiken, 1993	Fliegenschnee & Schelakovsky, 1998 Moisander, 1998 Chawla, 1998/99 Michelsen, McGuckin, & Stumpf, 1999 Lehman, 1999

		Stern & Dietz, 1994 Fuhrer, Kaiser, Seiler, & Maggi, 1995 Staats, Wit, & Midden, 1996 Espey, Espey, & Shaw, 1997	Kaiser, Woelfing, & Fuhrer, 1999 Schultzs & Zelezny, 1999 Schultz, 2002 Kollmuss & Agyeman, 2002 Clark, Kotchen, & Moore, 2003
2	Motivation to action gap	Sheeran & Orbell, 1999 Blake, 1999	Kollmuss & Agyeman, 2002 Gollwitzer & Sheeran, 2006
3	The role of external influence	Tajfel & Turner, 1979 Liere & Dunlap, 1981 Burn & Oskamp, 1986 Cialdini, Reno, & Kallgren, 1990 Coleman, 1990 Ajzen, 1991 Putnam, 1993 Danielson, Hoban, Van Houtven, & Whitehead, 1995 Schultz, Oskamp, & Mainieri, 1995 Ackermann, 1997 Putnam, 2000 Alsmadi, 2007 Ajzen & Albarracín, 2007 Engel, Pagiola, & Wunder, 2008 Hage, Söderholm, & Berglund, 2009 Brécard, Hlaimi, Lucas, Perraudeau, & Salladarré, 2009 Amutenya, Shackleton, & Whittington-Jones, 2009 Sidique, Joshi, & Lupi, 2010 Feygina, Jost, & Goldsmith, 2010 Scannell & Gifford, 2010 Filippini, 2011	Jamison, 2001 Steg, Vlek, & Slotegraaf, 2001 Kollmuss & Agyeman, 2002 Kemmelmeier, Król, & Kim, 2002 Gosken, Adaman, & Zenginobuz, 2002 Domina & Koch, 2002 Felder & Schleiniger, 2002 Greunz, 2003 Bamberg & Schmidt, 2003 Dupont, 2004 Torgler & García-Valiñas, 2005 Jackson, 2005 Takahashi & Selfa, 2014 Clark, 2014 Botetzagias, Dima, & Malesios, 2015 López-Mosquera, Lera-López, & Sánchez, 2015 Han, 2015 Kyriacou, Muinelo-Gallo, & Roca-Sagalés, 2015 Crociata, Agovino, & Sacco, 2015 Steinhorst, Klöckner, & Matthies, 2015

		Saphores, Ogunseitan, & Shapiro, 2012 Markowitz, Lewis, Goldberg, Ashton, & Lee, 2012 Basile, Capello, & Caragliu, 2012 Laidley, 2013 Valkering, Beumer, de Kraker, & Ruelle, 2013 Graham-Rowe, Jessop, & Sparks, 2014	Imas, Sado, & Samek, 2016 Agovino, Crociata, & Luigi Sacco, 2016 Zhang, Zhang, Yu, & Ren, 2016 De Quidt, 2017 Ifegbesan & Rampedi, 2018 Jagers, Harring, & Matti, 2018 Li, Zhao, Ma, Shao, & Zhang, 2019 Ghesla, Grieder, Schmitz, & Stadelmann, 2019 Silvi & Padilla, 2021
4	Internal and external motivations connectivity	Fife-Schaw, Sheeran, & Norman, 2007 Welsch & Kühling, 2010 De Bruin, et al., 2012 Fan, et al., 2013 Liiu & Bai, 2014 Dixit & Badgaiyan, 2016	Fielding, et al., 2016 Zhang, Zhang, Yu, & Ren, 2016 Hanss, Böhm, Doran, & Homburg, 2016 Li, Zhao, Ma, Shao, & Zhang, 2019 Wang & Mangmeechai, 2021
5	Internal and external connectivity in motivation to action gap	Van der Bergh, 2008 Sidique, Joshi, & Lupi, 2010 Turaga, Howarth, & Borsuk, 2010 Miafodzyeva & Brandt, 2013 Van der Werff, Steg, & Keizer, 2013 Kirakozian, 2016	Liobikienė, Mandravickaitė, & Bernatonienė, 2016 Agovino, Crociata, & Luigi Sacco, 2016 Li, Zhao, Ma, Shao, & Zhang, 2019 Silvi & Padilla, 2021

(Compiled by author)

Overall research discusses how many factors play an essential role in an individual behaving pro-environmentally (Carrus, Bonaiuto, & Bonnes, 2005; Steg & Vlek, 2009; Gifford & Nilsson, 2014; Takahashi & Selfa, 2014). Influences on pro-environmental behaviour have been studied due to their ability to shape an individual's actions toward the desired outcome. By thoroughly understanding the mechanisms influencing an individual's actions, behaviours can be targeted effectively and efficiently. Influences on pro-environmental behaviour work both as catalysts to action and barriers.

Blake (1999) breaks down barriers taking the forms of individuality, responsibility, and practicality (Blake, 1999). Individual barriers are internalized attitudes and temperaments towards a behaviour. These barriers can vary from day to day. Responsibility barriers can be internal and external to an individual, referring to internalized moral responsibilities or external motivations, such as job expectations or family needs. Practical barriers take the form of external social and institutional constraints that can prevent individuals from acting pro-environmentally, regardless of their attitudes or intentions (Blake, 1999; Kollmuss & Agyeman, 2002). An individual's responses to barriers are discussed through a low-cost/high-cost model (Diekmann & Preisendoerfer, 1992), which frames a decision to perform a behaviour being made by weighing the costs and choosing the perceived least costly option. Cost, in this context, does not entirely refer to the financial cost; rather, in a broader sense, it includes the time, effort and moral motivation needed to undertake pro-environmental behaviours (Kollmuss & Agyeman, 2002). For example, a large majority of individuals value environmental preservation but hold skepticism surrounding the potential for individual behaviour to sufficiently mitigate the problems we face, reducing the moral motivation behind acting pro-environmentally (Crompton, 2008; Jackson, 2009; Nilsson, Bergquist, & Schultz, 2017).

All these discussion areas can be categorized into the influences of an individual's internal and external motivations on acting pro-environmentally. The effectiveness of internal versus external influences varies from study to study, and many conclusions contradict one another. Studies have documented limitations to the robustness of internal and external influences (Silvi & Padilla, 2021). These conflicting results and limitations suggest a potential gap in research regarding analyzing the overlap and interconnectivity of internal and external influences and how they shape pro-environmental behaviours. A recent study by Silvi and Padilla (2021) notes that studies that account for the integrative influence of internal and external influences are rare. They describe pro-environmental research to date as being studied as one of two potential frames. The first framing is pro-environmental behaviour as the result of internal moral deliberation without acknowledgement of an individual's external context (Heberlein, 1981; Black, Stern, & Elworth, 1985; Hopper & Nielsen, 1991; Grodzinska-Jurczak, 2003; Bamberg & Moser, 2007; Sidique, Joshi, & Lupi, 2010; Liobikienė, Mandravickaitė, & Bernatonienė, 2016). The second research framing is that pro-environmental behaviour is the automatic response to an external stimulus regardless of an individual's values (Jacobs & Bailey, 1983; Palmer & Walls, 1997; Linderhof, Kooreman, Allers, & Wiersma, 2001; Ferrara & Missios, 2005). These assumptions neglect heterogeneity across individuals' values,

responsibilities, knowledge, relationships, and finances, which will influence various potential behavioural outcomes in a singular intervention (Silvi & Padilla, 2021).

A significant gap in research exists discussing any other potential interconnections between influences. Connections between socio-demographic factors and internal influences need to be improved in discourse. Also, there is room for more thorough discussions exploring the influence of institutions and location on environmental knowledge and personal experience. A final research gap exists in how internal motivations impact external motivations. No studies consider how one's internal value system or motivations can shape their external world and how that connects to pro-environmental behaviour. This study addresses these gaps through a household Pro-Environmental Behaviour Index ($PEBI_h$) that scores internal and external motivations and outward actions. Additionally, it views the feedback of institutions and households through the relationship between $PEBI_h$ and insurance claims.

2.4 Methods

The study consisted of four core steps to determine a relationship between pro-environmental and risk-mitigating behaviours; (1) pro-environmental behaviour data is collected, and the index of a household is calculated, (2) insurance claim frequency and severity data are collected, and both the pro-environmental behaviour and insurance data are aggregated by a common variable, (3) statistical analysis is done on the pro-environmental and insurance claim data to determine if a relationship between them exists, and (4) multiple variable analysis is done on household characteristics and behaviours to determine any additional influences on pro-environmental behaviours.

2.4.1 Geographic and Temporal Scale

This research study uses data from the Nova Scotia Quality of Life Survey conducted in the spring of 2019 and carried out by researchers with the Canadian Index of Wellbeing (CIW) at the University of Waterloo. A stratified random sample of residents across the province was drawn based on ten distinct regions (see Figure 2-1: The distinct regions in Nova Scotia). Potential participants were contacted using two different approaches to encourage participation.

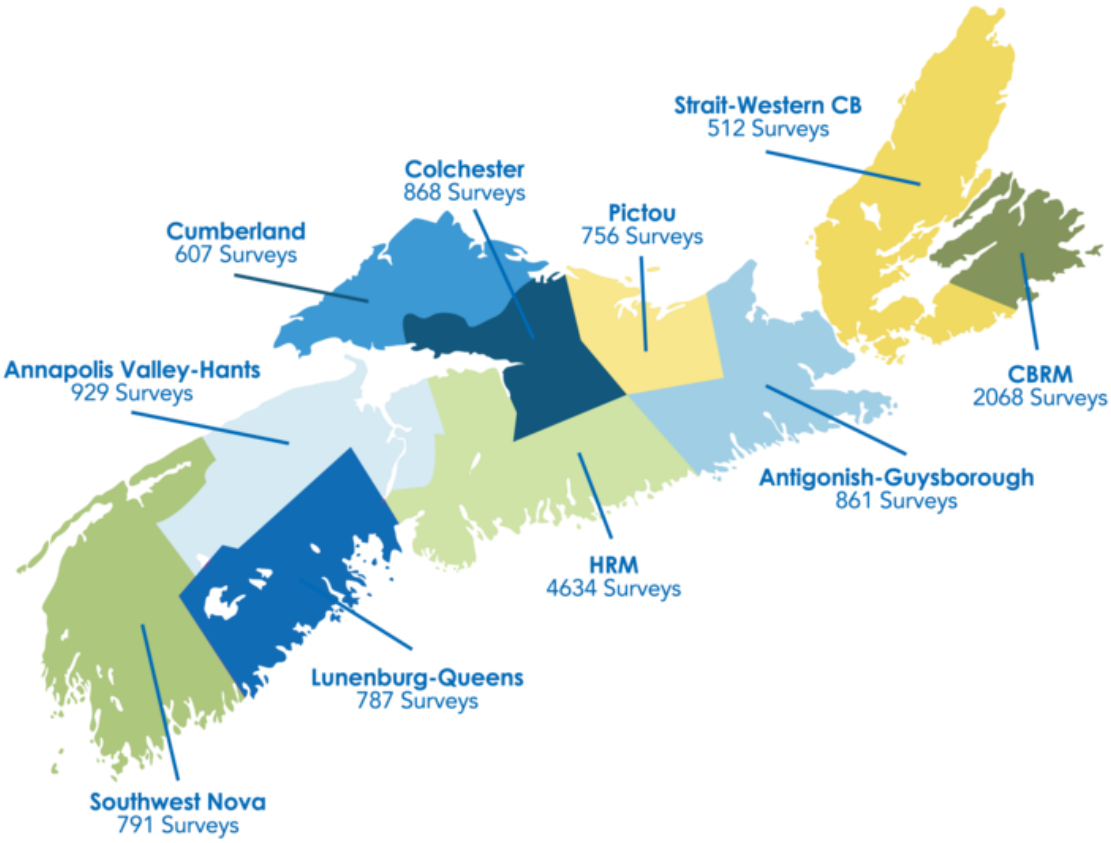

Figure 2-1: The distinct regions in Nova Scotia

The first approach involved sending a personalized letter to over 80,000 randomly selected households inviting the person in the household (at least 16 years of age) whose birthday fell closest to June 1 to go to a website. The second approach involved a targeted outreach to specific populations that might not typically have similar opportunities to complete a questionnaire using traditional survey methods (e.g., persons with disabilities, immigrants, refugees, seniors, low-income persons, and younger persons). The more rural regions of the province were oversampled during the random selection of households to ensure that residents who reside in smaller communities and outlying areas were sufficiently represented. Potential participants were offered the option of requesting a paper version of the online survey, which was mailed to them along with a description of the study and a postage-paid return envelope. The respective analysis is based on the sample for Halifax Regional Municipality (n=4634).

The study was done in partnership with the Cooperators, a Canadian insurance company that provided insurance claim data from 2019. The data is aggregated by a common variable between the two sets to compare the insurance data with pro-environmental behaviour. The first common variable used is region type due to objective and readily available household location data. Regression analysis is carried out at two geographic scales - the forward sortation area (FSA) and the dissemination area (DA).

A forward sortation area (FSA) is a designated geographical unit based on the first three characters in a Canadian postal code. A dissemination area (DA) is a small, relatively stable geographic unit composed of one or more adjacent dissemination blocks with an average population of 400 to 700 persons based on data from the previous Census of Population Program. It is the smallest standard geographic area for which all census data are disseminated (Statistics Canada, 2016. Dictionary Census of Population 2016. Catalogue no. 98-301-X).

2.4.2 Household Pro-Environmental Behaviour Index

We identified nine questions relevant to pro-environmental behaviour under the Environmental section (D2) of the 2019 Nova Scotia Quality of Life Survey (Canadian Index of Wellbeing, 2019). An index referred to as the household PEB index ($PEBI_h$) was developed as a single representation of the total pro-environmental behaviour profile to analyze the relationship between pro-environmental behaviour and insurance claims. The index includes five categories: energy, water, food, waste, and transportation. Each category is scored out of 1, and the categories are weighted equally in the $PEBI_h$. An index score of 0 indicates no pro-environmental behaviour, and a score of 5 indicates strong pro-environmental behaviour.

Environmental behaviour-related questions were chosen, and the scoring system is presented in Table 2-2: Household pro-environmental behaviour index ($PEBI_h$) breakdown. The survey's energy, water, food, and waste categories asked respondents to answer questions using a Likert scale from “Never” to “All the time.” To build the index, the respective responses were converted to a numeric value where “Never” equaled a score of 0, “Sometimes” equaled a score of 0.25, “Regularly” equaled a score of 0.5, “Quite Often” equaled a score of 0.75, and “All the time” equaled a score of 1. See Table 2-2: Household pro-environmental behaviour index ($PEBI_h$) breakdown for a summary of how PEB categories were calculated. The waste category was derived based on three questions: recycling habits, waste reduction efforts, and separation efforts. In this case, the average value of the three

scores was used in the $PEBI_h$. The transportation category PEB score was based on the question what is your primary method of transportation to get around the community? We assigned a score of 1 if the primary method of transportation was "Biking," "Walking," or "Public Transit," and a score of 0 if the answer was "Personal Vehicle."

Table 2-2: Household pro-environmental behaviour index ($PEBI_h$) breakdown

Category	Question	Value Key	Value
Energy	How often in the last year did you conserve energy?	0 = Never 0.25 = Sometimes 0.5 = Regularly 0.75 = Quite Often 1 = All the time	Value of listed question
Water	How often in the last year did you conserve water?		
Food	How often in the last year did you purchase foods produced locally?		
Waste	How often in the last year did you recycle materials?		Average value of 3 listed questions
	How often in the last year did you try to reduce household waste?		
	How often in the last year did you recycle materials?		
Transportation	How often in the last year did you walk/bike rather than drive?		Took the highest score of the four listed questions
	How often in the last year did you take transit rather than drive?		
	How often in the last year did you carpool?		
		Total:	$PEBI_h$ Score

(Compiled by author)

2.4.3 Insurance Claim Frequency and Severity

The Cooperators data is aggregated by household frequency and severity scores. The insurance claim frequency (F) is the number of claims divided by the number of insurance policies. The insurance claim severity (S) is the total dollar value divided by the number of claims. To ensure data privacy,

frequency and severity are scaled by an unknown factor to "hide" the data. Additionally, a credibility index is assigned to each aggregate to describe the data confidence. This index is a score from 1-5; 1 means a very low volume of claims in that aggregate, and the frequency/severity measured are subject to "luck," while five means there is very high confidence in the frequency and severity calculated.

2.4.4 Insurance Claims and $PEBI_h$ Relationship Analysis

The aggregated $PEBI_h$ and insurance claim data are then analyzed through linear regression and regression trees. Nine methods are applied based on the aggregation variable, regression type and data manipulations. For each method, the model is built twice for the outcome variable to be modelled as frequency and severity separately. The predictor variable for each model is the $PEBI_h$. The models constructed are outlined in Table 2-3: Regression models built for analysis.

