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National-level factors affecting planned, public adaptation to health impacts of climate change

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ABSTRACT

Our understanding of whether adaptive capacity on a national level is being translated into adaptation policies, programs, and projects is limited. Focusing on health adaptation in Annex I Parties to the UNFCCC, we examine whether statistically significant relationships exist between regulatory, institutional, financial, and normative aspects of national-level adaptive capacity and systematically measured adaptation. Specifically, we (i) quantify adaptation actions in Annex I nations, (ii) identify potential factors that might impact progress on adaptation and select measures for these factors, and (iii) calculate statistical relationships between factors and adaptation actions across countries. Statistically significant relationships are found between progress on adaptation and engagement in international environmental governance, national environmental governance, perception of corruption in the public sector, population size, and national wealth, as well as between responsiveness to health vulnerabilities, population size and national wealth. This analysis contributes two key early empirical findings to the growing literature concerning factors facilitating or constraining adaptation. While country size and wealth are necessary for driving higher levels of adaptation, they may be insufficient in the absence of policy commitments to environmental governance. Furthermore, governance and/or incentive frameworks for environmental governance at the national level may be an important indicator of the strength of national commitments to addressing health impacts of climate change.

1. Introduction

Research is only beginning to examine the potential health implications of climate change and indicates significant vulnerabilities (Haines et al., 2009). Key risks include increasing exposure to infectious diseases, exacerbated water and food insecurity, declining air quality, increased magnitude and frequency of natural disasters, and population displacement (Costello et al., 2011; Watts, 2011; Costello et al., 2009; Patz et al., 2007, 2008). Populations are differentially vulnerable to these impacts, with those already at high risk for poor health outcomes expected to experience a disproportionate share of the health costs of climate change (Ford, 2012; Ford et al., 2010; Campbell-Lendrum et al., 2009; Walpole et al., 2009; Friel et al., 2008; Louis and Hess, 2008; McMichael et al., 2008; Patz et al., 2008; Watson et al., 2005). Those at highest risk include populations with a high burden of ill-health, who are sensitive to climate-related health risks, and live in nations with limited technological capacity, weak institutions, high levels of poverty, and political inequality (Costello et al., 2009; Walpole et al., 2009). In the least developed countries (LDCs), climate change is expected to compromise the millennium development goals (Friel et al., 2008) while, in advanced economies, recent studies have also identified significant health vulnerabilities (Ford and Berrang-Ford, 2011; Ford et al., 2011; Hajat et al., 2005, 2010; Ebi, 2009a; Ebi et al., 2009; Kovats and Ebi, 2006).

Finding ways to adapt to the health effects of climate change will be one of the key policy challenges for public health this

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century (Ebi, 2009a; Ebi and Burton, 2008; Ebi and Semenza, 2008). A significant body of scholarship has emerged examining health system vulnerabilities and opportunities for adaptation. Governments at various levels have also begun planning for, and in some cases, initiating adaptation actions (Berrang-Ford et al., 2011; Ford and Berrang-Ford, 2011; Ford et al., 2011; Moser, 2011; Preston et al., 2011; Ebi, 2009b). Despite growing acceptance of adaptation as a public health issue, understanding of the factors that drive adaptation is limited. While several scholars have considered whether adaptation is taking place (Poutiainen et al., in press; Berrang-Ford et al., 2011; Lesnikowski et al., 2011; Preston et al., 2011; Biesbroek et al., 2010; Tompkins et al., 2010; Preston et al., 2009; Gagnon-Lebrun and Agrawala, 2007), few have systematically attempted to identify what makes policy-makers more or less likely to engage in adaptation, particularly in a health context. We therefore have a limited understanding of what contextual factors influence whether countries are likely to be high adapting countries or low adapting countries. Identifying these factors is critical if we are to develop and test hypotheses to better understand why some nations are progressing more quickly on adaptation than others, and to identify nations that are more or less likely to invest in future action.