Table 2-3: Regression models built for analysis

#	Aggregation Variable	Regression Type
1	FSA	Linear
2	FSA	Tree
3	DA	Linear
4	DA	Tree
5	DA	Linear[1]
6	DA	Tree[1]
7	DA	Linear[2]
8	DA	Linear[3]
9	DA	Tree[3]

[1] Left skew adjusted • Outcome variable log-transformed (0's are dealt with by adding 1 to all outcome variables)

[2] Left skew adjusted • Outcome variable log-transformed (remove 0's) data looks at the claim and PEB relationship only in the case of a claim being made

[3] Left skew adjusted • Outcome variable log-transformed (0s are dealt with by adding 1 to all outcome variables) • Outliers: 39 possible outliers (6.2% of points are potential outliers - remove 8 pts to be within the 5% - removed eight highest residual values) • Influential Points: none found
(Compiled by author)

2.4.5 Multi-Variable and $PEBI_h$ Relationship Analysis

A regression analysis is conducted to enhance the understanding of the $PEBI_h$ with household characteristics and behaviours. The variables of interest and their potential categorical responses are listed in Table 2-4: Variables analyzed. Individual regression analysis and one multivariable regression analysis are done with all variables, where $PEBI_h$ is the outcome variable.

Table 2-4: Variables analyzed

Variable		Response Options
FSA	FSA	First three digits of postal code
Federal Government Interest Provincial Government Interest Local Government Interest	INT_FED INT_PROV INT_LOCAL	1 = No interest at all to 10 = A great deal of interest
Age	AGE	Number
Income	INCOME	1 = Under $10,000 2 = $10,000 to $19,999 3 = $20,000 to $29,999 4 = $30,000 to $39,999 5 = $40,000 to $59,999 6 = $60,000 to $79,999 7 = $80,000 to $99,999 8 = $100,000 to $119,999 9 = $120,000 to $149,999 10 = $150,000 and over
Highest level of education completed	EDUCAT	1 = Elementary school 2 = High school 3 = Post-secondary certificate, trade 4 = College diploma 5 = University degree 6 = Graduate degree
Gender	GENDER	1 = Male, 2 = Female

		3 = *Or please specify
Answer to the question “I feel I have a personal responsibility to help protect the natural environment”	ENVR_R1	1 = Very strongly disagree 2 = Strongly disagree 3 = Disagree 4 = Neutral 5 = Agree 6 = Strongly agree 7 = Very strongly agree
Answer to the question “I regularly participate in events organized by local groups to protect the natural environment”	ENVR_R2	
Self-assessed physical health	PYSHLTH	1 = Poor 2 = Fair 3 = Good 4 = Very good 5 = Excellent
Self-assessed mental health	MNTLHLTH	
Life satisfaction	LIFESAT	1 = Very dissatisfied to 10 = Very satisfied
Marital Status	MARSTAT	=Single, never married 2 = Married 3 = Living common-law 4 = Separated 5 = Divorced 6 = Widowed
Ethnic Origin	ETHNIC1	1 = British Isles 2 = Acadian 3 = French 4 = Mi’kmaq 5 = Other Indigenous 6 = African Nova Scotian 7 = Other African origins 8 = Asian origins

	9 = Middle Eastern origins 10 = Central/South American origins 11 = Western European (non-French) origins 12 = Eastern European origins 13 = Northern European origins 14 = Southern European origins 15 = American 16 = Other

(Compiled by author)

2.5 Results

The statistical analysis results on the $PEBI_h$ and insurance claim data determine whether a relationship exists. The multiple variable analysis on household characteristics and behaviours determines the level of any additional influences on pro-environmental behaviours.

2.5.1 Insurance Claims and $PEBI_h$ Relationship Analysis

For each model outlined in Table 2-3: Regression models built for analysis, the results of the linear regression relationships are as follows in Table 2-5: Linear regression model results and regression tree relationships in Table 2-6: Regression tree model results. Tables 2-5 and 2-6 show that the relationship between $PEBI_h$ and insurance claim data is not strong or nonexistent. The best r-squared is 11.8%, and regardless of data cleaning and manipulation, the r-squared of the model does not improve. The regression tree model does not identify any clear steps within the data where the tree could split. Most models' best n-split is zero, and no n-split is larger than 3. This signifies a lack of relationship throughout the data.

Table 2-5: Linear regression model results

#	Aggregation Variable	Regression Type	Outcome Variable	R-Squared
1	FSA	Linear	Frequency	0.118 (11.8%)
2			Severity	0.018 (1.8%)

3	DA	Linear	Frequency	0.002 (0.2%)
4			Severity	0.017 (1.7%)
5		Linear[1]	Frequency	0.007 (0.7%)
6			Severity	0.017 (1.7%)
7		Linear[2]	Frequency	0.023 (2.3%)
8			Severity	0.003 (0.3%)
9		Linear[3]	Frequency	0.013 (1.3%)

(Compiled by author)

Table 2-6: Regression tree model results

#	Aggregation Variable	Regression Type	Outcome Variable	Best n-split
1	FSA	Tree	Frequency	1
2			Severity	0
3	DA	Tree	Frequency	0
4			Severity	0
5		Tree[1]	Frequency	0
6			Severity	3
7		Tree[3]	Frequency	2

(Compiled by author)

When checking models' assumptions, all show to be heteroscedastic and nonlinear. Further investigation shows, with a scatter plot of the insurance claim data, the mean $PEBI_h$ and the $PEBI_h$ standard deviation, that the data within the aggregate variable is heterogeneous, as seen in Figure 2-2: Frequency and average PEBI for FSA aggregated households. Figure 2-2: Frequency and average PEBI for FSA aggregated households indicates that the chosen variables for aggregation, FSA, and DA, do not have a strong enough relationship with $PEBI_h$ for any meaningful analysis to be further derived with insurance claim data.

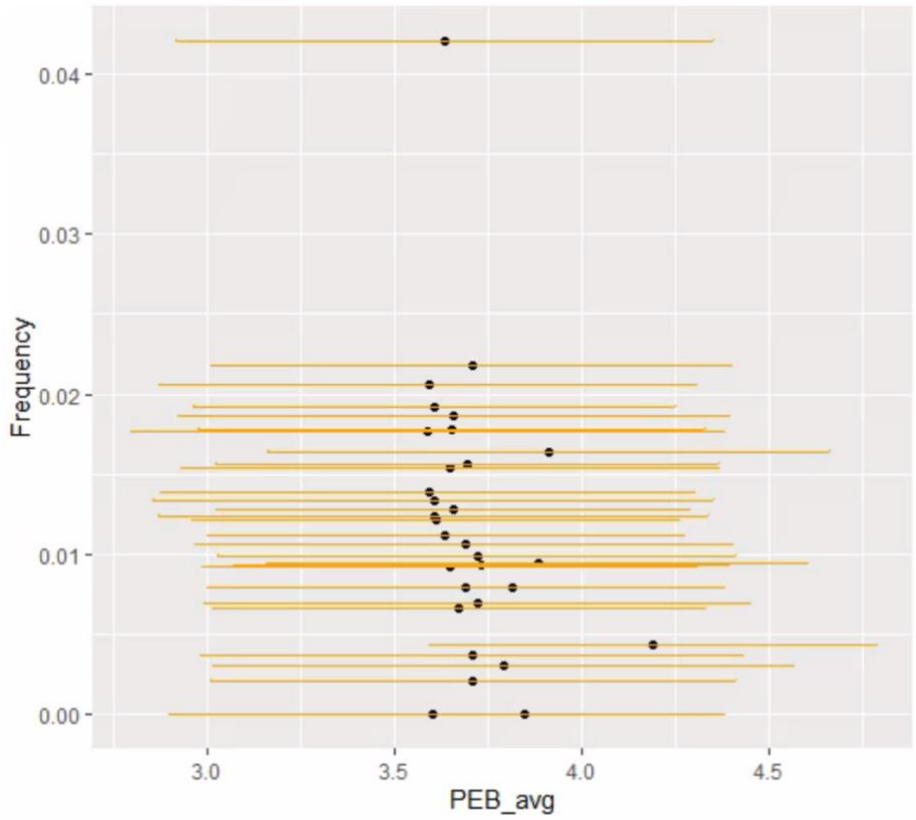

Figure 2-2: Frequency and average PEBI for FSA aggregated households

The scatter plot of insurance claim frequency and average $PEBI_h$ of an FSA. The orange lines indicate the FSA group's standard deviation, which ranges from 2.5 to 5.

2.5.2 Multi-Variable and $PEBI_h$ Relationship Analysis

The correlation coefficients from each regression analysis and the B coefficients from the multivariable regression analysis are presented in Table 2-7: Multi-variable analysis results. The results outlined in Table 2-7: Multi-variable analysis results indicate little relationship between $PEBI_h$ and most of the variables. Correlation coefficients range from -1, a strong negative relationship, to 1, a strong positive relationship; zero indicates no relationship. Similarly, while the B coefficient is not bounded between -1 to 1, the closer to zero, the weaker the relationship. If the B coefficient is zero, there is no relationship. The FSA variable shows no relationship at all, supporting the above

conclusion. Additional variables unrelated to PEB are INT_FED, AGE, INCOME, EDUCAT and ETHNIC1. All other variables have a weak positive relationship with $PEBI_h$. The most substantial relationship is between ENVR_R1 and $PEBI_h$. This shows that if a household feels a personal responsibility to the environment, they are more likely to perform pro-environmental behaviours. However, this conclusion is still weak. These results indicate that the data source or the $PEBI_h$ scoring system does not provide enough insight into a household's behaviours and cannot be confidently used in further analysis.

Table 2-7: Multi-variable analysis results

#	Variable	Singular Regression Correlation Coefficient	Multiple Regression B Coefficient
1	FSA	0.02	0.00
2	INT_FED	0.15	0.00
3	INT_PROV	0.16	0.01
4	INT_LOCAL	0.18	0.02
5	AGE	0.00	0.00
6	INCOME	0.00	-0.02
7	EDUCAT	0.10	0.00
8	GENDER	0.09	0.09
9	ENVR_R1	0.36	0.19
10	ENVR_R2	0.24	0.06
11	PYSHLTH	0.21	0.09
12	MNTLHLTH	0.17	0.04
13	LIFESAT	0.14	0.01
14	MARSTAT	0.04	0.01
15	ETHNIC1	0.02	0.00

(Compiled by author)

2.6 Discussion

The study set out to determine the relationship between environmental behaviours and risk-mitigating behaviours and hypothesized that similar pro-environmental behaviours will spill over into risk-mitigating behaviours at a household level. Through the regression and multivariable analysis, the hypothesis could not be directly accepted or rejected. The household behaviour and insurance claim data did not satisfy the assumptions of a regression model and therefore could not be directly assessed. Instead, three alternate findings were discovered. The first result shows no relationship between pro-environmental behaviours and age, income, or education. Similarly, the second result of this study finds no relationship between PEB and the location at an FSA or DA scale. The results conflict with previous research suggesting that factors such as age, income, education, and location impact the likelihood of an individual feeling motivated and able to perform pro-environmental behaviours.

Reasons for discrepancies in the results could be explained simply by concluding that the data source used in the present study is unreliable or the $PEBI_h$ scoring system does not provide enough insight into a household's behaviours. However, diving deeper into the contradicting studies, potential gaps in the research field can be highlighted through the scale variation across studies. While many studies have examined the dynamics of PEB, the majority have been done nationally or globally. The regression and multivariable analysis done in the current study lends insight into the dynamics of PEB at a fine data resolution. Of the studies with conflicting results, the scales of studies by Ifegbesan and Rampedi (2018), Brécard, Hlaimi, Lucas, Perraudeau, and Salladarré (2009), Saphores, Ogunseitan, and Shapiro (2012), Botetzagias, Dima, and Malesios (2015), and López-Mosquera, Lera-López, and Sánchez (2015) are done by comparing provinces nationally or comparing countries internationally. Studies by Kollmuss and Agyeman (2002) and Li, Zhao, Ma, Shao, and Zhang (2019) are literature review studies without any primary analysis. The lack of a relationship between PEB and the location at an FSA or DA conflicts with the results of other studies for potentially similar reasons. Studies by Ifegbesan and Rampedi (2018); Gosken, Adaman, and Zenginobuz (2002); and Agovino, Crociata, and Luigi Sacco (2016) found a relationship between the location of residence and PEB by comparing provinces at national scales or countries at international scales. Studies by Markowitz, Lewis, Goldberg, Ashton, and Lee (2012), Scannell and Gifford (2010), Takahashi and Selfa (2014), and Han (2015) looked at data with finer resolutions, focusing on towns and rural communities. However, their results showed relationships between regional identity and PEB. These

results do not indicate whether household behaviour has a relationship to the actual location or place. Instead, location will be related to behaviour where a regional identity is distinct. Studies by Alsmadi (2007) and Markowitz, Lewis, Goldberg, Ashton, and Lee (2012) conducted studies within universities, showing a relationship between the university location and PEB. However, these results are highly dependent on the university community and are not compared to non-university environments, so they are not directly comparable to the results of this study.

An essential finding of the current study is that at a finer resolution, age, income, education, or place of residence do not influence the PEBs of an individual. This result suggests that many external influences are inconsequential in the analysis of PEBs when viewed at a community level. Future analysis should explore the strength of the relationship between other external influences such as economy, culture, or policy on PEB. Additional analysis at a finer resolution on all variables would also confirm or add discourse to these results. Also, future research could compare households in specific region types (Northern, rural, suburban, urban, etc., …) to determine if some regions contain more homogenous behaviours.

Additionally, data resolution could be utilized to explore individuality versus cultural dynamics. For example, the heterogeneity at a fine scale could be due to the heightened noise of individuality. Whereas aggregating at larger scales smooths over some of the noise of individuality and allows for more apparent collective and cultural PEB analysis.

The third result is a weak relationship between feelings of personal responsibility to the environment and PEBs. These findings are consistent with the discourse surrounding internal values and motivations impacting PEBs. Many studies have varying results with varying levels of statistical strength connecting values to PEBs (Fuhrer, Kaiser, Seiler, & Maggi, 1995; Lehmann, 1999; Stern & Dietz, 1994; Schultz & Zelezny, 1999; Kollmuss & Agyeman, 2002; Clark, Kotchen, & Moore, 2003; Van der Werff, Steg, & Keizer, 2013; Wang & Mangmeechai, 2021; Silvi & Padilla, 2021). The variation in results brings up an interesting discussion of internal versus external influence on PEBs and the intention-action gap. Some individuals who answered to feeling a personal responsibility to the environment still scored low on $PEBI_h$, suggesting internal analysis needs to be completed to understand PEBs. This gap suggests that focusing research on an individual's intentions does not produce consistent results with reality (Gollwitzer & Sheeran, 2006). Likewise, focusing on influencing pro-environmental behaviour through internal motivations does not guarantee a

subsequent behaviour change (Fife-Schaw, Sheeran, & Norman, 2007; Wang & Mangmeechai, 2021). Intentions have been found to only explain around 20% to 30% of the variance in the behaviour (De Bruin et al., 2012). Many other studies have acknowledged and discussed this gap (Liu & Bai, 2014; Dixit & Badgaiyan, 2016; Fielding et al., 2016; Zhang, Zhang, Yu, & Ren, 2016; Hanss, Böhm, Doran, & Homburg, 2016). These studies have suggested that the motivation-behaviour gap is due to situational factors. Therefore, intentions or motivations mediate between infrastructural, relational, or cultural factors and actual behaviour (Fielding et al., 2016).

By using behavioural spillover theory to understand the intention action gap, the study focuses on internal influences and affect-based decision modes like their values and motivations. This approach neglects calculation-based and rule-and-roll decision modes, which can coincide with affect-based decision modes. Further study would benefit from running a regression between the specific actions and questions that could indicate which mode an individual is in rather than exclusively $PEBI_h$. Doing this would shed light on the behavioural spillover occurring within the behaviours and the original motivations behind the actions. Considering the theory of planned behaviour, there is a lack of connection to subjective norms, social norms, perceived power, and perceived behavioural control. While perceived power and perceived behavioural control would be heavily subjective to variables, social norms could be assessed through external methods such as policy. Social Cognitive Theory further highlights the need for more depth in studying internal and external influences and the potential feedback that occurs between them. Going forward, studies would benefit by noting these interconnections and feedbacks to account for the 70% to 80% of behaviour not explained by intention through the external systems. These results could indicate how likely behaviours will stick with an individual.

2.7 Conclusions and Recommendations

Insurance companies are looking at rewarding households displaying pro-environmental behaviours by offering rate reductions. The link between pro-environmental behaviour and risk-mitigating behaviour needs to be established statistically or within the research to justify the decision. This study investigates if pro-environmental behaviours spill over into risk-mitigating behaviours. The regression and multivariable analysis did not identify a clear link between pro-environmental and risk-mitigating behaviours. Instead, three unexpected results occurred. The first and second results show that at a community level, data resolution, the age, income, education, or place of residence do

not influence the PEBs of an individual. The final result is that the intentions of an individual do not reflect the reality of their behaviour. Therefore, focusing on influencing pro-environmental behaviour through internal motivations does not guarantee a subsequent behaviour change. Considering both results, evaluating PEB of an individual through isolating external or internal influences will not produce results reflective of reality. Rather, intentions or motivations mediate between infrastructural, relational, or cultural barriers/resources and actual behaviour.

These results provide recommendations for the following potential research. (1) Further analysis at a finer resolution on all variables to determine the strength of their relationship with PEBs at a household or individual level; (2) data resolution could be utilized to explore individuality versus cultural dynamics; (3) additional studies could be done comparing households in specific region types to determine if some regions contain more homogenous behaviours; (4) determine the relationship between household or individual actions and questions that target internal motivations; (5) social norms could be assessed through other external methods such as policy; (6) more generally, studies would benefit by noting internal and external influences, interconnections, and feedback.

2.8 Acknowledgements

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Chapter 3

Municipal pro-environmental behaviour relationship to insurance claim frequency

Submitted to: Carbon Footprints

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Abstract: Climate change's effect on insurance premiums is becoming increasingly evident within the industry. Homeowners are financially vulnerable as insurance rates will continue to rise with increased risk of exposure to climate change impacts. Insurance companies are considering a rate reduction for homeowners displaying pro-environmental behaviours. The link between pro-environmental behaviour and risk-mitigating behaviour needs to be validated statistically and affirmed within the broader academic research. This study investigates if pro-environmental behaviours spillover into risk-mitigating behaviours at a municipal level, indicating behaviours being enacted at a broader scale among households within that municipality. The study used regression analysis of municipal milestone programming data as a proxy for pro-environmental behaviour and insurance claim frequency data. The mechanism of spillover between municipal pro-environmental behaviours and risk-mitigating behaviour could not be analyzed within this study. Therefore, the hypothesis of pro-environmental behaviours spilling over into risk-mitigating behaviours was not confirmed. Instead, it was found that within Ontario municipalities, there is a lack of centralized participation in mitigation and adaptation efforts. The non-uniformity and absence of engagement have created barriers to understanding the behavioural mechanisms behind pro-environmental behaviour and have prevented further exploration of the link to risk-mitigating behaviour. Further research is needed to understand the interconnectivity of municipal and household pro-environmental and risk-mitigating behaviours if policy and program makers are to implement targeted and effective programs. Also, analyzing these behaviours with timescale integration through the annual rate of insurance claim frequency increase will ensure a clearer understanding of program impacts over time.

Keywords: pro-environmental behaviour, insurance claims, spillover, regression analysis, municipal behaviour

3.1 Introduction

Climate change's effect on insurance premiums is an emerging research topic. Regarding flood risk alone, home insurance premiums for Canadians increased from 20% to 25% between 2015 and 2019 (Bakos, Feltmate, Chopik, & Evans, 2022). Homeowners are financially vulnerable as insurance rates will continue to rise with increased risk of exposure to climate change impacts (Chopik, 2019). The annual average amount of money spent by insurance companies on climate change-related damages has quadrupled from the 1983 to 2008 average of $422 million, to a $2 billion average between 2009 and 2020 (Rosanes, 2021). These extreme losses have already spurred the transformation of the insurance industry in a variety of ways (Malloy & Sylvester, 2010), and the predicted increase in losses over the next ten years and beyond is expected to continue to drive profound, transformative change in Canada's insurance industry (McCaffery, 2022).

Canada's infrastructure is aging and was primarily designed to anticipate historic, moderate weather events and smaller populations (McCaffery, 2022). Therefore, Canada is simply unprepared for the projected future impacts of climate change. Damages to buildings and infrastructure are expected to increase as infrastructure ages and areas deemed high-risk spread across the country. Financial losses with average annual severe weather claims paid by insurers in Canada are expected to double from $2.1 billion in 2020 to $5 billion in 2030 (Kovacs, 2020). Along with increased insurance rates, insurance companies are predicted to withdraw property coverage in areas deemed too costly or avoid insuring certain risks altogether if circumstances do not change (Rosanes, 2021).

Canada has committed to being net zero by 2050 and to have achieved a 40-45% emission reduction below 2005 levels by 2030 (Government of Canada, 2022). To achieve these commitments, the federal government aims to target initiatives such as clean power, pollution mitigation, reducing energy waste, designing resilient communities, reducing solid waste, improving transportation networks and engaging with indigenous communities. Individuals and private households have been recognized as essential players in mitigating the effects of climate change through environmentally conscious behaviours, known as pro-environmental behaviours (PEB) (Oskamp, 2000). On a personal level, individuals and private households can take proactive actions to reduce risk exposure to climate-related hazards, especially regarding flood prevention and storm preparation. For example, in the United States, researchers have determined that through behavioural changes alone, CO_2 emissions can be reduced by 20% within ten years (Schultz & Zelezny, 1999; Steinhorst, Klöckner, &

Matthies, 2015). Therefore, insurance companies are looking at reducing rates to those displaying pro-environmental behaviours.

Pro-environmental behaviours are subject to an array of influences that serve as motivators or barriers (Carrus, Bonaiuto, & Bonnes, 2005; Steg & Vlek, 2009; Gifford & Nilsson, 2014; Takahashi & Selfa, 2014; Kollmuss & Agyeman, 2002). These influences affect an individual's commitment toward completing the activity and the likelihood of doing subsequent PEBs or risk-mitigating behaviours. Policy and governmental infrastructure are often effective mechanisms that policymakers and civil servants utilize to provide more convenience in acting pro-environmentally and incentivizing individuals to change their behaviours. Many barriers to pro-environmental behaviour are more influential than an individual's personal beliefs, and governments often have the power to remove or reduce the significance of those barriers (Schultz, Oskamp, & Mainieri, 1995; Steg, Vlek, & Slotegraaf, 2001; Kollmuss & Agyeman, 2002; Bamberg & Schmidt, 2003; Jackson, 2005).

Behavioural spillover theory is the process of one behaviour resulting in subsequent behaviours, such as recycling behaviours spilling over into composting behaviours (Schultz & Zelezny, 1999; Steinhorst, Klöckner, & Matthies, 2015). At a municipal level, local governments can ease barriers to initial behaviours, and spillover could be a mechanism for them spilling into subsequent behaviours. Behavioural spillover theory offers a mechanism for significant impact by catalyzing broad lifestyle changes from one behaviour to another (Nash, et al., 2017).

Therefore, understanding the execution of PEBs should not be perceived as the result of exclusive individual analysis; rather is sensitive to the domain of an array of socio-spatial analyses (Agovino, Crociata, & Luigi Sacco, 2016). However, a gap in research exists connecting pro-environmental behaviour spillover into risk-mitigating behaviours and the subsequent potential impacts this could have on insurance rates. The research within this study aims to bridge that gap by determining the relationship between pro-environmental behaviour and risk-mitigating behaviours through understanding the determinants and relationships of behaviours. Results offer policymakers and insurance companies important insights to promote more sustainable lifestyles (Silvi & Padilla, 2021).

3.2 Research Objectives and Questions

This study proposes the possibility of municipal pro-environmental behaviour spillover into household risk-mitigating behaviour. Studies have found evidence that municipalities providing green

bin services created an increase in overall participation in blue bin programs (Domina & Koch, 2002; Zhang, Zhang, Yu, & Ren, 2016). Therefore, we hypothesize municipal pro-environmental behaviours spill over into household risk-mitigating behaviours. Currently, no studies have been identified noting the link between pro-environmental and risk-mitigating behaviour through the influence of municipal behaviours and the potential benefits for insurance companies. Therefore, this research aims to address the gap by examining the relationship between municipal pro-environmental behaviour and household risk-mitigating behaviours. Supporting research questions include:

10. How closely connected are municipal pro-environmental behaviours to household pro-environmental behaviour?
11. Can spillover occur from a municipal to a household level?
12. Is there a relationship between pro-environmental behaviour and risk-mitigating behaviour due to behavioural spillover?

3.3 Literature Review

Environmental degradation can be addressed in part through behaviour and the transition to pro-environmental behaviours (Oskamp, 2000). Pro-environmental behaviour is the action of consciously aiming to minimize environmental impacts (Kollmuss & Agyeman, 2002; Wang & Mangmeechai, 2021). These activities cover behaviours that "harm the environment as little as possible or even benefit the environment" (Steg & Vlek, 2009; Steinhorst, Klöckner, & Matthies, 2015; Kollmuss & Agyeman, 2002). Municipal pro-environmental actions can consist of conscious and proactive behaviours to be more environmentally friendly, such as energy conservation (Sparks & Shepherd, 1992) and retrofitting programs, or culturally standard behaviours, such as recycling pickups (Whitmarsh & O'Neill, 2010). These actions can be done to minimize the health risk to self, others, next generations, other species, and whole ecosystems (Bamberg & Moser, 2007).

In 1981, Liere and Dunlap published their study analyzing the different measurement types of environmental concerns and the consistency of measurement methods and results (Liere & Dunlap, 1981). Their study addressed growing concern for the environment and the emerging research which applied behavioural studies to environmentally friendly behaviour. Studies around this time had applied behaviour studies to environmental concerns through the analysis of electricity conservation (Slavin, Wodarski, & Blackburn, 1981) or water conservation (Geller, Scott, Erickson, & Buttram, 1983). Also, in 1981, Fietkau and Kessel published a paper using sociological and psychological

factors to explain the presence of environmentally conscious behaviours. Their analysis focused on the attitudes and values of individuals, including a model of potential variables that can directly or indirectly influence an individual to behave with environmental preservation in mind. Before the 1980s, behavioural studies considered acting environmentally friendly as examples in their research, but it was never the focal point (Tajfel & Turner, 1979).

Hines, Hungerford, and Tomera formalized the topic of pro-environmental behaviour on an individual level in 1986 through a model of environmental behaviour built from a list of 128 primary studies which assessed variables associated with environmentally friendly behaviour (Hines, Hungerford, & Tomera, 1986-87; Bamberg & Moser, 2007). Their work analyzed the intentions behind behaviour and objective situational factors as determinates in a person acting "pro-environmentally." The study assessed this by focusing on the association between five "psychosocial variables," attitude, locus of control/self-efficacy, moral responsibility, behavioural intention, and pro-environmental behaviour.

Hines, Hungerford, and Tomera (1986) formalized the groundwork for subsequent research to expand on for the next 20 years. Initially, research focused heavily on the influence of an individual's internal motivations on pro-environmental behaviour, presented in row one of Table 3-1: Pro-environmental behaviour research topics and studies that covered them for a compiled list of studies discussing this topic. Then, in the early 2000s, research expanded and acknowledged a motivation-to-action gap consistently occurring, see row two of Table 3-1: Pro-environmental behaviour research topics and studies that covered them, where the motivations and desires of an individual to act pro-environmentally did not line up with their actual actions. The consistency of this finding caused a pivot to focus more intently on the role of external influences, like municipal behaviours, see row three of Table 3-1: Pro-environmental behaviour research topics and studies that covered them. External influences were acknowledged previously in research, see row three of Table 3-1: Pro-environmental behaviour research topics and studies that covered them. However, the focus on external influences became a more prominent focus in explaining the intention-action gap.

Table 3-1: Pro-environmental behaviour research topics and studies that covered them

#	PEB Topic	Studies Covering the Topic	
1	Influence of internal	Borden & Francis, 1978 Wilkie, 1990	Fliegenschnee & Schelakovsky, 1998 Moisander, 1998

	motivations on pro-environmental behaviour	Preuss, 1991 Grob, 1991 Diekmann & Preisendoerfer, 1992 Eagly & Chaiken, 1993 Stern & Dietz, 1994 Fuhrer, Kaiser, Seiler, & Maggi, 1995 Staats, Wit, & Midden, 1996 Espey, Espey, & Shaw, 1997	Chawla, 1998/99 Michelsen, McGuckin, & Stumpf, 1999 Lehman, 1999 Kaiser, Woelfing, & Fuhrer, 1999 Schultzs & Zelezny, 1999 Schultz, 2002 Kollmuss & Agyeman, 2002 Clark, Kotchen, & Moore, 2003
2	Motivation to action gap	Sheeran & Orbell, 1999 Blake, 1999	Kollmuss & Agyeman, 2002 Gollwitzer & Sheeran, 2006
3	The role of external influence	Tajfel & Turner, 1979 Liere & Dunlap, 1981 Burn & Oskamp, 1986 Cialdini, Reno, & Kallgren, 1990 Coleman, 1990 Ajzen, 1991 Putnam, 1993 Danielson, Hoban, Van Houtven, & Whitehead, 1995 Schultz, Oskamp, & Mainieri, 1995 Ackermann, 1997 Putnam, 2000 Alsmadi, 2007 Ajzen & Albarracín, 2007 Engel, Pagiola, & Wunder, 2008 Hage, Söderholm, & Berglund, 2009 Brécard, Hlaimi, Lucas, Perraudeau, & Salladarré, 2009 Amutenya, Shackleton, & Whittington-Jones, 2009	Jamison, 2001 Steg, Vlek, & Slotegraaf, 2001 Kollmuss & Agyeman, 2002 Kemmelmeier, Król, & Kim, 2002 Gosken, Adaman, & Zenginobuz, 2002 Domina & Koch, 2002 Felder & Schleiniger, 2002 Greunz, 2003 Bamberg & Schmidt, 2003 Dupont, 2004 Torgler & García-Valiñas, 2005 Jackson, 2005 Takahashi & Selfa, 2014 Clark, 2014 Botetzagias, Dima, & Malesios, 2015 López-Mosquera, Lera-López, & Sánchez, 2015 Han, 2015

		Sidique, Joshi, & Lupi, 2010 Feygina, Jost, & Goldsmith, 2010 Scannell & Gifford, 2010 Filippini, 2011 Saphores, Ogunseitan, & Shapiro, 2012 Markowitz, Lewis, Goldberg, Ashton, & Lee, 2012 Basile, Capello, & Caragliu, 2012 Laidley, 2013 Valkering, Beumer, de Kraker, & Ruelle, 2013 Graham-Rowe, Jessop, & Sparks, 2014	Kyriacou, Muinelo-Gallo, & Roca-Sagalés, 2015 Crociata, Agovino, & Sacco, 2015 Steinhorst, Klöckner, & Matthies, 2015 Imas, Sado, & Samek, 2016 Agovino, Crociata, & Luigi Sacco, 2016 Zhang, Zhang, Yu, & Ren, 2016 De Quidt, 2017 Ifegbesan & Rampedi, 2018 Jagers, Harring, & Matti, 2018 Li, Zhao, Ma, Shao, & Zhang, 2019 Ghesla, Grieder, Schmitz, & Stadelmann, 2019 Silvi & Padilla, 2021
4	Internal and external motivations connectivity	Fife-Schaw, Sheeran, & Norman, 2007 Welsch & Kühling, 2010 De Bruin, et al., 2012 Fan, et al., 2013 Liiu & Bai, 2014 Dixit & Badgaiyan, 2016	Fielding, et al., 2016 Zhang, Zhang, Yu, & Ren, 2016 Hanss, Böhm, Doran, & Homburg, 2016 Li, Zhao, Ma, Shao, & Zhang, 2019 Wang & Mangmeechai, 2021
5	Internal and external connectivity in motivation to action gap	Van der Bergh, 2008 Sidique, Joshi, & Lupi, 2010 Turaga, Howarth, & Borsuk, 2010 Miafodzyeva & Brandt, 2013 Van der Werff, Steg, & Keizer, 2013 Kirakozian, 2016	Liobikienė, Mandravickaitė, & Bernatonienė, 2016 Agovino, Crociata, & Luigi Sacco, 2016 Li, Zhao, Ma, Shao, & Zhang, 2019 Silvi & Padilla, 2021

(Compiled by author)

No additional metanalysis within the field was conducted until 2007, when Bamberg and Moser (2007) compiled the updated research with modern statistical methods. Their conclusion focused on the need for more integrative internal and external influence analysis within the field (Bamberg & Moser, 2007). Since then, several studies have looked to connect internal and external motivations, see row four of Table 3-1: Pro-environmental behaviour research topics and studies that covered them. Additional studies use these connections to explain the gap between an individual's motivation and actual pro-environmental behaviours, see row five of Table 3-1: Pro-environmental behaviour research topics and studies that covered them. Overall research discusses how many factors play an essential role in an individual behaving pro-environmentally (Carrus, Bonaiuto, & Bonnes, 2005; Steg & Vlek, 2009; Gifford & Nilsson, 2014; Takahashi & Selfa, 2014).

Influences on pro-environmental behaviour have been studied due to their ability to shape an individual's actions toward the desired outcome. By thoroughly understanding the mechanisms influencing an individual's actions, behaviours can be targeted effectively and efficiently. Influences on pro-environmental behaviour work both as catalysts to action and barriers. Blake (1999) breaks down barriers taking the forms of individuality, responsibility, and practicality (Blake, 1999). Individual barriers are internalized attitudes and temperaments towards a behaviour. These barriers can vary from day to day. Responsibility barriers can be internal and external to an individual, referring to internalized moral responsibilities or external motivations, such as job expectations or family needs. Practical barriers take the form of external social and institutional constraints that can prevent individuals from acting pro-environmentally, regardless of their attitudes or intentions (Blake, 1999; Kollmuss & Agyeman, 2002).