An existing body of literature considers determinants of and barriers to adaptive capacity, and examines how this in turn impacts vulnerability and adaptation (Huang et al., 2011; Dovers and Hezri, 2010; Gupta et al., 2010; Adger et al., 2009; Smit and Wandel, 2006; Brooks et al., 2005; Ford and Smit, 2004). While it is critical to understand what makes countries more or less capable of adapting, higher adaptive capacity may not necessarily translate into actual adaptation action: adaptive capacity is hypothetical and does not capture whether capacity results in actual action (Eisenack and Stecker, 2012; O'Brien et al., 2006; Repetto, 2009). This paper contributes to this body of literature by assessing statistically significant relationships between core aspects of adaptive capacity and systematically measured adaptation occurring in 38 high income countries. To our knowledge, this is the first study to statistically examine the relationship between determinants of adaptive capacity and adaptation occurring within countries. The findings herein provide an empirical foundation from which to better understand whether countries with higher adaptive capacity are pursuing deeper levels of adaptation planning, and which aspects of adaptive capacity seem to be particularly critical to achieving adaptation gains. Our findings also contribute to our understanding of how certain aspects of adaptive capacity are inter-related with others. The study tests eight factors that capture financial, institutional, regulatory, and normative aspects of adaptive capacity, and provides a basis from which to develop further hypotheses about the translation of adaptive capacity into adaptation.

The factors tested in each hypothesis were selected to represent societal contexts pertinent to anticipatory health adaptation, and are drawn from a basic understanding of the dynamics of vulnerability and adaptive capacity developed in the literature (e.g. Füssel and Ebi, 2009; Smit and Wandel, 2006; Ebi et al., 2006; Costello et al., 2009; Smith and Vogel, 2009; Moser and Ekstrom, 2010). All 38 Annex I countries included here are assumed to have high adaptive capacity with respect to resources, institutions, governance, and information. The analysis focuses on factors at the national level among Annex I Parties to the UN Framework Convention on Climate Change (UNFCCC). This national-level focus reflects the importance of government departments and bodies in promoting (or constraining) health adaptation, and the pivotal role of national governments in climate change policy (Berrang-Ford et al., 2011; Ford and Berrang-Ford, 2011; Dovers and Hezri, 2010; Füssel, 2010a; Smith and Vogel, 2009). The paper goes beyond the existing literature regarding capacity for adaptation to assess whether adaptation is actually occurring, and identify aspects of national contexts that may impact the likelihood of greater or lesser follow-through on adaptation. A key goal of the paper is to also provide a methodological foundation to examine influences on adaptation, developed in a health context but applicable more broadly.

2. Methods

A systematic methodology was developed to examine factors affecting national-level adaptation by: (i) quantifying individual adaptation actions (policies, projects, and programs) reported by Annex I Parties and coding them by both a typology of adaptive measures and by the health vulnerability(ies) targeted, (ii) calculating national adaptation outcomes by two indices that measure the range of adaptation actions being implemented and the range of health vulnerabilities being responded to, (iii) identifying potential factors that might impact progress on adaptation and selecting data sources for these factors, and (iv) calculating statistical relationships between factors and adaptation indices across countries. See Table 1 for a summary and description of the terminology used in this paper.

2.1. Data source: adaptation actions

The first step in the analysis was to systematically quantify the number of adaptation actions being reported among Annex I Parties to the UNFCCC in the Fifth National Communication (NC5). Consistent with Berrang-Ford et al. (2011) and Lesnikowski et al. (2011), adaptation actions are defined here as studies, policies, programs, and projects that are implemented to better understand or reduce vulnerability to the health impacts of climate change. For the purposes of data collection, adaptation was measured by individual actions reported within each country's vulnerability and adaptation chapter of the NC5. This measure of individual actions was then used to calculate indices that compare progress on adaptation to health impacts of climate change at a national level (see Section 2.3 for further information).

The Annex I group includes countries that have committed themselves to reducing greenhouse emissions levels primarily below 1990 levels. Data on adaptation actions were collected from the National Communications of 38 Parties, which are submitted to the UNFCCC Secretariat with the purpose of outlining national progress on implementing the convention. These 38 countries represent 25% of the world's population and include 29 of the 34 Organisation for Economic Co-operation and Development (OECD) countries, providing a broad snapshot of adaptation efforts being made across higher income nations. The most recent series of submissions is the Fifth National Communication, which was

Table 1
Terminology.

Term	Definition
Adaptive capacity	The ability of countries to engage in adaptation
Factors influencing adaptive capacity	National-level aspects of adaptive capacity, encompassing institutional, normative, financial, and regulatory frameworks that facilitate the translation of adaptive capacity into adaptation
Likeliness to adapt	The extent to which countries may channel adaptive capacity into adaptation action
Adaptation action	Policies, programs, and projects that aim to either inform/prepare for action or to reduce vulnerability to impacts of climate change
Adaptation outcomes	National-level measure of adaptation progress arrived at based on the range of adaptation actions reported through the Fifth National Communications

submitted during 2009 and 2010 and addresses impacts, vulnerabilities, and adaptation in accordance with commitments listed in Article 4 of the Convention (see Appendices A and B in Supplementary Materials). The NC5 was therefore selected as the data source for this analysis.