An individual's responses to barriers are discussed through a low-cost/high-cost model (Diekmann & Preisendoerfer, 1992), which frames a decision to perform a behaviour being made by weighing the costs and choosing the perceived least costly option. Cost, in this context, does not entirely refer to the financial cost; rather, in a broader sense, it includes the time, effort and moral motivation needed to undertake pro-environmental behaviours (Kollmuss & Agyeman, 2002). For example, a large majority of individuals value environmental preservation but hold skepticism surrounding the potential for individual behaviour to sufficiently mitigate the problems we face, reducing the moral motivation behind acting pro-environmentally (Crompton, 2008; Jackson, 2009; Nilsson, Bergquist, & Schultz, 2017).

All these discussion areas can be categorized into the influences of an individual's internal and external motivations on acting pro-environmentally. The effectiveness of internal versus external influences varies from study to study, and many conclusions contradict one another. Studies have documented limitations to the robustness of internal and external influences (Silvi & Padilla, 2021). These conflicting results and limitations suggest a potential gap in research regarding analyzing the overlap and interconnectivity of internal and external influences and how they shape pro-environmental behaviours.

A recent study by Silvi and Padilla (2021) notes that studies that account for the integrative influence of internal and external influences are rare. They describe pro-environmental research to date as being studied as one of two potential frames. The first framing is pro-environmental behaviour as the result of internal moral deliberation without acknowledgement of an individual's external context (Heberlein, 1981; Black, Stern, & Elworth, 1985; Hopper & Nielsen, 1991; Grodzinska-Jurczak, 2003; Bamberg & Moser, 2007; Sidique, Joshi, & Lupi, 2010; Liobikienė, Mandravickaitė, & Bernatonienė, 2016). The second research framing is that pro-environmental behaviour is the automatic response to an external stimulus regardless of an individual's values (Jacobs & Bailey, 1983; Palmer & Walls, 1997; Linderhof, Kooreman, Allers, & Wiersma, 2001; Ferrara & Missios, 2005). These assumptions neglect heterogeneity across individuals' values, responsibilities, knowledge, relationships, and finances, which will influence a wide variety of potential behavioural outcomes in a singular intervention (Silvi & Padilla, 2021).

A significant gap in research exists discussing any other potential interconnections between influences. Connections between socio-demographic factors and internal influences are lacking in discourse. Also, there is room for more thorough discussions exploring the influence of institutions and location on environmental knowledge and personal experience. A final research gap exists in how internal motivations impact external motivations. No studies consider how one's internal value system or motivations can shape their external world and how that connects to pro-environmental behaviour.

3.4 Methods

The study consisted of three core steps to determine a relationship between pro-environmental and risk-mitigating behaviours; (1) pro-environmental behaviour data is collected, (2) insurance claim frequency data is collected, and both the pro-environmental behaviour and insurance data are

aggregated by municipality, (3) extensive statistical analysis – using single linear regression, multi-variable regression, Poisson regression, logical regression and regression trees – is done on the pro-environmental and insurance claim data to determine if a relationship between them exists.

3.4.1 Geographic and Temporal Scale

Pro-environmental behaviour of a municipality was quantified through milestone achievement data tracked by the International Council for Local Environmental Initiatives (ICLEI). ICLEI is a global network of more than 2500 local and regional governments committed to sustainable urban development through low-emission, nature-based, equitable, resilient, and circular development (International Council for Local Environmental Initiatives - Local Governments for Sustainability (ICLEI), 2022). ICLEI runs a Partners for Climate Protection (PCP) program to guide municipalities to take action on climate change by reducing emissions through a five-step milestone framework (Partners for Climate Action (PCP), 2021). The first step is to create an emissions inventory to track and project emissions, energy use and energy spending. The second step is to set emission reduction targets to set the tone and direction of emission reduction efforts. The third step is to develop a local climate action plan to outline how the municipality will achieve the reduction targets through municipal operations and/or community-based initiatives. The fourth step is to implement the local climate action plan. The final step is to monitor and report the results to evaluate the effectiveness of the initiatives and allow for adjustments in activities to achieve targets.

The PCP dataset has milestone data for community, corporate and highest for each municipality. The corporate data addresses milestones achieved for emissions of municipal government emissions only. The community data refers to the entire community emissions including corporate emissions. Some municipalities only report on one of these values; therefore, the highest dataset is the largest value from community or corporate.

Additionally, ICLEI Canada runs the national program called Building Adaptive & Resilient Communities (BARC) program. BARC is a unique tool Canadian municipalities can access for researching, planning, and tracking their adaptation progress. It follows a similar milestone framework to PCP, emphasizing research and problem space exploration in steps one and two (International Council for Local Environmental Initiatives - Local Governments for Sustainability (ICLEI), 2023). Also, the program includes additional support systems such as providing check-ins, consultation, and research assistance. The municipalities participating in PCP and BARC track their

progress and report it to ICLEI. This study uses PCP and BARC milestone data for 106 municipalities in Ontario, Canada, as an indicator of pro-environmental behaviour.

The study was done in partnership with the Cooperators, a Canadian insurance company, who provided insurance claim data for each Ontario city identified in the PCP program, plus an additional 305 cities that did not participate in the program. Their data is made of a score for the magnitude of insurance claim frequency within a municipality during 2019. Frequency (f) is the number of claims divided by the number of insurance policies. To ensure data privacy, frequency is scaled by an unknown factor to "hide" the data. All population data was retrieved from Stats Canada for the census year of 2020.

3.4.2 Models

The ICLEI data is compared to insurance claim frequency and analyzed through a series of regression models to determine if a relationship exists and the type of relationship. The models built are a single variable linear regression, multi-variable linear regression, Poisson regression, logical regression, and a regression tree.

The models are then repeated based on various dataset manipulations and categorizations outlined in Figure 3-1: Datasets used in model analysis. The first model assessments are done with the complete ICLEI raw dataset, indicated in Figure 3-1: Datasets used in model analysis data group 1, and insurance claim frequency. Then the entire dataset is scaled by population density from Statistics Canada (StatsCan), group 2, and the assessment is repeated. Data group 3 is the complete dataset broken into three groups based on population center size, as determined from StatsCan census groupings. The assessment is done with insurance claim frequency individually for each population center size. Then the same model is repeated for data groups 4 and 5. All analysis is done using the program RStudio. The complete package list and the code are compiled in the supplemental materials.

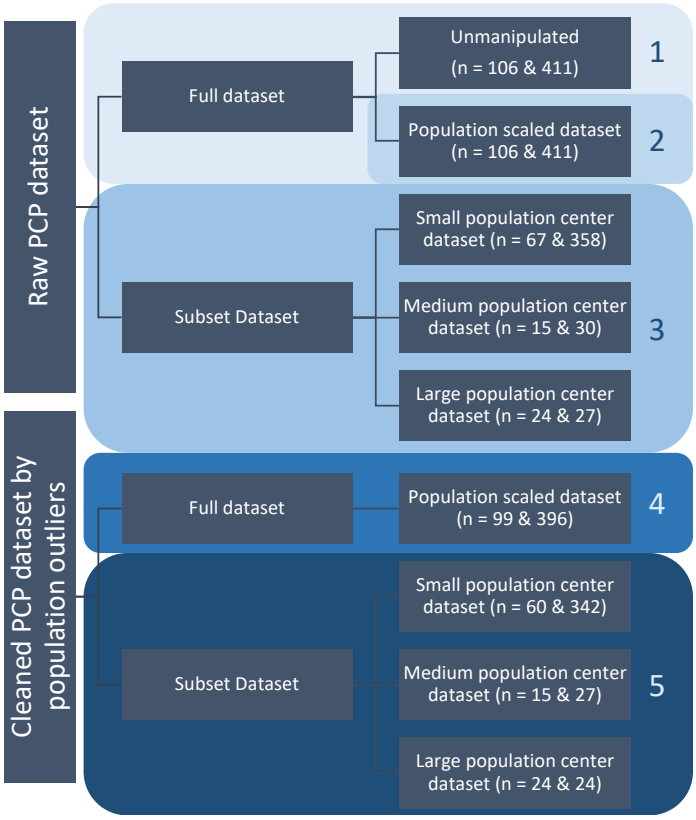

Figure 3-1: Datasets used in model analysis

3.4.2.1 Single Variable Linear Regression

Single-variable linear regression is a common method for assessing a linear relationship between two variables. It is a simple algorithm that can be implemented easily with easily interpretable outcomes. The limitations of these models are the reduced application to linear relationships, and they are only valid if the assumptions of linearity, normality, heterogeneity, independence, and no autocorrelation are true.

The single-variable linear regression consisted of 27 models based on raw, clean and population-clustered data, comparing the ICLEI data to the insurance claim frequency. Each separate model with its corresponding predictor and outcome variable is outlined in Table 3-2: Single variable linear and Poisson regression model variables.

Table 3-2: Single variable linear and Poisson regression model variables

#	Dataset	n	Predictor Variable	Outcome Variable
1	Full Raw	*106*	PCP.highest	Frequency
2	Full Raw	*106*	PCP.community	Frequency
3	Full Raw	*106*	PCP.corporate	Frequency
4	Full Raw Scaled	*106*	PCP.highest	Frequency
5	Full Raw Scaled	*106*	PCP.community	Frequency
6	Full Raw Scaled	*106*	PCP.corporate	Frequency
7	Small Population Center Subset Raw	67	PCP.highest	Frequency
8	Small Population Center Subset Raw	67	PCP.community	Frequency
9	Small Population Center Subset Raw	67	PCP.corporate	Frequency
10	Medium Population Center Subset Raw	15	PCP.highest	Frequency
11	Medium Population Center Subset Raw	15	PCP.community	Frequency
12	Medium Population Center Subset Raw	15	PCP.corporate	Frequency
13	Large Population Center Subset Raw	24	PCP.highest	Frequency
14	Large Population Center Subset Raw	24	PCP.community	Frequency
15	Large Population Center Subset Raw	24	PCP.corporate	Frequency
16	Full Cleaned Scaled	99	PCP.highest	Frequency
17	Full Cleaned Scaled	99	PCP.community	Frequency
18	Full Cleaned Scaled	99	PCP.corporate	Frequency
19	Small Population Center Subset Cleaned	60	PCP.highest	Frequency
20	Small Population Center Subset Cleaned	60	PCP.community	Frequency
21	Small Population Center Subset Cleaned	60	PCP.corporate	Frequency
22	Medium Population Center Subset Cleaned	15	PCP.highest	Frequency
23	Medium Population Center Subset Cleaned	15	PCP.community	Frequency
24	Medium Population Center Subset Cleaned	15	PCP.corporate	Frequency
25	Large Population Center Subset Cleaned	24	PCP.highest	Frequency
26	Large Population Center Subset Cleaned	24	PCP.community	Frequency
27	Large Population Center Subset Cleaned	24	PCP.corporate	Frequency

(Compiled by author)

After the models are built, the R-squared (R^2), variance and normality are extracted. Additionally, the assumptions were checked with the functions listed in Table 3-3: Regression assumptions. Then a residual vs fitted plot, Q-Q plot, scale location plot, cooks plot and scatter plot with regression line is generated and exported.

Table 3-3: Regression assumptions

Assumption	Function/Figure	Use
Non-zero variance	var()	If variance of both data sets in model are greater than zero, assumption satisfied
Linearity	resettest() Residual vs Fitted Plot	If p-value is less than the confidence interval, assumption satisfied. Visual inspection of residual vs fitted plot
Homoscedasticity	gqtest() Scale Location Plot	If p-value is greater than the confidence interval, assumption satisfied. Visual inspection of scale location plot
Independence & No Autocorrelation	durbinWatsonTest()	If p-value is greater than the confidence interval, assumption satisfied
Normality	shapiro.test() Q-Q Plot	If p-value of both data sets in model is greater than the confidence interval, assumption satisfied. Visual inspection of Q-Q plot

(Compiled by author)

3.4.2.2 Multi-Variable Linear Regression

Multi-variable liner regression models are useful in interpreting linear relationships between multiple variables and the output variable. It allows for determining the relative influence of each predictor variable on the output variable. The limitations of these models are the potential for overfitting and indicating a false higher explanation of variance.

One multi-variable linear regression model compared the combination of the ICLEI data to the insurance claim frequency. Each separate model with its corresponding predictor and outcome variable is outlined in Table 3-4: Multi-variable linear regression model variables (full raw dataset).

Table 3-4: Multi-variable linear regression model variables (full raw dataset)

#	Predictor Variables	Outcome Variable	n
1	PCP.community PCP.corporate BARC	Insurance Claim Frequency	106

(Compiled by author)

After the models are built, the R^2 and b-coefficients are extracted. Additionally, the same assumptions were checked with the functions listed in Table 3-3: Regression assumptions. Then a residual vs fitted plot, Q-Q plot, scale location plot, cooks plot and scatter plot with regression line are generated and exported.

3.4.2.3 Poisson Regression

Poisson regression is often used as a simple alternative to other regression models, where fewer parameters and assumptions are required to be met. These models are most used with integer and count data. The limitations of these models are the oversimplification of the data and the assumption that the mean of the distribution is equal to the variance, which is true in most count data sets.

The Poisson regression consisted of three models, comparing the ICLEI data to the insurance claim frequency. Each model's predictor and outcome variables are the same as the single-variable regression outlined in Table 3-5: Poisson regression model variables. After the models are built, the model characteristics of interest are extracted. Additionally, the same assumptions were checked with the functions listed in in Table 3-3: Regression assumptions. Then a residual vs fitted plot, Q-Q plot, scale location plot, cooks plot, scatter plot with a regression line, and a conditional density plot are generated and exported.

Table 3-5: Poisson regression model variables

#	Predictor Variable	Outcome Variable
1	PCP.highest	Frequency
2	PCP.community	Frequency
3	PCP.corporate	Frequency

(Compiled by author)

3.4.2.4 Logical Regression

Logical regression fits a linear model when the output variable is binary. It is easy to implement and interpret and very efficient. The limitations of these models are that the dimensions of the data need to be low and cannot consider overly complex data.

The logical regression consisted of nine models, comparing binary yes (1) or no (0) statements to having participated in ICLEI programming to the insurance claim frequency. Each separate model with its corresponding predictor and outcome variable is outlined in Table 3-6: Logical regression model variables.

Table 3-6: Logical regression model variables

#	Dataset	n	Predictor Variable	Outcome Variable
1	Full Raw	*106*	Frequency	PCP.highest
2	Full Raw	*106*	Frequency	PCP.community
3	Full Raw	*106*	Frequency	PCP.corporate
4	Full Raw Scaled	*106*	Frequency	PCP.highest
5	Full Raw Scaled	*106*	Frequency	PCP.community
6	Full Raw Scaled	*106*	Frequency	PCP.corporate
7	Full Cleaned Scaled	99	Frequency	PCP.highest
8	Full Cleaned Scaled	99	Frequency	PCP.community
9	Full Cleaned Scaled	99	Frequency	PCP.corporate

(Compiled by author)

After the models are built, the model characteristics of interest are extracted. Additionally, the assumptions were checked with the functions listed in Table 3-3: Regression assumptions. Then a residual vs fitted plot, Q-Q plot, scale location plot, cooks plot, scatter plot with a regression line, and a conditional density plot is generated and exported.

3.4.2.5 Regression Tree

Regression tree models are useful for non-linear data and fits piecewise functions to the dataset. The results are easy to visualize and interpret and very robust with missing values. Also, it does not require the assumptions of linearity, normality, or no collinearity to be met. The limitations of these

models are their sensitivity to outliers and instability. Additionally, these models are prone to overfitting and do not work with continuous numerical variables.

The regression tree analysis consisted of 36 models, comparing the ICLEI data to the insurance claim frequency. The number of data points for medium population centers is 15 and is too low to run a regression tree analysis. Each separate model with its corresponding predictor and outcome variables is outlined in Table 3-7: Regression tree model variables.