These reports are robust data sources for a systematic analysis because they provide a standardized source of information on adaptation for high-income countries. As reports submitted by national governments to the UNFCCC Secretariat, they are expected to comprehensively outline climate change policies and programs, offering a picture of priorities and progress. The reports have been used to assess the general status of adaptation among Annex I countries (Gagnon-Lebrun and Agrawala, 2007) and the specific status of health adaptation among these countries (Lesnikowski et al., 2011), but to our knowledge this is the first time they – or other systematically collected international sources – have been applied to examine contextual factors associated with adaptation progress.

Discrete actions in the NC5 were categorized under three levels of action – recognition, groundwork, or adaptation – building upon the work of Lesnikowski et al. (2011). These levels of action in turn draw on scholarship that defines adaptation as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (McCarthy et al., 2001). Our separation of levels of action, however, further distinguishes between types of action that tangibly affect human systems and actions that are taken to prepare for or inform tangible action, providing a snapshot of the range of adaptation policies, programs, and projects being completed in Annex I countries. *Statements of recognition* indicate an awareness of health risks of climatic change, but do not indicate that any action has been taken to respond to risks posed. *Groundwork actions* constitute preliminary steps taken toward adaptation that inform and prepare countries to implement adaptations, but do not themselves constitute changes in policy, programs, or delivery of services. The five types of groundwork actions include impact and vulnerability assessments, adaptation research, development of conceptual tools, stakeholder networking, and provision of policy recommendations. *Adaptation actions* are tangible steps taken to alter institutions, policies, programs, built environments, or mandates in response to experienced or predicted risks of climate change. The eight types of health adaptation actions include: legislative change, departmental development (working groups, ministries, departments), public awareness and outreach, surveillance and monitoring, infrastructure and technology, program or policy evaluations, financial support for autonomous adaptation, and medical interventions (Lesnikowski et al., 2011).

All actions coded from the NC5s address at least one health vulnerability associated with climate change. Health vulnerabilities were defined according to categories of major impacts identified in the IPCC Fourth Assessment Report (2007). They include extreme temperatures, declining air quality, infectious disease, extreme weather events, and food and water safety and security. Countries report on adaptation across a wide range of sectors in the NCs, of which health is one. Given the range of sectors that affect health, data inclusion was approached in terms of adaptation to health vulnerabilities, rather than in terms of adaptation in the health sector. This expanded inclusion criteria to actions being implemented within other sectors that aim to reduce impacts and vulnerabilities that have consequences for health. Furthermore, data inclusion criteria did not require that every action explicitly recognize the health aspects of each action. Actions that addressed health impacts as defined in the findings of the Fourth Assessment Report were included as implicitly addressing human health. For example, municipal planning guidelines addressing flood management infrastructure would be included because of the implications flood events have for public safety, drinking water quality, and communicable disease. Actions that concerned vulnerabilities which do not as directly impact human health were omitted. These largely included adaptations for biodiversity, the economy, and industry (as their primary impact is beyond health even though it is recognized that these can have long term health impacts). A detailed codebook defined criteria for inclusion and exclusion of information with regards to adaptation actions, as well as indicators that standardized information collection for discrete actions (see Appendix C in Supplementary Materials).

Two individuals separately coded each NC5, and all data were then compared to ensure accuracy and validation. Every NC5 submitted in English and French was coded directly by the team, with submissions in Spanish and Russian (Russia, Ukraine) coded by native speakers.

It is important to consider that the National Communications are country-level reports, and therefore focus primarily on actions occurring either exclusively within or in cooperation with national level governments. Indeed, 78% of groundwork and adaptation actions discussed in these 38 reports occurred with involvement from a national government. Information about actions occurring at the regional or local level is provided in lesser detail; data used in this study should therefore not be interpreted as a complete inventory of adaptation occurring in these 38 countries. Furthermore, data provided in individual NC5s are subject to varying levels of reporting detail, which suggests that additional adaptation efforts may be ongoing within Annex I countries that are not being reported in the National Communication reports.

We attribute this variation in reporting detail to the vague reporting guidelines set out by the UNFCCC Secretariat. Furthermore, given the purpose of the NCs (to self-report on progress toward meeting requirements of the UNFCCC agreement) it is also important to acknowledge that there is some incentive for countries to overemphasize attributes of adaptation actions. Some countries therefore report more liberally on adaptation-relevant initiatives and also draw more attention to mainstreaming efforts, while others restrict reporting to examples of adaptation conducted in direct response to climate change impacts. Given the need for a data source that provides adaptation information across the majority of high income countries, the NC5 remains the most appropriate source of information for analysis of this nature. To facilitate researcher consistency in determining what qualifies as adaptation, we accepted all country descriptions of adaptation initiatives that explicitly identified climate change and at least one relevant vulnerability in their description.