Table 3-7: Regression tree model variables

#	Dataset	n	Predictor Variable	Outcome Variable
1	Full Raw	*106*	PCP.highest	Frequency
2	Full Raw	*106*	PCP.community	Frequency
3	Full Raw	*106*	PCP.corporate	Frequency
4	Full Raw	*106*	PCP.community PCP.corporate BARC	Frequency
5	Full Raw Scaled	*106*	PCP.highest	Frequency
6	Full Raw Scaled	*106*	PCP.community	Frequency
7	Full Raw Scaled	*106*	PCP.corporate	Frequency
8	Full Raw Scaled	*106*	PCP.highest PCP.community PCP.corporate	Frequency
9	Small Population Center Subset Raw	67	PCP.highest	Frequency
10	Small Population Center Subset Raw	67	PCP.community	Frequency
11	Small Population Center Subset Raw	67	PCP.corporate	Frequency
12	Small Population Center Subset Raw	67	PCP.highest PCP.community PCP.corporate	Frequency
13	Medium Population Center Subset Raw	15	PCP.highest	Frequency
14	Medium Population Center Subset Raw	15	PCP.community	Frequency

15	Medium Population Center Subset Raw	15	PCP.corporate	Frequency
16	Medium Population Center Subset Raw	15	PCP.highest PCP.community PCP.corporate	Frequency
17	Large Population Center Subset Raw	24	PCP.highest	Frequency
18	Large Population Center Subset Raw	24	PCP.community	Frequency
19	Large Population Center Subset Raw	24	PCP.corporate	Frequency
20	Large Population Center Subset Raw	24	PCP.highest PCP.community PCP.corporate	Frequency
21	Full Cleaned Scaled	99	PCP.highest	Frequency
22	Full Cleaned Scaled	99	PCP.community	Frequency
23	Full Cleaned Scaled	99	PCP.corporate	Frequency
24	Full Cleaned Scaled	99	PCP.community PCP.corporate	Frequency
25	Small Population Center Subset Cleaned	60	PCP.highest	Frequency
26	Small Population Center Subset Cleaned	60	PCP.community	Frequency
27	Small Population Center Subset Cleaned	60	PCP.corporate	Frequency
28	Small Population Center Subset Cleaned	60	PCP.community PCP.corporate	Frequency
33	Large Population Center Subset Cleaned	24	PCP.highest	Frequency
34	Large Population Center Subset Cleaned	24	PCP.community	Frequency
35	Large Population Center Subset Cleaned	24	PCP.corporate	Frequency
36	Large Population Center Subset Cleaned	24	PCP.community PCP.corporate	Frequency

(Compiled by author)

After the models are built, the model characteristics of interest are extracted. Additionally, the assumptions were checked with the tests for independence listed in Table 3-3: Regression assumptions. Then, the tree models are generated and exported.

3.5 Results

The statistical analysis results on the ICLEI and insurance claim data determine whether a relationship exists. The linear regressions assess the potential linear relationships, and the regression trees assess the potential piecewise relationships. In total, the 271 tests yielded 40 models that meet their corresponding assumptions and 20 additional models of interest. Any non-pertinent results can be found in the supplemental materials.

The p-value is relevant to linear, Poisson and logical regressions and indicates the statistical significance of the variable estimate; if the p-value is less than the confidence interval (0.1), then the variable estimate is statistically significant, and the hypothesis of a relationship between the two variables is failed to be rejected. In other words, the relationship of the variable estimate between the predictor and outcome variables exists with limited uncertainty. In the case of this study, the p-value indicates if a relationship between the predictor and outcome variable exists at all.

The variable estimate is relevant to linear, Poisson and logical regressions and is the interval of change of the output variable based on a single unit of predictor variable change. This value indicates the magnitude and type, positive or negative, of the relationship between the predictor and output variable.

The mean absolute error (MAE) is relevant to the regression tree models. MAE tells us how big of an error we can expect on average. There are no distinct thresholds universal to satisfy, and it is relative to the data and model, but the closer to zero, the better. The mean squared error (MSE) is used to determine the existence of instability in the model. Regression trees are known to be unstable and are highly affected by outliers. MSE is the squared prediction error over all instances in the test set. This indicates if outliers or errors are existing within the dataset by accentuating their existence by squaring the data point. While each residual in MAE contributes proportionally to the total error, the error grows quadratically in MSE. An MSE bigger than MAE around the power of 2 is considered normal and indicates no outliers.

The R^2 value corresponds to the linear regression and regression tree models and indicates the percentage of variability that is explained in the model. The higher the R^2, the more accurate the predictions of the model. In the case of this study, R^2 is used to indicate the accuracy of the type of relationship and how much of the relationship is affected by randomness.

The X^2 p-value is relevant to Poisson and logical regressions and tests the statistical significance of the relationship between the predictor and outcome variable directly. The hypothesis of an X^2 is that there is no relationship between the two variables. If the hypothesis is rejected, then it is concluded that there is statistical significance in the relationship.

Variable importance is relevant to the multi-variable regression tree models. This value is a score for each predictor variable indicating the level of influence the variable has on making a prediction in the model. The more an attribute is used to make key decisions with the tree, the higher its relative importance.

3.5.1 Full Dataset Ungrouped

The full dataset of group 1 in Figure 3-1: Datasets used in model analysis was assessed through single and multi-variable linear regressions, regression trees, Poisson regressions and logical regressions.

3.5.1.1 Single Variable Linear Regression, Poisson Regression and Regression Tree

The results of the statistical analysis of single variable models are outlined in Table 3-8: Full dataset single variable analysis results (range = 5).

Table 3-8: Full dataset single variable analysis results (range = 5)

#	Model	Outcome Variable	Predictor Variable	R^2 / X^2 p-val	Variable Estimate (m) & MAE/range	p-value (p) & MSE/MAE^2
1	Linear	Frequency	PCP.community	4.8%	0.14	2.4%
2	Regression	Frequency	PCP.corporate	7.7%	0.18	0.4%
3	Regression	Frequency	PCP.community	6.0%	31.4%	2.92 / 2.46
4	Tree	Frequency	PCP.corporate	9.0%	32.6%	2.92 / 2.46
5	Poisson	Frequency	PCP.community	100%	0.06	9.0%
6	Regression	Frequency	PCP.corporate	100%	0.09	3.2%

(Compiled by author)

Each of the six models outlined in Table 3-8: Full dataset single variable analysis results (range = 5) met all the assumptions of their respective model types and, therefore, can be analyzed for a relationship between the outcome and predictor variables. All p-values are within the confidence

interval and therefore indicate an existing relationship. Additionally, models have MSE and MAE around a power of two difference. Insurance claim frequency with PCP.corporate and PCP.community are consistently valid models and are therefore plotted with the three model types in Figure 3-2: Linear, Poisson and regression tree models plotted with raw data for insurance claim frequency as an output of PCP.community and PCP.corporate..

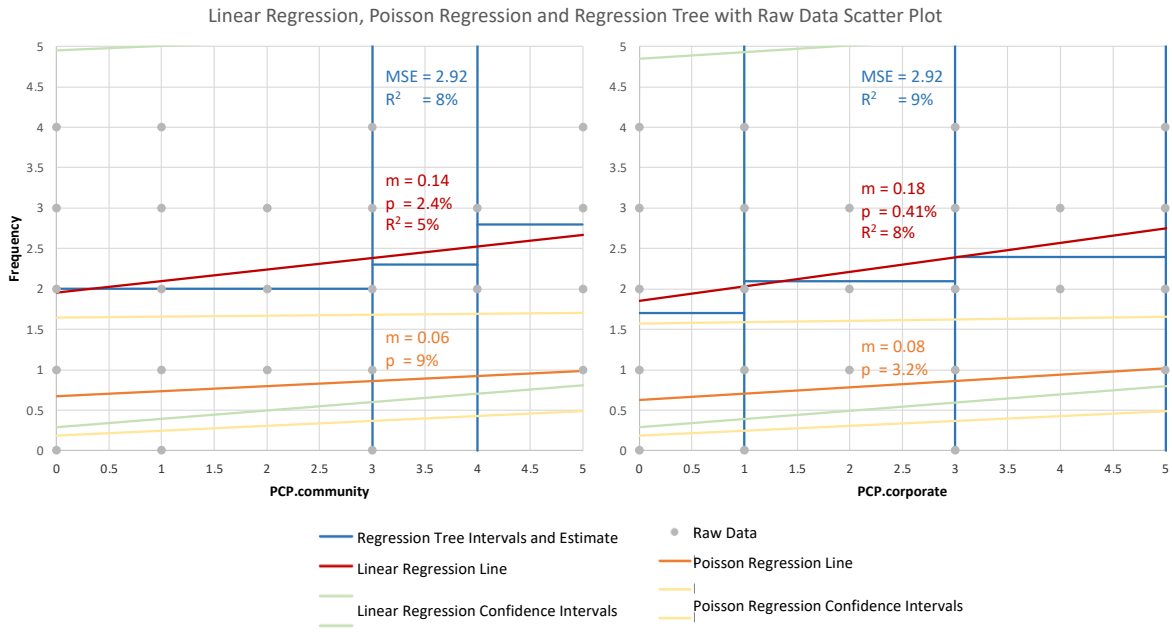

Figure 3-2: Linear, Poisson and regression tree models plotted with raw data for insurance claim frequency as an output of PCP.community and PCP.corporate.

Overall, the R^2 values are low, indicating randomness and variation in the data that cannot be explained with the models. The models show an increase in insurance claim frequency as ICLEI milestones are completed.

3.5.1.2 Logical Regression

The results of the statistical analysis of logistic regression models are outlined in Table 3-9: Full dataset logical regression analysis results.

Table 3-9: Full dataset logical regression analysis results

#	Outcome Variable	Predictor Variable	X^2	X^2 p-value	Variable Estimate	Variable p-value
1	PCP.highest	Frequency	5.33	100%	0.19	2.2%
2	PCP.community	Frequency	5.87	100%	0.21	1.7%
3	PCP.corporate	Frequency	7.63	100%	0.24	0.7%
4	PCP.overall	Frequency	5.33	100%	0.19	2.2%

(Compiled by author)

The four logical regression models in Table 3-9: Full dataset logical regression analysis results meet their assumptions, the p-values of all the models are within the confidence interval and the X^2 p-value indicates a relationship. The lowest p-values are associated with PCP.corporate and PCP.community, indicating the most statistically confident relationships. These predictor variables are plotted with insurance claim frequency and their raw data in Figure 3-3: The single variable raw data plotted with the logical regression line outputs and confidence intervals..

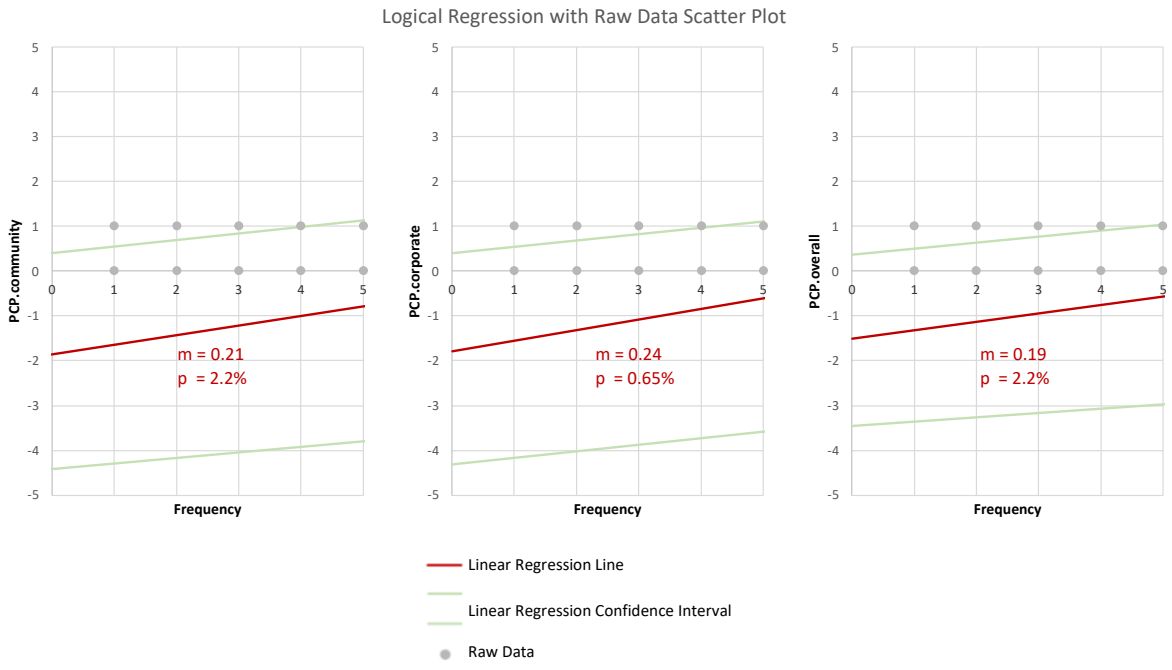

Figure 3-3: The single variable raw data plotted with the logical regression line outputs and confidence intervals.

Considering the values in Table 3-9: Full dataset logical regression analysis results the models indicate that as the frequency of insurance claims increases, communities are completing more ICLEI mitigation and adaptation milestones. However, based on the plots of Figure 3-3: The single variable raw data plotted with the logical regression line outputs and confidence intervals., the relationship exist with predictions subject to a range of randomness and variability beyond the binary outputs.

3.5.2 Scaled Dataset

The scaled dataset of groups 2 and 4 in Figure 3-1: Datasets used in model analysis was assessed through single variable linear regressions, regression trees and logical regressions.

3.5.2.1 Single Variable Linear Regression and Regression Tree

The results of the statistical analysis of single variable models are outlined in Table 3-10: Scaled dataset single variable analysis results.

Table 3-10: Scaled dataset single variable analysis results

#	Dataset	n	Model	Outcome Variable	Predictor Variable	R2	Variable Estimate (m) & MAE/range	p-value (p) & MSE/MAE^2
1					PCP.community	0.7%	0.56	39.0%
2	Raw	106	Linear	Frequency	PCP.corporate	1.4%	-0.79	24.0%
3					PCP.highest	0.2%	0.35	62.0%
4					PCP.community	0.3%	0.01	58.0%
5	Clean	99	Linear	Frequency	PCP.corporate	0.0%	0.00	97.0%
6					PCP. highest	0.3%	-0.01	59.0%
7					PCP.community	14.0%	6.3%	260 / 40
8	Raw	106	Tree	Frequency	PCP.corporate	13.0%	5.7%	136/ 32
9					PCP. highest	13.0%	7.3%	300/ 53
10	Clean	99	Tree	Frequency	PCP.community	14.0%	11.1%	25/ 11

11	PCP.corporate	22.0%	13.3%	37 / 16
12	PCP. highest	18.0%	13.4%	38 / 16

(Compiled by author)

None of the 12 models outlined in Table 3-10: Scaled dataset single variable analysis results met all the assumptions of their respective model types. In the raw data set, the Shapiro test for normality failed for all models, and the Q-Q plots did not visually indicate a normal distribution of the data. In the cleaned dataset, normality is fixed, but linearity and homoscedasticity fail their respective tests. Therefore, the models cannot be used for direct interpretation of the relationship between the predictor and outcome variables. The raw dataset model indicates significant outliers when comparing the MSE to the MAE^2. A threshold of max predictor variable being 30, 7 data points were removed, which is 6.6% of the dataset. The cleaned data MSE is still over double MAE^2. Removing further data points has a risk of misrepresenting and skewing the data. Therefore, even after cleaning the dataset, the relationship of the regression tree model isn't considered highly reliable. However, the models can give insight into why the tests failed and provide evidence to confirm if there is no relationship between the two variables. Each cleaned data model is plotted in Figure 3-4: Linear regression and regression tree models of the scaled cleaned dataset for each predictor variable and insurance claim frequency. for further assessment.

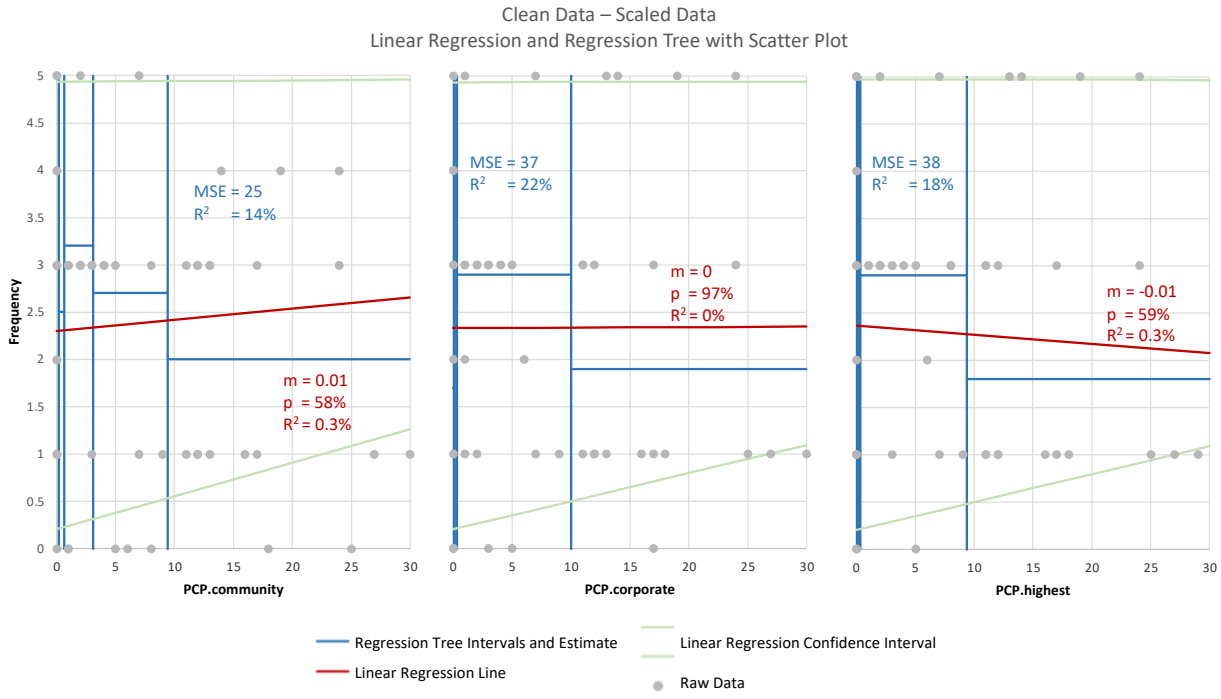

Figure 3-4: Linear regression and regression tree models of the scaled cleaned dataset for each predictor variable and insurance claim frequency.