In total, 1912 groundwork and adaptation actions were documented in the 38 NC5s. Australia, Finland, Canada, and the UK provided the greatest amount of information about groundwork and adaptation actions, over 100 initiatives each. Croatia, Iceland, Liechtenstein, Luxembourg, and Slovenia provided the least amount of information, with fewer than 25 initiatives reported by each. Single programs, policies, or projects that contained multiple types of groundwork or adaptation (e.g. a heat surveillance system that also issues public awareness alerts) were coded for each type of action.

2.2. Data source: adaptation factors

Ability to engage in adaptation is impacted by a variety of factors operating at a national and local level. The data provided in the NC5 focus largely on initiatives occurring at a national level or with the support of national institutions. Factors tested in this study are therefore appropriate to this scale and are most likely to operate on a national level.

Eight potential factors influencing adaptation were selected for analysis: international treaty participation (Esty et al., 2005), domestic environmental governance (Esty et al., 2005), social expenditures (OECD, 2007), public perceptions on climate change (Pugliese and Ray, 2011), commitment to mitigation (UN Statistics Division, 2010), size of economy (GDP) (World Bank, 2008), population (World Bank, 2008), and perception of corruption (Transparency International, 2009). These factors were selected based on potential determinants of adaptive capacity identified by the literature, including availability of resources, institutional structures, human and social capital, and public perceptions of risk (Kovats et al., 2003; Smit and Pilifosova, 2001). These factors capture total availability of national resources for addressing environmental and health externalities (measured in total GDP), country size (population), institutional capacity (domestic environmental governance), public social commitments (social expenditures), public pressure (public perspectives on personal risks of climate change), commitment to mitigation of future climate change (reductions in carbon emissions), participation in institutions of global governance (international treaty membership), and quality of governance (perception of corruption). Experience with extreme events has been widely studied as an impetus for engaging in adaptation (e.g. Berrang-Ford et al., 2011), but was not included in the short list of factors applied in this analysis. The primary reason for this omission is our specific interest in how institutional contexts are related to adaptation, not characteristics of exposure. These factors capture different aspects of national-level adaptive capacity, including institutional, regulatory, financial, and normative influences on adaptation outcomes.

Only eight factors are tested in this analysis as the primary purpose of this work is the development and initial application of a systematic approach for examining how national processes impact adaptation. Further applications of this approach should examine a

Table 2
Adaptation factors.

Factor	Description	Reference year
Global environmental governance (treaty participation)	Experiences with international environmental agreements (IEA) like the Montreal Protocol on Substances that Deplete the Ozone Layer indicate that participation in international treaties can result in positive environmental policy outcomes. We thus examine whether there is a statistically significant relationship between greater participation in IEAs and the range of adaptation policies, programs and projects reported in the NC5. The Environmental Sustainability Index creates a participation score ranging from 0 to 1 and is based on the level of participation in the UNFCCC and Kyoto Protocol, Vienna Convention and the accompanying Montreal Protocol, UN Convention on Biological Diversity, UN Convention to Combat Desertification, CITES, the Basel Convention, and the Ramsar Convention. Points are allocated based on signature, accession, ratification without signature, ratification with signature, acceptance, approval, or succession. Data were available for 36 countries	2004
Domestic environmental governance	We examine whether greater commitment to environmental protection at the national level is significantly related to higher levels of adaptation: do countries that already commit to stronger environmental protection and management report a larger range of adaptation policies, programs, and projects to the UNFCCC? The World Economic Forum Survey on environmental governance creates a score (minimum score 27.83, maximum score 59.74) based on pollution regulations, waste regulations, regulatory frameworks, leadership in policy, consistency in regulations and enforcement, and flexibility of regulations. Data were available for 36 countries	2003/2004
Social expenditures	We examine whether there is a statistically significant relationship between the strength of social expenditures at a national level and measured adaptation. This study is particularly concerned with adaptation to health impacts of climate change; this measure is designed to test whether countries that invest in stronger public social programs (including preventative care, health insurance, and social determinants of health) at the national level are more likely to act on health risks of climate change. OECD data for 29 countries measures the percentage of GDP spent on social programs related to old age, survivors, incapacity, health, family, active labor, unemployment, and housing	2007
Public perceptions of climate change risks	Our understanding of how public opinion impacts climate policy is much debated (Marquart-Pyatt et al., 2011; Kim, 2011). We use public perceptions of climate change risks as a proxy for public attitudes on climate change to assess whether there is a relationship between perceived levels of risk from climate change impacts and measured adaptation. Gallup Poll surveyed 206,193 individuals in 128 countries about perceived personal threats from climate change. Individuals who responded positively that they knew a great deal or something about climate change were asked whether they feel there is a very or somewhat serious personal threat from climate change. Percentages are reported of individuals who answered positively. Nationally representative samples of adult populations age 15 and older were interviewed by phone or in person. Data were used for 26 countries	2007/2008
Commitment to GHG mitigation	Commitment to reducing emissions was selected to test whether there are trade-offs between adaptation and mitigation actions, or whether they are going to be pursued at the same time. This follows on literature examining the relationship between adaptation and mitigation (Klein et al., 2007). If mitigation and adaptation are not compatible, we would expect to see an inverse relationship between the two. Country commitment to mitigation is measured by percentage change in carbon emissions in 1990 to 2007. Data were available for all countries from the UN Statistics Division	1990 – 2007
GDP	GDP was selected to measure whether there is a statistically significant relationship between total country income and measured adaptation. Economic growth has been shown to affect adaptation through sensitivity to risk and adaptive capacity, impacting countries abilities to absorb climate stress (Bowen et al., 2012). As a widely used proxy for measuring economic growth, GDP has been shown elsewhere to significantly affect changes in government social expenditures (including old age, health, family, housing, and unemployment) (e.g. Clemente et al., 2012; Herce et al., 2000). It was thus selected for this study to assess whether a relationship could also be detected between economic growth and adaptation. Future analyses that examine high, middle, and low income countries may wish to go beyond measuring national economic growth to also consider income distribution (i.e. standard of living) within countries, as this is likely to vary considerably among high and low income economies. Data were available for all countries from the World Bank World Development Indicators	2008
Population	Population was tested to determine whether a statistically significant relationship is found between country size and adaptation. This is based on findings in Berrang-Ford et al. (2011), which indicated that large countries are more likely to be high adaptors. Data were available for all countries from the World Bank World Development Indicators	2008
Good governance (perception of corruption)	Public perception of corruption levels was tested as an indicator of good governance, which is a mediating factor with respect to the implementation of public policy. Do countries with stronger records of transparency and institutional legitimacy demonstrate higher levels of adaptation action? Data were available from the 2009 Corruption Perceptions Index produced by Transparency International, which measures perceptions of corruption in the public sector. Scores were available for all countries except Liechtenstein and ranged from a high of 9.4 to a low of 1.1	2009

larger number of factors and may establish more complex hypotheses. When selecting data for each factor, we took into account that the NC5 was largely drafted during 2008, and so used information primarily from the mid-2000s. See Table 2 for definitions of adaptation factors and data sources. For full details on data available for each factor please refer to Appendix D: Adaptation Scores and Factors in Supplementary Materials.

Thirty-eight countries were included in the analysis. Data were available for the overwhelming majority of countries: treaty participation (36), domestic environmental governance (36), social expenditures (29), public perceptions of climate change risks (26), commitment to GHG reduction (38), perceptions of corruption (37), GDP (38), and population (38).

2.3. Statistical analysis

Two indices were calculated that build on action-level data on adaptation collected from the NC5. These indices measure (i) the range of types of action being taken within each country (adaptation response score – ARS) and (ii) the range of health vulnerabilities being addressed at the groundwork and adaptation levels (health areas score – HAS). Both indices are weighted according to level of action: one indicates a groundwork level of action, and two indicates an adaptation level of action. While statements of recognition demonstrate that countries are at least thinking about climate change and health, they do not indicate that any action is being taken to respond to climate change, and therefore were assigned a value of 0 and not included in this analysis. See Table 3 for examples of high, medium, and low scoring countries.

Given that some variation exists in the quality of reporting by individual nations (even in the context of the systematic reports), we caution against placing too much weight on small differences between countries on these indices and suggest that these country adaptation scores be used to compare groupings of high, medium, and low adaptors. To reduce bias from variations between NC5s in the quantity of individual actions reported, the adaptation and health indices were calculated based on how many of the 13 types of action were identified in the adaptation chapter, as well as how many kinds of vulnerability were addressed at a groundwork and an adaptation level. The scores therefore are not reflective of the absolute number of actions reported by each country, but rather the range of adaptation being reported by each country.