Based on the Figure 3-4: Linear regression and regression tree models of the scaled cleaned dataset for each predictor variable and insurance claim frequency. plots, the linear relationship between ICLEI and insurance claim frequency appears flat to non-existent. Also, the regression tree output values have a small range, around 1.2 intervals of change, when the entire dataset range is 5. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs. Additionally, the R^2 values are low, indicating randomness and variation in the data that cannot be explained with the models. Therefore, the predictor and outcome variables appear to not have any relationship when scaled by population density.

3.5.2.2 Logical Regression

The results of the statistical analysis of logistic regression models are outlined in Table 3-11: Scaled dataset logistic regression analysis results.

Table 3-11: Scaled dataset logistic regression analysis results

#	Dataset	n	Outcome Variable	Predictor Variable	X^2 p-value	Variable Estimate	p-value
1				PCP.community	100%	-0.03	0.1%
2	Raw	411	Frequency	PCP.corporate	100%	-0.03	0.1%
3				PCP.highest	100%	-0.03	0.0%
4				PCP.community	100%	0.014	0.1%
5	Cleaned	396	Frequency	PCP.corporate	100%	0.014	0.1%
6				PCP. highest	100%	0.014	0.0%

(Compiled by author)

None of the six models outlined in Table 3-11: Scaled dataset logistic regression analysis results met all the assumptions of a logical regression model. The Durbin Watson test for independence failed for each model. Therefore, the models cannot be used for direct interpretation of the relationship between the predictor and outcome variables. However, considering that the p-values indicate statistical significance between the two variables, the models can give insight into why the tests failed and provide evidence to confirm if there is no relationship between the two variables. Each model is plotted in Figure 3-5: logical regression models of the scaled raw and cleaned datasets for each predictor variable and insurance claim frequency. for further assessment.

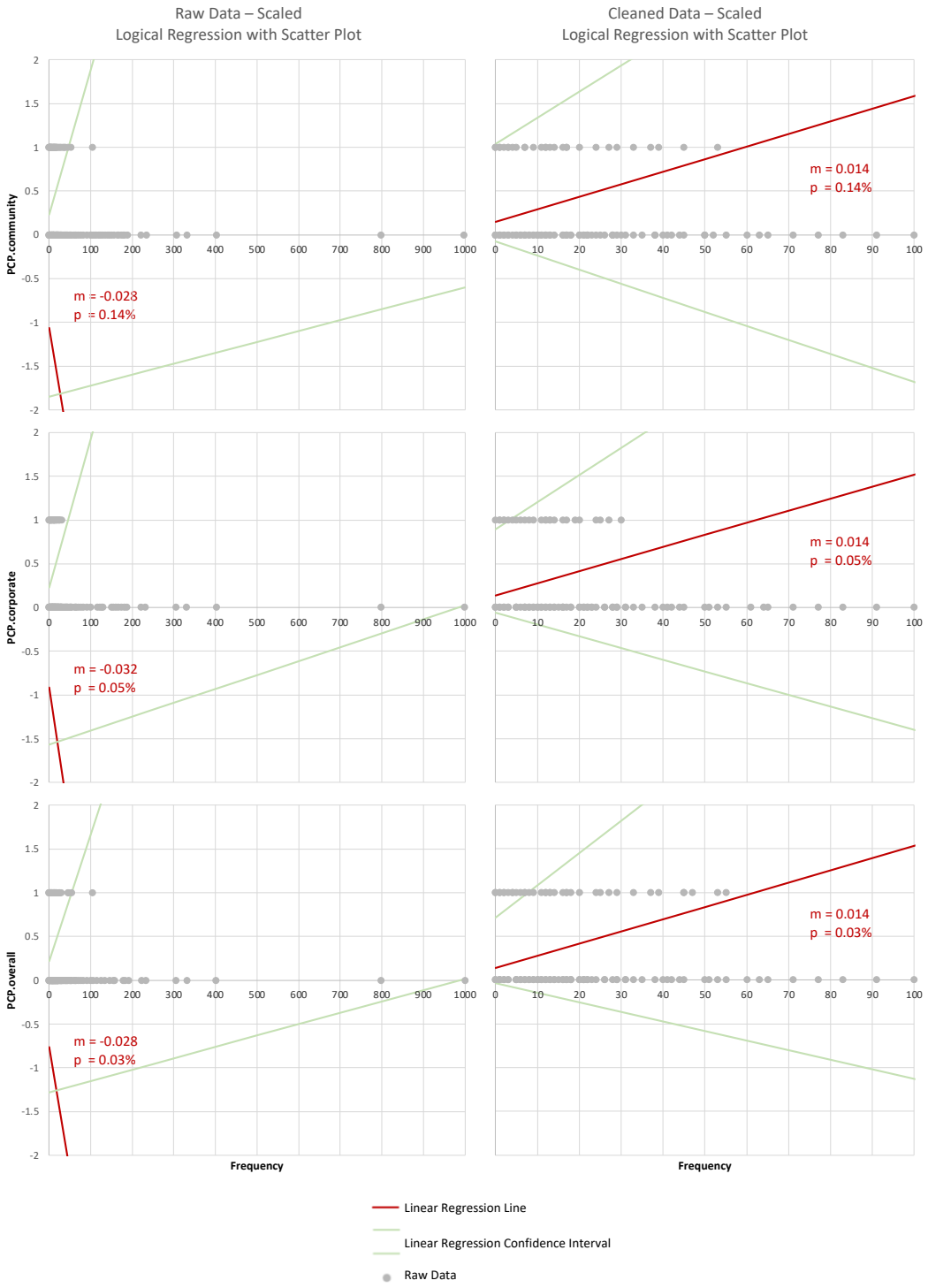

Figure 3-5: logical regression models of the scaled raw and cleaned datasets for each predictor variable and insurance claim frequency.

Based on the Figure 3-5: logical regression models of the scaled raw and cleaned datasets for each predictor variable and insurance claim frequency. plots, the linear relationship between ICLEI and insurance claim frequency of the raw data shows a strong negative relationship, while the cleaned data is a positive relationship. Both confidence intervals indicate predictions to be subject to a range of randomness and variability beyond the binary outputs. The raw data models indicate that the model is not actually representative of the data at all, and considering the failed assumptions, the raw data models are not considered in collecting information. The cleaned data models continue to show that as the frequency of insurance claims increase, communities are completing more ICLEI mitigation and adaptation milestones.

3.5.3 Small Population Centers Dataset

The small population-centred grouped dataset of groups 3 and 5 in Figure 3-1: Datasets used in model analysis was assessed through single variable linear regressions and regression trees.

3.5.3.1 Single Variable Linear Regression and Regression Tree

The results of the statistical analysis of single variable models are outlined in Table 3-12: Small population center dataset single variable analysis results.

Table 3-12: Small population center dataset single variable analysis results

#	Datset	n	Model	Outcome Variable	Predictor Variable	R2	Variable Estimate (m) & MAE/range	p-value (p) & MSE/MAE^2	Assump
1	Raw	67	Linear	Frequency	PCP.community	6.0%	0.21	4.7%	Satisfied
2					PCP.corporate	9.0%	0.25	1.4%	Satisfied
3					PCP. highest	8.3%	0.25	1.8%	Not Satisfied
4	Clean	60	Linear	Frequency	PCP.community	7.1%	0.21	4.0%	Satisfied
5					PCP.corporate	16.0%	0.31	0.2%	Satisfied

6					PCP. highest	10.0%	0.26	1.4%	Satisfied
7					PCP.community	10.4%	24.2%	1.69 / 1.46	Satisfied
8	Raw	67	Tree	Frequency	PCP.corporate	3.9%	25.4%	1.87/ 1.61	Satisfied
9					PCP. highest	5.7%	25.4%	2.16 / 1.61	Not Satisfied
10					PCP.community	6.7%	18.0%	1.40 / 0.81	Satisfied
11	Clean	60	Tree	Frequency	PCP.corporate	13.3%	18.3%	1.45 / 0.84	Satisfied
12					PCP. highest	7.5%	14.7%	1.03/ 0.54	Satisfied

(Compiled by author)

Ten of the models outlined in Table 3-12: Small population center dataset single variable analysis results meet all the assumptions of their respective model types. In the two cases where the assumptions are not satisfied, it is due to the non-linearity of the raw dataset for PCP.highest. Therefore, all the PCP.community and PCP.corporate models were plotted with the raw datapoints in Figure 3-6: Linear regression and regression tree models of the raw and cleaned small population center datasets for each predictor variable and insurance claim frequency..

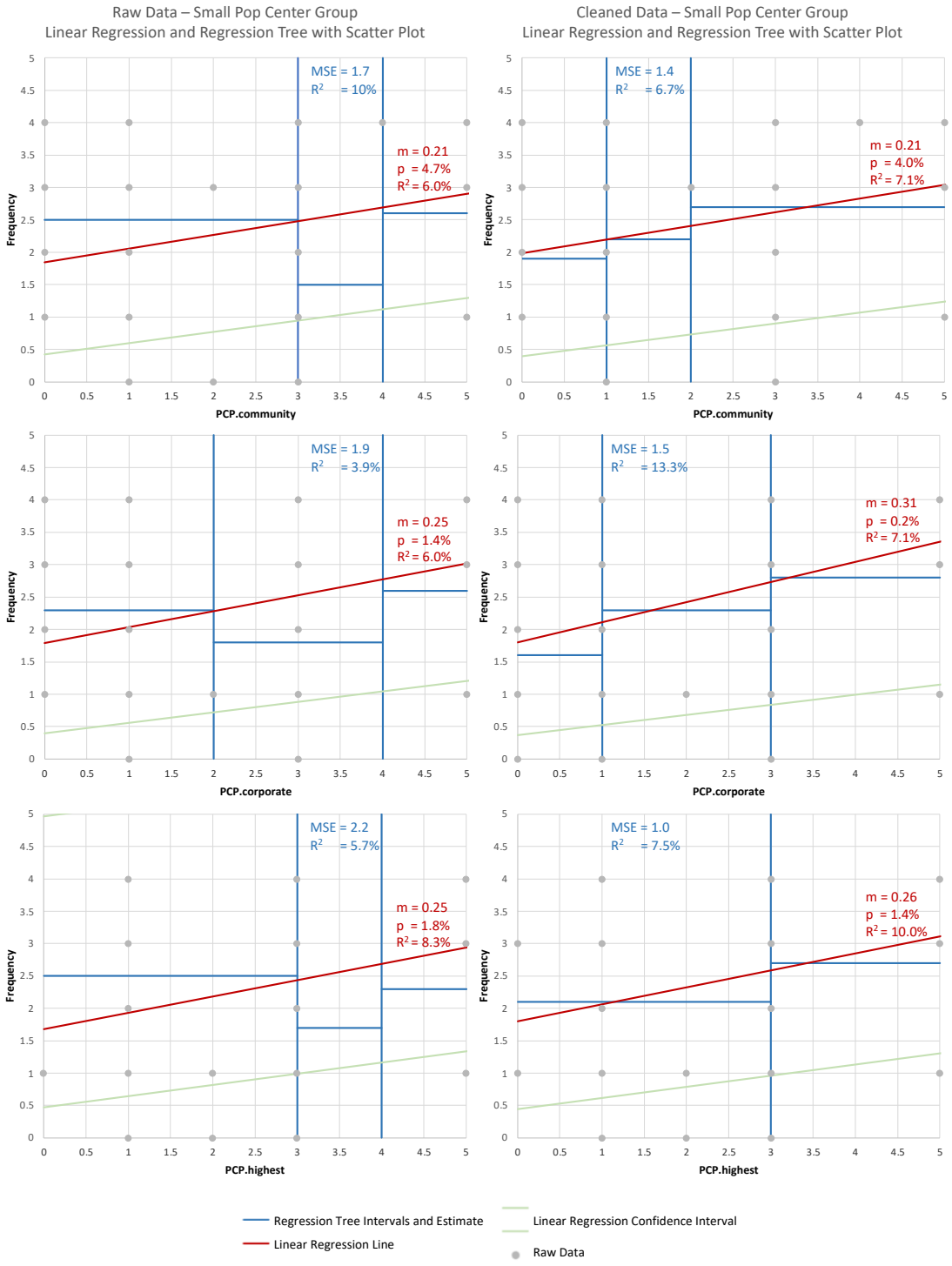

Figure 3-6: Linear regression and regression tree models of the raw and cleaned small population center datasets for each predictor variable and insurance claim frequency.

Based on the Figure 3-6: Linear regression and regression tree models of the raw and cleaned small population center datasets for each predictor variable and insurance claim frequency. plots, the linear relationship between ICLEI and insurance claim frequency appears to be positive. There appears to be very little difference between cleaned and raw datasets, indicating that cleaning isn't relevant when the predictor variable hasn't been scaled by population density. Also, the regression tree output values have a small range, around 1intervals of change, when the entire dataset range is 5. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs. Additionally, the R^2 values are low, indicating randomness and variation in the data that cannot be explained with the models.

3.5.3.2 Multi-Variable Regression Tree

The results of the statistical analysis of multi-variable models are outlined in Table 3-13: Small population center dataset multi-variable analysis results.

Table 3-13: Small population center dataset multi-variable analysis results

#	Dataset	n	Outcome Variable	Predictor Variable	Variable Importance	R2	MAE/range	MSE / MAE^2
1	Small Pop Raw	67	Frequency	PCP.community	11	12%	31.6%	2.99 / 2.50
				PCP.corporate	13		31.6%	2.90 / 2.50
				PCP.highest	15		29.0%	2.46 / 2.10
2	Small Pop Clean	60	Frequency	PCP.community	10	13.3%	20.3%	1.65 / 1.03
				PCP.corporate	5		18.3%	1.45 / 0.84

(Compiled by author)

Both multi-variable regression tree models satisfied their required assumptions. Both models have an MSE and MAE around a difference of a power of two, with the raw dataset showing a closer range than the cleaned dataset. Therefore, the models are considered valid for further assessment and the raw dataset model is presented in Figure 3-7: The raw small population center multivariable regression tree model, with PCP.community and PCP.corporate as predictor variables and insurance claim frequency as the output variable..

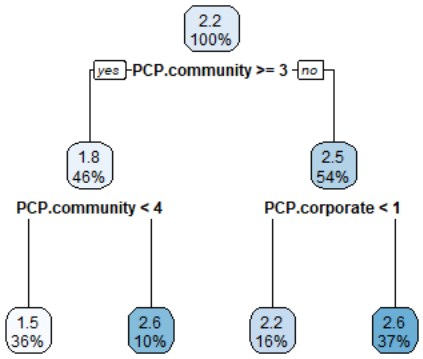

Figure 3-7: The raw small population center multivariable regression tree model, with PCP.community and PCP.corporate as predictor variables and insurance claim frequency as the output variable.

The information that the model does tell us is that once the data is scaled and cleaned, PCP.community has more influence than PCP.corporate, the same as the scaled data and the opposite of the full dataset results. Additionally, when looking at the regression tree outputs, presented in Figure 3-7: The raw small population center multivariable regression tree model, with PCP.community and PCP.corporate as predictor variables and insurance claim frequency as the output variable., the values range from 1.5 to 2.6, a range of 1.1 when the entire dataset range is 5. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs.

3.5.4 Large Population Centers Dataset

The large population-centred grouped dataset of groups 3 and 5 in Figure 3-1: Datasets used in model analysis was assessed through single variable linear regressions, regression trees and logical regressions.

3.5.4.1 Single Variable Linear Regression and Regression Tree

The results of the statistical analysis of single variable models are outlined in Table 3-14: Large population center dataset single variable analysis results.

Table 3-14: Large population center dataset single variable analysis results

#	Dataset	n	Model	Outcome Variable	Predictor Variable	R2	Variable Estimate (m) & MAE/range	p-value (p) & MSE/MAE^2
1	Raw /Cleaned	24	Linear	Frequency	PCP.community	0.5%	0.02	75.3%
2					PCP.corporate	2.9%	0.05	43.1%
3					PCP. highest	0.9%	0.04	65.9%
4	Raw	24	Tree	Frequency	PCP.community	31.7%	32.5	2.88 / 2.64
5					PCP.corporate	1.2%	41.7%	5.25 / 4.34
6					PCP. highest	11.4%	43.3%	5.83 / 4.69
7	Cleaned	24	Tree	Frequency	PCP.community	0.0%	40.8%	4.96 / 4.17
8					PCP.corporate	4.0%	41.7%	5.25 / 4.34
9					PCP. highest	4.0%	42.5%	5.63 / 4.52

(Compiled by author)

All of the models outlined in Table 3-14: Large population center dataset single variable analysis results meet all the assumptions of their respective model types. The PCP.community and PCP.corporate models were plotted with the raw data points in Figure 3-8: Linear regression and regression tree models of the raw and cleaned large population center datasets for each predictor variable and insurance claim frequency..