The ARS captures the range of different types of groundwork and adaptation action being taken by each country according to the weighted values described above. The ARS was calculated by the following equation:

$$\mathrm{ARS} = (\text{Action Type} \times \text{Level of action})$$

Table 3
Example country profiles.[a]

	High: Belgium ARS: 18 HAS: 28 HAS: 28	Mid: Canada ARS: 12 HAS: 15	Low: Iceland ARS: 3 HAS: 3
Groundwork actions	Impact/vulnerability assessments	Impact/vulnerability assessments	Impact/vulnerability assessments
	Adaptation research	Adaptation research	Adaptation research
	Conceptual tools	Conceptual tools	Conceptual tools
	Stakeholder networking	Stakeholder networking	Stakeholder networking
	Policy recommendations	Policy recommendations	Policy recommendations
Adaptation actions	Departmental development	Departmental development	Departmental development
	Legislation	Legislation	Legislation
	Public awareness and outreach	Public awareness and outreach	Public awareness and outreach
	Surveillance and monitoring	Surveillance and monitoring	Surveillance and monitoring
	Infrastructure and technology	Infrastructure and technology	Infrastructure and technology
	Medical interventions	Medical interventions	Medical interventions
	Financial support	Financial support	Financial support
	Evaluations	Evaluations	Evaluations
Health vulnerabilities (groundwork level)	Extreme heat	Extreme heat	Extreme heat
	Extreme cold	Extreme cold	Extreme cold
	Air quality	Air quality	Air quality
	General extreme weather events	General extreme weather	General extreme weather
	Floods	Floods	Floods
	Fires	Fires	Fires
	Storms	Storms	Storms
	Drought	Drought	Drought
	Land shifts	Land shifts	Land shifts
	Food safety and security	Food safety and security	Food safety and security
	Water safety and security	Water safety and security	Water safety and security
	Infectious disease	Infectious disease	Infectious disease
	General health	General health	General health
Health vulnerabilities (adaptation level)	Extreme heat	Extreme heat	Extreme heat
	Extreme cold	Extreme cold	Extreme cold
	Air quality	Air quality	Air quality
	General extreme weather events	General extreme weather	General extreme weather
	Floods	Floods	Floods
	Fires	Fires	Fires
	Storms	Storms	Storms
	Drought	Drought	Drought
	Land shifts	Land shifts	Land shifts
	Food safety and security	Food safety and security	Food safety and security
	Water safety and security	Water safety and security	Water safety and security
	Infectious disease	Infectious disease	Infectious disease
	General health	General health	General health

Shading refers to types of action or health vulnerabilities reported in the NC5 of that country.
[a] Each cell provides a list of all possible types of action and health vulnerabilities.

A maximum ARS indicates that a country has been, is, or will be engaged in each of the 5 types of groundwork action and 8 types of adaptation action. It would be calculated as follows:

$$\text{ARS} = (5 \times 1) + (8 \times 2) = 21$$

The HAS captures the number of health vulnerabilities being addressed at groundwork and adaptation levels. It therefore considers both the range of health vulnerabilities being responded to, and the level of action being taken on each:

$$\text{HAS} = (\text{Health vulnerability} \times \text{Level of action})$$

A maximum HAS indicates that a country addresses every health vulnerability at both the groundwork and adaptation levels. It would be calculated as follows:

$$\text{HAS} = (13 \times 1) + (13 \times 2) = 39$$

Pearson correlation coefficients were used to evaluate statistical associations between variables representing adaptation factors and the ARS and HAS. The number of observations (countries) in the dataset provided insufficient statistical power to allow for multivariate regression analysis. The purpose of the analysis was neither to establish causation nor to attempt to quantify causal contributions. Instead, we explore preliminary evidence of correlative trends in factors hypothesized to be potential predictors of adaptation. The results are thus exploratory, contributing to an emerging and critically needed literature on systematic approaches for quantitative assessment of adaptation predictors. The natural log of GDP and population were used. Associations were considered significant at the 95% confidence level. All statistical analyses were conducted in STATA (StataCorp v.11).

3. Results

No country received a maximum adaptation response score (21) or health areas score (39). Australia and Belgium received the highest ARS (18), while Russia received the lowest (2). The median ARS was 11. Health area scores ranged from a high of 28 (Belgium and Italy) to a low of 3 (Iceland, Luxembourg, and Slovenia). The median HAS was 14. See Table 3 for examples of the range of actions and health vulnerabilities reported by countries fitting the high, medium, and low ranges of adaptation response scores and health areas scores.

The adaptation response score and health areas score were strongly correlated with GDP, population, international treaty participation, domestic environmental governance, and perceptions of corruption. Adaptation was independent in these analyses of levels of mitigation and other social investments, as well as of personal threats from climate change perceived by the public (see Table 4).

3.1. Adaptation response score

Significant correlations were found between adaptation response score and treaty participation, domestic environmental governance, GDP, population, and perception of corruption (Fig. 1). A higher level of participation in international treaties was associated with higher ARS's. All six countries (France, Germany, Norway, Sweden, Switzerland, and UK) that received perfect treaty participation scores had ARS's above the median of 11. Lower levels of international treaty participation tend to correlate with lower ARS's; of 16 countries that had treaty participation scores below the median score of 0.82, 12 also had ARS's below the median level. Australia stands out as scoring only a 0.79 on the treaty participation index, and yet (along with Belgium) having the highest ARS of 18. Similarly, lower levels of national environmental governance tended to correlate with lower ARS's; of 18 countries that had Domestic Environmental Governance scores below the median score of 46, 12 had ARS's below the median level. Of the six countries with environmental governance scores below the median and ARS's above the median, four (Germany, Ireland, Italy, Spain) had treaty participation scores above the median. Notably, almost all countries with ARS's above the median had a treaty participation score and/or domestic environmental governance score above the median; the only exception to this trend is Ukraine, which has both a treaty participation score and domestic environmental governance score below median levels.

Table 4
Adaptation action and key national indicators.

Factor	Adaptation response score (ARS)	Health areas score (HAS)
	Correlation coeff. (*prob*)	Correlation coeff. (*prob*)
Treaty participation	0.47 (*<0.01*)**	0.26 (*0.13*)
Domestic environmental governance	0.50 (*<0.01*)**	0.31 (*0.06*)
Social expenditures	0.09 (*0.63*)	0.08 (*0.68*)
Public attitudes on climate change risks	0.20 (*0.32*)	0.09 (*0.68*)
Commitment to mitigation	0.21 (*0.20*)	−0.15 (*0.37*)
GDP (log 10)	0.51 (*<0.01*)**	0.55 (*<0.01*)**
Population size (log 10)	0.36 (*0.03*)*	0.52 (*<0.01*)**
Perception of corruption	0.35 (*0.03*)*	0.08 (*0.62*)

* Significant at 95% confidence level.
** Significant at 99% confidence level.

GDP and population were also found to be significantly associated with ARS's. Of the 10 countries with GDPs above a trillion USD, nine had ARS's above the median. Russia is a notable outlier, with a GDP of over $1.5 trillion USD but a very low ARS of 2. Only six of the 21 countries with ARS's above the median had GDPs below the median. It is also apparent that higher GDP levels do not necessarily translate into higher levels of adaptation; Austria and Poland both have GDPs above the median (almost 415 million and 529.5 million, respectively), but low ARS's of six and seven. Three countries have population sizes above 100 million (Japan, Russia, US), and two of these countries (Japan and US) have ARS's at or above the median (11 and 14, respectively). Of the ten countries with populations between 20 and 100 million, only two (Poland and Romania) have ARS's below the median. Results demonstrate, however, that larger GDPs and populations do not always correspond to more adaptation; Russia is a clear outlier. Russia's low score on the corruption perceptions index, representing higher levels of perceived corruption in the public sector, suggests that poor governance may mediate the significance of other factors (such as GDP) in driving adaptation. Four countries with ARS's above the median are notable for having both GDPs and populations below the median: Denmark, Norway, Sweden, Switzerland, and Ukraine. All other countries with ARS's above the median have GDPs and/or populations above the median.

A further three variables were found to be statistically insignificant when correlated with adaptation. Social expenditures ($p = 0.63$), public perceptions of climate change risks ($p = 0.32$), and commitment to mitigation ($p = 0.21$) were not significantly associated with adaptation response score.

3.2. Health areas score

GDP and population were correlated with action on a wider range of health vulnerabilities, as reflected in national health area scores (Table 4). Statistically significant relationships were