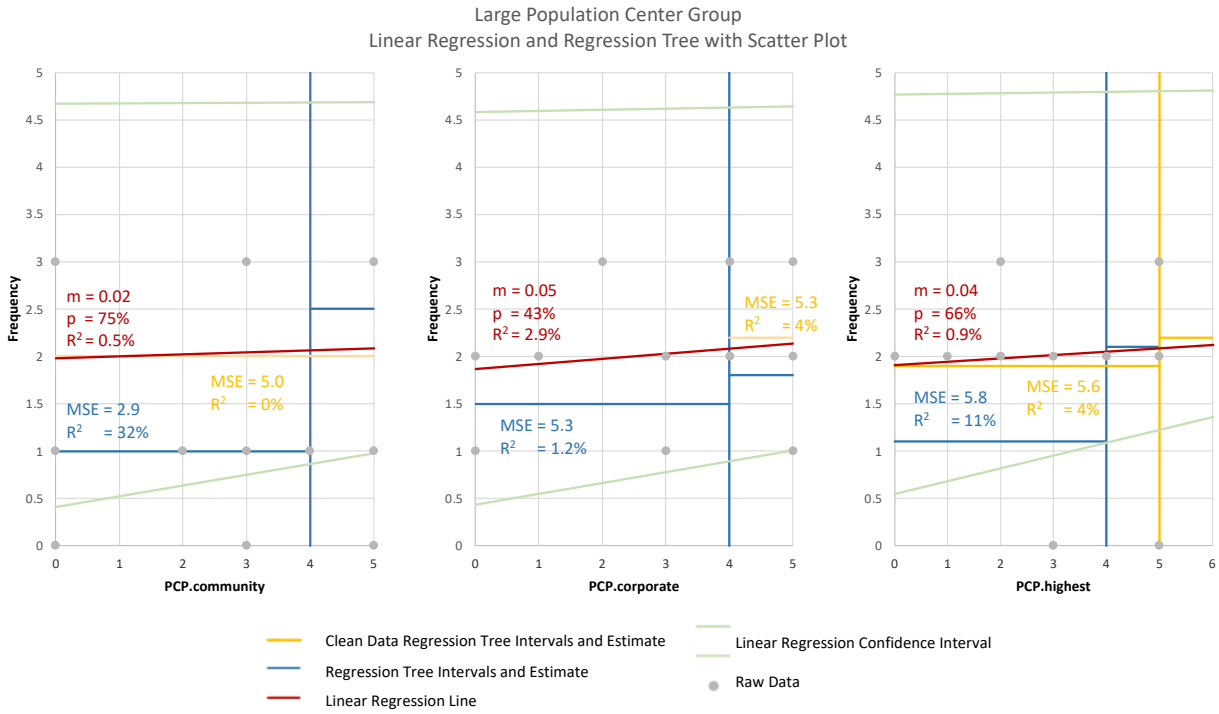

Figure 3-8: Linear regression and regression tree models of the raw and cleaned large population center datasets for each predictor variable and insurance claim frequency.

Based on the Figure 3-8: Linear regression and regression tree models of the raw and cleaned large population center datasets for each predictor variable and insurance claim frequency. plots, the linear relationship between ICLEI and insurance claim frequency appears to be flat. Also, the regression tree output values have a small range, when the entire dataset range is 5. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs. Additionally, the R^2 values are low, indicating randomness and variation in the data that the models cannot explain.

3.5.4.2 Multi-Variable Regression Tree

The results of the statistical analysis of multi variable models are outlined in Table 3-15: Large population center dataset multi-variable analysis results.

Table 3-15: Large population center dataset multi-variable analysis results

#	Dataset	n	Outcome Variable	Predictor Variable	Variable Importance	R2	MAE/range	MSE / MAE^2
1	Large Pop Raw	24	Frequency	PCP.community	6	32%	32.5	2.88 / 2.64
				PCP.corporate	9		35.0	4.75 / 3.06
				PCP.highest	14		37.5	4.88 / 3.52
2	Large Pop Clean	24	Frequency	PCP.community	0.36	4%	40.8	4.96 / 4.17
				PCP.corporate	0.23		41. 7	5.25 / 4.34

(Compiled by author)

Both multi-variable regression tree models satisfied their required assumptions. Both models have certain variables with MSE and MAE around a difference of a power of two, but neither model has all variables with this criterion met. Additionally, the MAE is the furthest from zero compared to all dataset models, making it the worst fit for multi-variable regression tree models. The information that the model does tell us is that for the large population center dataset the PCP.corporate has more influence than the PCP.community, the opposite of the scaled and small population datasets and the same as the full dataset. Additionally, when looking at the regression tree outputs, the values range from 1.9 to 2.2, a range of 0.3 when the entire dataset range is 5. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs.

3.5.5 Primary Results

Across all the models and analyses, there are a number of consistent results. The first result is that the BARC dataset showed no relationship to the insurance claim frequency, while the PCP milestones did show a potential relationship that was further studied by considering population.

The second result is that for the single variable linear regression and regression trees of the full dataset, small, and large population center grouped datasets, there appeared to be a positive relationship. Indicating that as ICLEI milestones are completed, the insurance claim frequency increases. This is a counterintuitive result and requires further investigation. Looking deeper at this, the R^2 values are very low, indicating randomness and variation in the data that cannot be explained with the models. R^2 is expected to be low considering that behavioural data is being analyzed, but the variation of the models seems to be even beyond that consideration and indicates an inconsistent, possibly weak, or nonexistent, relationship between the predictor and outcome variables.

Then, in the scaled dataset single variable linear and tree analyses, the models did not meet the assumptions of normality, and when cleaned, they did not meet the assumptions of linearity and homoscedasticity. This reinforces the conclusion that there is a weak to no relationship between the predictor and outcome variables.

Plus, the output values of the single and multivariable regression trees have a very narrow range and are not representative of the actual data that gets outputted. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs.

The third result is that the base logical regression models show that as the frequency of insurance claims increases, communities are completing more ICLEI mitigation and adaptation milestones. These models use an X^2 value that shows a very strong relationship. However, once the data was scaled and cleaned by population, the logical regressions no longer met the assumptions of independence. This indicates that there are still outliers in the data, but removing further data points is not possible without potentially skewing the dataset, leaving the scaled logical models to be unusable for interpretation. These results indicate that the relationship is highly influenced by the population density of the municipality.

The final result is when considering the influence of the individual predictor variables PCP.highest, PCP.community and PCP.corporate on insurance claim frequency. The multivariable regression trees give insight into the variable importance, showing that when PCP.highest, PCP.corporate and PCP.community are assessed together, PCP.highest always has the most influence, then corporate, then community. When only PCP.corporate and PCP.community are considered then the community has the highest influence then corporate. The linear regression p-values across all the models show that the PCP.corporate has the strongest statistical significance.

3.6 Discussion

The study set out to determine the relationship between environmental behaviours and risk-mitigating behaviours and hypothesized that similar pro-environmental behaviours will spill over into risk-mitigating behaviours at a municipal and household level. Through the regression analysis, the hypothesis can be rejected. No model showed significant evidence of any relationship between the ICLEI milestone data and the frequency of insurance claims for a municipality. Therefore, no connection between municipal pro-environmental behaviours and risk-mitigating behaviour is

observed, indicating an absence of spillover. Additionally, no conclusion can be made about the connection between municipal pro-environmental behaviours and household pro-environmental behaviours. The reasons behind this and a few unexpected results are worth discussing.

The lack of a relationship between the ICLEI milestone data and the frequency of insurance claims conflicts with the observations and findings of previous research. Research by Schultz, Oskamp and Mainieri (1995), Steg, Vlek and Slotegraaf (2001), Kollmuss and Agyeman (2002), Bamberg and Schmidt (2003), and Jackson (2005) suggest that policy and governmental infrastructure are often effective mechanisms that policymakers and civil servants utilize to provide more convenience in acting pro-environmentally and incentivizing individuals to change their behaviours. In the research, this statement is predicated on the fact that the most effective form of governmental intervention is through the removal of barriers (Kollmuss & Agyeman, 2002; Ghesla, Grieder, Schmitz, & Stadelmann, 2019). Policies, programs and infrastructure implemented to target convenience and economics often have the most participation in conjunction with cultural and environmental knowledge-based initiatives (Silvi & Padilla, 2021). Research has shown that programs singly focused on knowledge building are ineffective due to their indirect approach to the topic (Chawla, 1998; Chawla, 1999), and programs focused singly on convenience or economics can have pushback or lack of participation in the community due to misinformation (Wang & Mangmeechai, 2021; Silvi & Padilla, 2021). Therefore, programming that uses an integrated approach is recommended. The ICLEI programming primarily targets behaviours already motivated by environmental knowledge and provides additional knowledge and resources for the pursuit of climate change mitigation. While this approach integrates motivations of environmental knowledge and provides the removal of barriers to some resources, the findings of this study still show a lack of impact. The lack of impact could be due to the optional nature of the programming. Programs like this are called “gain-based” and are limited to individuals who already have the desire to act pro-environmentally (Silvi & Padilla, 2021). These programs are viewed as favourable by the public because they are enabled to perform actions they have not previously been able to do, and have been shown to improve the pro-environmental behaviours of individuals, but they face limitations and cannot alone provide long-term substantial behavioural change. The results of this study reinforce the limitations of gain-based programming. Out of the 444 cities within Ontario, only 106 of them actually participate in ICLEI programming. Additionally, out of the cities that participate, only 34 of the municipalities have progressed to the point of implementing a local climate action plan,

milestones 4 and 5. That means only 7% of Ontario cities are taking action on climate mitigation through the ICLEI programming. Therefore, there is potential value in regrouping the dataset and reanalyzing it by comparing municipalities that do not participate in ICLEI programming (76%), municipalities that do participate but are only at milestones 1 to 3 (16%), and municipalities that are at milestones 4 and 5 (7%). The limitation of this potential analysis is the high skew of municipalities not participating in the programming, making the dataset non-linear and non-normal. Municipalities could also participate in alternative adaptation and mitigation programming to the ICLEI programming. These results suggest that there is a lack of regulation across Canada and Ontario to encourage municipalities to take action on climate change. Within Canada, no federal or provincial regulations or policies mandate municipalities to act on climate change. Instead, gain-based incentives, such as subsidies, exist to engage municipalities in a net zero transition. The lack of engagement in the ICLEI program could indicate that the current federal and provincial gain-based incentives are not enough, and governments need to explore additional means to improve municipal participation. Also, there is an absence of a centralized system for tracking progress.

When considering spillover theory, the framework moderates the spillover process by bounding the process with the characteristics and interrelationships between the behaviours. The behaviour processes are broken down into decision modes, causal attribution, characteristics, interrelationships, and difficulty of the behaviours. Based on the results and analysis, engaging in ICLEI programming at a municipal level has not resulted in further risk-mitigating behaviours. The ICLEI program lays out a distinct roadmap with milestones to achieve adaptation (BARC) or mitigation (PCP). The decision mode of the behaviours for each milestone is calculation-based. Relying on motivators of economics, geography, environmental knowledge and socio-demographics of that municipality. The BARC dataset, which focused on adaptation efforts, had no relationship to analyze, while the PCP dataset showed a potential relationship indicating that emission mitigation rather than adaptation programs has closer ties to insurance claims. But, as a whole, emission mitigation alone is not enough to experience an insurance claim frequency decline. This study suggests that within the bounds of such a program, the municipality experiences little causal attribution to do activities beyond the designated programming. Causal attribution occurs post-behaviour when an individual assigns an understanding behind the action being driven and can associate it with additional related activities. The barrier to spillover can be due to financial, labour, or bureaucratic restraints (Stephan & Paterson,

2012; Ghesla, Grieder, Schmitz, & Stadelmann, 2019). Therefore, programming that encourages or integrates causal attribution could result in more impactful results.

These results and the logical regression analysis indicate that milestones achieved by a municipality appear to be more of a function of the population and the insurance claim frequency rather than the insurance claim frequency being a function of actions within the community. The relationship between milestones achieved and population conflicts with research that suggests rural areas have more support for climate mitigation strategies over urban dwellers due to their regional identity being more connected to place and nature (Ifegbesan & Rampedi, 2018). Regional identity is a concept that describes an individual's relationship with their surrounding community and environment. The level of exposure to the natural environment and surrounding geography in a location will influence the level of environmental connection one will experience in their regional identity. Studies have identified this concept as a significant predictor for individuals supporting climate mitigation strategies (Ifegbesan & Rampedi, 2018) and their willingness to invest financially and temporally in solutions (Gosken, Adaman, & Zenginobuz, 2002; Ifegbesan & Rampedi, 2018). While literature suggests that a rural, regional identity will be more motivated to act pro-environmentally, this study shows that in higher population density locations more milestones have been achieved. A study further looking at the perspectives of climate change in rural and urban areas and the mitigation/adaptation efforts adopted could add to the conversation of regional identity.

Also, to consider is that the relationship between milestones achieved by a municipality and the insurance claim frequency could be the result of insurance claims being on the rise in general. Therefore, an analysis integrating the timescale and the rate of insurance claim increase could provide insight into whether these adaptation and mitigation efforts are impacting the rate of increase.

When looking at the individual milestone programs, focusing on community or corporate actions, the connection between insurance claims and municipal operation milestone efforts seems to have the strongest connection. With the variable p-values across all the single linear regression models having the strongest statistical significance, and when comparing all variables in a multi-variable regression tree, corporate had more importance than community. This indicates that the behaviours of operations over individual actions have the most potential to impact the future of climate change positively or negatively. There is a significant lack of research comparing industry and operational impacts on climate change to household impacts. StatsCan reported that 46% of all Canadian greenhouse gas

(GHG) emissions were from direct and indirect household behaviours in 2004 (Statistics Canada, 2015). Direct household emissions account for the actual behaviours taking place in a household. While indirect household emissions account for the background industrial and operational emissions for goods and services obtained by households. The results of this study suggest a need to look further at the relationship between indirect household and industrial behaviours to insurance claim frequency. Current research is limited in integrating municipal and individual behaviours in accounting for emissions and mitigation efforts. Many studies focus solely on industry behaviours or direct household behaviours without considering the integrated picture and potential spillover between the behaviours. Further research considering these connections and potential spillover between municipal and household behaviours would expand the understanding and impact of policy measures of municipalities.

3.7 Conclusions and Recommendations

The study set out to determine the relationship between environmental behaviours and risk-mitigating behaviours and hypothesized that similar pro-environmental behaviours will spill over into risk-mitigating behaviours at a municipal level. A thorough analysis of the International Council for Local Environmental Initiatives (ICLEI) municipal programming as a proxy for pro-environmental behaviour and the Co-operators' insurance claim frequency data indicated that there is not any significant evidence of a relationship between the two. Additionally, the research highlighted a gap in understanding between municipal to household pro-environmental behaviour and the potential spillover.

The lack of a relationship between pro-environmental behaviour and the frequency of insurance claims conflicts with the observations and findings of previous research. The lack of relationship could be due to the limited reach of the ICLEI programming. Few Ontario municipalities participate in ICLEI programming, and out of the cities that do participate, even fewer municipalities have progressed to the point of implementing a local climate action plan. These results suggest that there is a lack of regulation across Canada and Ontario to encourage municipalities to take action on climate change and an absence of a centralized system for tracking progress. Therefore, governments need to explore additional means to improve municipal participation. When considering spillover theory, this study suggests that programming with distinct milestones narrowly bounded by that municipality's economics, geography, environmental knowledge, and socio-demographics leads to minimal spillover

activities beyond the designated programming. Further research considering spillover in governmental programming would expand the understanding and impact of policy measures in municipalities. Plus, an analysis integrating the timescale and the rate of insurance claim increase could provide insight into whether these adaptation and mitigation efforts impact the insurance claim frequency rate.

Results also conflict with existing literature in the discussion of regional identity shaping motivations for acting pro-environmentally. While literature suggests that a rural, regional identity will be more motivated to act pro-environmentally, this study shows that more milestones have been achieved in higher population density locations. A study further looking at the perspectives of climate change in rural and urban areas and the mitigation/adaptation efforts adopted could add to the conversation of regional identity.

The mechanism of spillover between municipal pro-environmental behaviours to household pro-environmental and risk-mitigating behaviour could not be analyzed within this study. Therefore, the hypothesis of pro-environmental behaviours spilling over into risk-mitigating behaviours was not confirmed. These results suggest that there is a lack of regulation across Canada and Ontario to encourage municipalities to take action on climate change and an absence of a centralized system for tracking progress. Additionally, the measures that are in place by the local government are underutilizing causal attribution and missing out on the potential benefits of behavioural spillover. Further research is needed to understand the interconnectivity of municipal and household pro-environmental and risk-mitigating behaviours if policy and program makers are to implement targeted and effective programs. Also, analyzing these behaviours with timescale integration through the annual rate of insurance claim frequency increase will ensure a clearer understanding of program impacts over time.

3.8 Acknowledgements

In addition to providing funding support, the model applied in this study benefited from substantial input provided by the Cooperators Team, notably Tom Ewart and Sylvain Pannetier-Lebeuf. We greatly appreciate their support and commitment to the study. Additionally, we would like to thank the Smart Prosperity Institute and ICLEI for providing us with access to their programming data for the study.

Chapter 4
Discussion, Conclusion and Recommendations

The primary objective of the research has been to determine the relationship between pro-environmental behaviour (PEB) and risk-mitigating behaviours. Chapter 2 approached the objective by comparing a direct measurement of individual household behaviours and motivations and compiling them into a Pro-Environmental Behaviour Index ($PEBI_h$). The index was then compared to an indirect measurement of risk-mitigating behaviour using insurance claim frequency scores from the Co-operators. Chapter 3 approached the objective by measuring municipal actions based on milestones completed for carbon mitigation, based on International Council for Local Environmental Initiatives (ICLEI) programming, as an indirect proxy for pro-environmental behaviour at a municipal level. The milestone data was then compared to the same insurance claim frequency scores.

The studies were both limited by data availability and privacy requirements. Due to the household data of Chapter 2 needing to be aggregated, the relationship between risk-mitigating and pro-environmental behaviours could not be assessed at all. Then, due to a lack of participation in municipal mitigation programming, the number of data points in Chapter 3 and the statistical significance in the models was lacking. Therefore, the overall analysis suffered from uncertainty.

The outcome of both studies did not identify a clear link between pro-environmental and risk-mitigating behaviour through behavioural spillover. Instead, Chapter 2 found that at a community level data resolution, the age, income, education, or place of residence do not influence the PEBs of an individual. Also, Chapter 2 found that the intentions of an individual do not reflect their behaviour. Therefore, focusing on influencing pro-environmental behaviour through internal motivations does not guarantee a subsequent behaviour change. Considering both results, evaluating the PEB of an individual through isolating external or internal influences will not produce accurate predictions of behaviour. Rather, intentions or motivations mediate between infrastructural, relational, or cultural barriers/resources and actual behaviour.

Chapter 2 highlights a lack of understanding within research in the initiation of the initial pro-environmental behaviour of an individual, stalling any further analysis of spillover to risk-mitigating behaviour. The intention action gap describes individuals reporting to have strong motivations to protect the environment and their lack of PEBs, which is observed in the research of Chapter 2. By

using the framework of behavioural spillover theory, the intention action gap highlights the misunderstanding within the research of the initial mechanisms for behaviour. Studies describing the intention action gap focus solely on affect-based decision modes, like values and motivations, to explain individual behaviour., Individual behaviours result from a combination of decision modes, characteristics, and interrelationships, highlighted by behavioural spillover theory. An individual's mode is made up of interconnected internal motivations and external logistical barriers/influences, as seen in Figure 1-1: Spillover theory framework found in Chapter 1. To best understand PEBs and if they spillover into risk-mitigating behaviour, a more comprehensive dataset is required to assess the full complexity of an individual's decision mode, characteristics, and interrelationships to internal and external influences.

Chapter 3 found that within Ontario municipalities, there is a lack of regulation across Canada and Ontario to encourage municipalities to take action on climate change and an absence of a centralized system for tracking progress. Additionally, the few measures that are in place by the local government are underutilizing causal attribution and missing out on the potential benefits of behavioural spillover. Based on the results and analysis, engaging in ICLEI programming at a municipal level did not result in further risk-mitigating behaviours. The ICLEI program lays out a distinct roadmap with milestones to achieve within either the adaptation (BARC) methods or mitigation (PCP) methods. The decision mode of the behaviours for each milestone is predominately calculation-based; it considers external barriers/influences of economics, geography, and the internal motivations considered come from environmental knowledge and socio-demographics of that municipality. The BARC dataset, which focused on adaptation efforts, had no relationship to analyze, while the PCP dataset showed a potential relationship indicating that emission mitigation rather than adaptation programs has closer ties to insurance claims. But, as a whole, emission mitigation alone is not enough to experience an insurance claim frequency decline. This study suggests that within the bounds of such a program, an individual is experiencing either a lack of motivation for the initial behaviour or barriers to subsequent behaviours are too large. The barriers to spillover can be due to financial, labour, or bureaucratic restraints, which the milestone programs are aiming to ease (Stephan & Paterson, 2012; Ghesla, Grieder, Schmitz, & Stadelmann, 2019). The process of causal attribution is not being realized in the design of these milestone programs. Therefore, programming that encourages or integrates interconnectivity and causal attribution could result in more impactful climate-mitigating programs.

These findings contribute to academic discourse by filling the gap in literature connecting pro-environmental behaviours to discussions of risk due to climate change. Additionally, the findings provide essential insight for the insurance industry looking to provide premiums to individuals displaying PEBs. Showing that providing premiums based on fiscal motivations alone will not contribute any monetary advantage through reduced claims. The final contribution of this research is through highlighting the urgent need for Canadian governments to encourage municipalities to take action on climate change. Plus, there is a significant gap in a centralized system for tracking progress, which limits the robustness and depth of research that can take place within Canada.

Considering both papers, in order to fully assess and understand the relationship between PEBs and risk-mitigating behaviour, urgent transformation is needed in Canadian policy, regulations and programming. Literature within the field indicates that internal and external influences should be shaping the way Canadians behave with regard to the environment. However, the current programming, infrastructure and regulation limit motivations and create behavioural change barriers. The following areas of research would help further understanding of these areas.

1. Do a further analysis of data at a fine (community level) resolution on external and internal influences to determine the strength of their relationship with PEBs at a household or individual level.
2. Use fine (community level) data resolution to explore individuality versus cultural dynamics impacts on PEBs at a household and municipal level.
3. Compare household PEBs in specific region types (Northern, rural, suburban, urban) to determine if some regions contain more homogenous behaviours.
4. Assess PEBs through other external methods, such as
    a. federal or provincial policy and regulations
    b. provincial school curriculum
5. Do a case study on the effectiveness of programming that targets the integration of causal attribution for spillover from PEBs to risk-mitigating behaviour.
6. Do a study looking further at perceptions of climate change and the mitigation/adaptation efforts adopted.
7. Integrate timescale through the annual rate of insurance claim increase into PEB to risk-mitigating behaviour spillover.

8. Continue the research to compare and consider the interconnections of municipal, industrial, and direct household PEBs on insurance claim frequency or carbon emissions.
9. Do further research on the interconnectivity of municipal and household pro-environmental and risk-mitigating behaviours.

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Appendix A

[Pro-environmental behaviour impacts and their relationship to insurance claim frequency through individual household and municipal-level analyses]

Supplementary Materials

Additional Results

Full Dataset Multi-Variable Linear Regression and Regression Tree

The results of the statistical analysis of multi-variable models are outlined in Table 0-1: Full dataset multi-variable analysis results.

Table 0-1: Full dataset multi-variable analysis results

#	Model	Outcome Variable	Predictor Variable	R^2 / X^2 p-val	Variable Estimate & Variable Importance	p-value & MSE/MAE[2]
1	Linear Regression	Frequency	PCP.community	7.9%	0.05	63.0%
			PCP.corporate		0.16	7.1%
			BARC		-0.03	66.4%
2	Regression Tree	Frequency	PCP.community	11.0%	7.9	2.92 / 2.46
			PCP.corporate		11.8	
			BARC		6.2	

(Compiled by author)

All models meet their respective model assumptions. The linear regression model does not have all three predictor variables within the confidence interval. The regression tree has an MSE and MAE within a power of two difference. This model is plotted with the raw data and the corresponding linear regression line in Figure 0-1: The multi variable raw data plotted with the linear regression line and regression tree outputs..

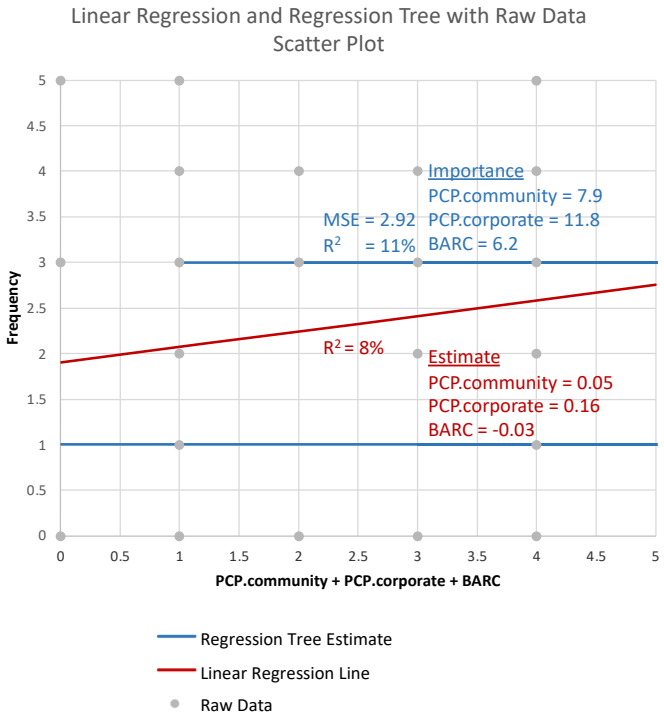

Figure 0-1: The multi variable raw data plotted with the linear regression line and regression tree outputs.

Like the single variable results, the R^2 values are low, indicating randomness and variation in the data that cannot be explained with the models. While the R^2 values are higher in the multi-variable models, this is more likely due to overfitting rather than a better fit when considering the p-values and MSE values. Across all models, the direct predictor variable comparison shows a stronger influence from PCP.corporate than the other variables.

Scaled Dataset Multi-Variable Regression Tree

The results of the statistical analysis of multi variable models are outlined in Table 0-2: Scaled dataset multi-variable analysis results.

Table 0-2: Scaled dataset multi-variable analysis results

#	Dataset	n	Outcome Variable	Predictor Variable	Variable Importance	R2	MAE/range	MSE / MAE^2

1	Full Raw Scaled	106	Frequency	PCP.community	26		6.7%	263/ 45
				PCP.corporate	28	19.0%	5.9%	138/ 35
				PCP.highest	34		7.5%	302/ 56
2	Full Clean Scaled	99	Frequency	PCP.community	24	22.2%	11.8%	26/ 13
				PCP.corporate	10		13.3%	37/ 16

(Compiled by author)

Both multi-variable regression tree models satisfied their required assumptions. One regression tree has an MSE and MAE within a power of two differences. The raw dataset model indicates significant outliers when comparing the MSE to the MAE^2. A threshold of max predictor variable being 30, 7 data points were removed, which is 6.6% of the dataset. The cleaned data MSE is still over double MAE^2. Removing further data points has a risk of misrepresenting and skewing the data. Therefore, even after cleaning the dataset the relationship of the regression tree model isn't considered highly reliable. The cleaned dataset model result is presented in Figure 0-2: The clean scaled multivariable regression tree model, with PCP.community and PCP.corporate as predictor variables and insurance claim frequency as the output variable..

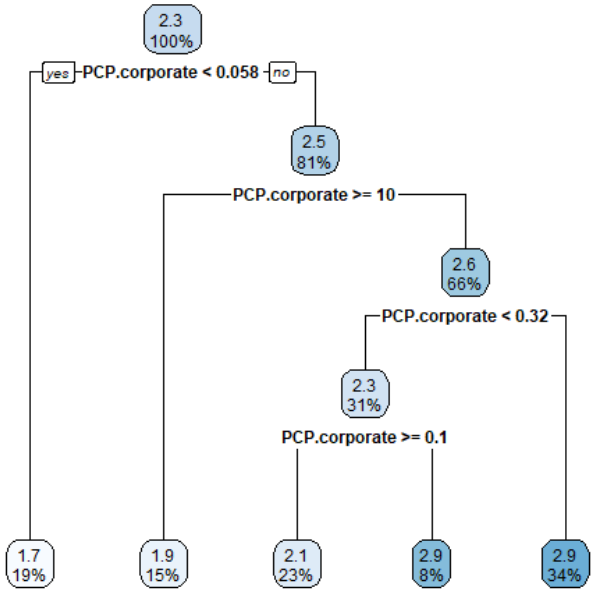

Figure 0-2: The clean scaled multivariable regression tree model, with PCP.community and PCP.corporate as predictor variables and insurance claim frequency as the output variable.

The information that the model does tell us is that once the data is scaled and cleaned, PCP.community has more influence than PCP.corporate, an opposite conclusion to the unscaled data result. Additionally, when looking at the regression tree outputs, presented in Figure 0-2: The clean scaled multivariable regression tree model, with PCP.community and PCP.corporate as predictor variables and insurance claim frequency as the output variable., the values range from 1.7 to 2.9, a range of 1.2 when the entire dataset range is 5. This indicates a weak to no relationship between the predictor and output variables since the model fails to produce a model of the relationship that produces a more representative range of outputs.

Medium Population Centers Dataset

The medium population-centred grouped dataset of groups 3 and 5 in Figure 3-1: Datasets used in model analysis was assessed through single variable linear regressions. The results of the statistical analysis of single variable models are outlined in Table 0-3: Medium population center dataset single variable analysis results.

Table 0-3: Medium population center dataset single variable analysis results

#	Dataset	n	Model	Outcome Variable	Predictor Variable	R2	Variable Estimate (m) & MAE/range	p-value (p) & MSE/MAE^2
1	Raw /Clean	15	Linear	Frequency	PCP.community	35.5%	0.31	1.9%
2					PCP.corporate	39.2%	0.41	1.3%
3					PCP. highest	36.6%	0.40	1.7%

(Compiled by author)

All of the models outlined in Table 0-3: Medium population center dataset single variable analysis results meet all the assumptions of their respective model types. The PCP.community and PCP.corporate models were plotted with the raw datapoints in Figure 0-3: Linear regression and regression tree models of the raw and cleaned medium population center datasets for each predictor variable and insurance claim frequency..

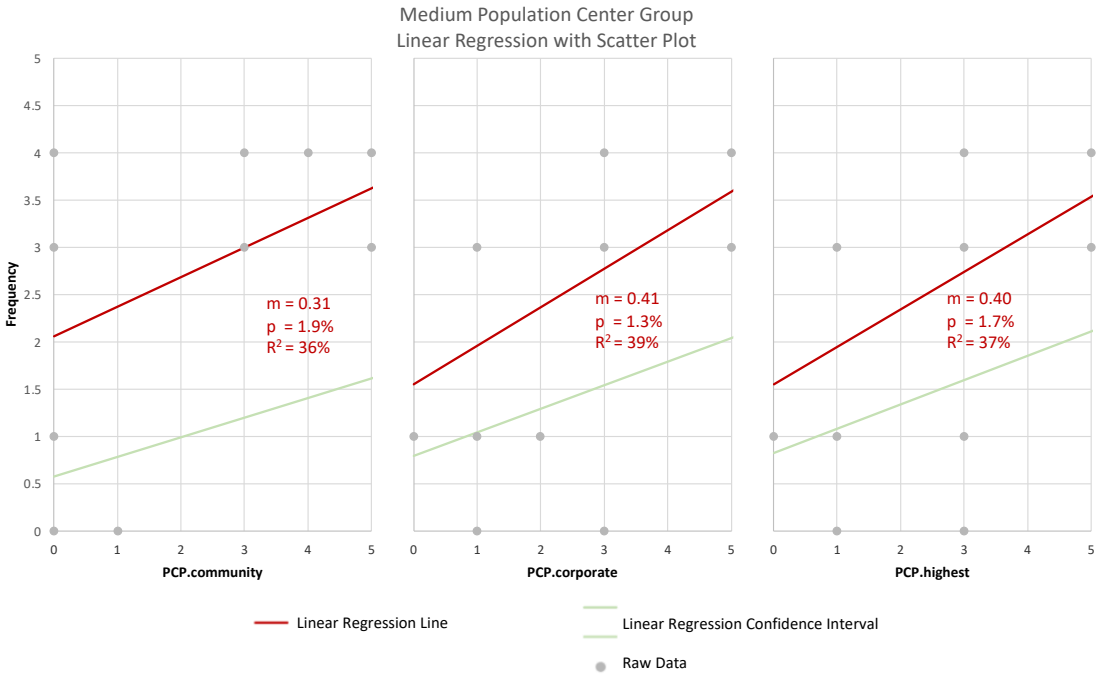

Figure 0-3: Linear regression and regression tree models of the raw and cleaned medium population center datasets for each predictor variable and insurance claim frequency.

Based on the Figure 0-3: Linear regression and regression tree models of the raw and cleaned medium population center datasets for each predictor variable and insurance claim frequency. plots, the linear relationship between ICLEI and insurance claim frequency appears to be positive. Additionally, the R^2 values are higher, but this is most likely due to the small number of datapoints in the model causing an overfit.