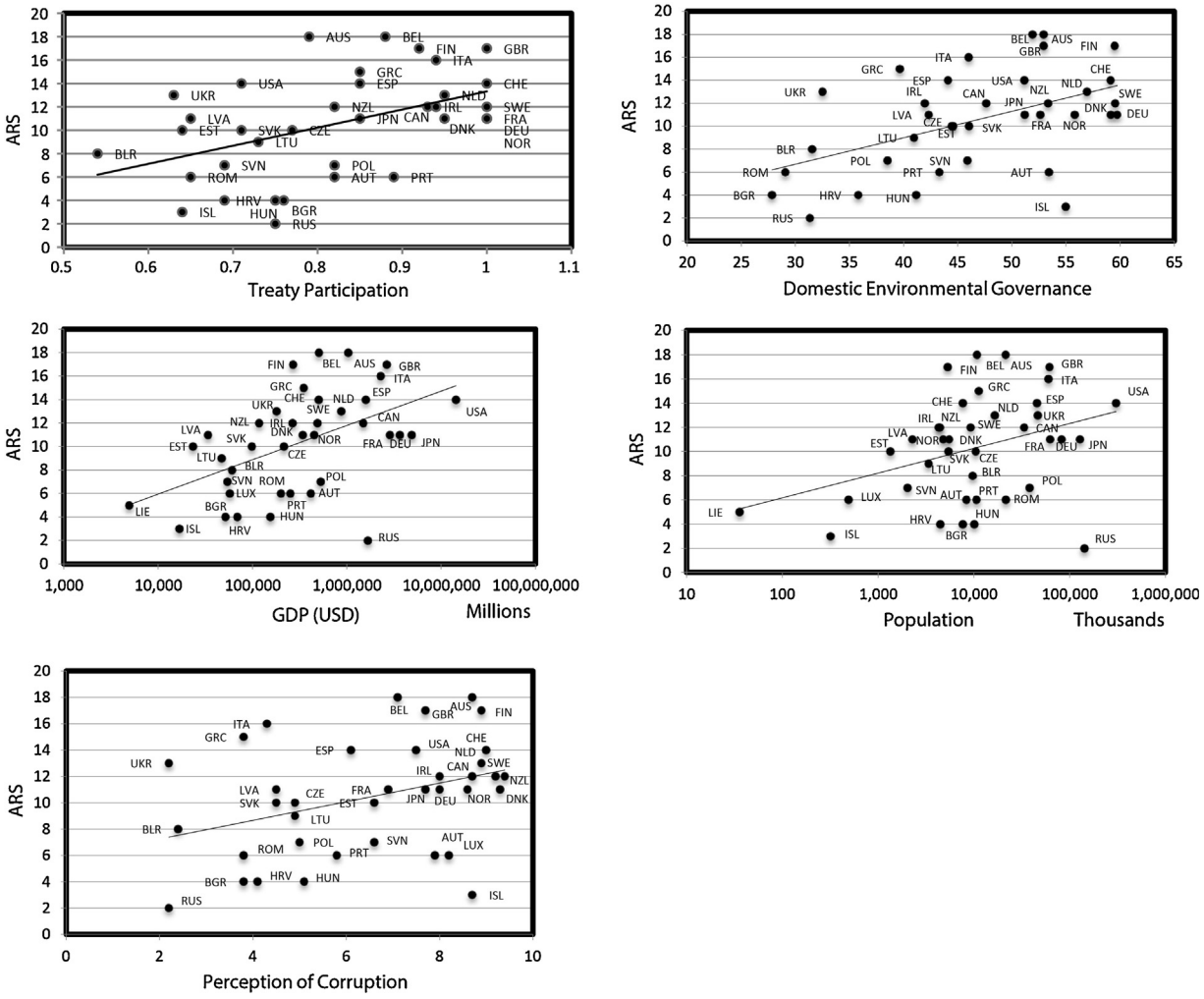

Fig. 1. Adaptation response scores. Black line indicates best-fit linear trendline.

identified between HAS's and both GDP and population (Fig. 2). The remaining six variables demonstrated no relationship with HAS's. Treaty participation ($p = 0.13$), social expenditures ($p = 0.68$), public attitudes on climate change risks ($p = 0.68$), commitment to mitigation ($p = 0.37$), and perception of corruption ($p = 0.62$) were not statistically significant, while domestic environmental governance ($p = 0.06$) was borderline significant.

These relationships indicate that wealthier, larger countries are more likely to be engaged in addressing a wider range of health vulnerabilities. Of the nine countries with GDPs over a trillion USD, seven have HAS's at or above the median score of 14. Two of the three countries with populations over 100 million (Japan, Russia, the US) have HAS's well above the median (22 and 26, respectively). Of those ten countries (Australia, Canada, France, Germany, Italy, Poland, Romania, Spain, Ukraine, and UK) with populations between 20 million and 100 million, seven have HAS's above the median.

Russia and Spain stand out as outliers, with very high GDPs and populations but HAS's of eight and nine, respectively. Conversely, Belgium and Finland demonstrated very high HAS's (28 and 25, respectively), but GDPs around the median, and smaller populations of 10.7 million and 5.3 million, respectively.

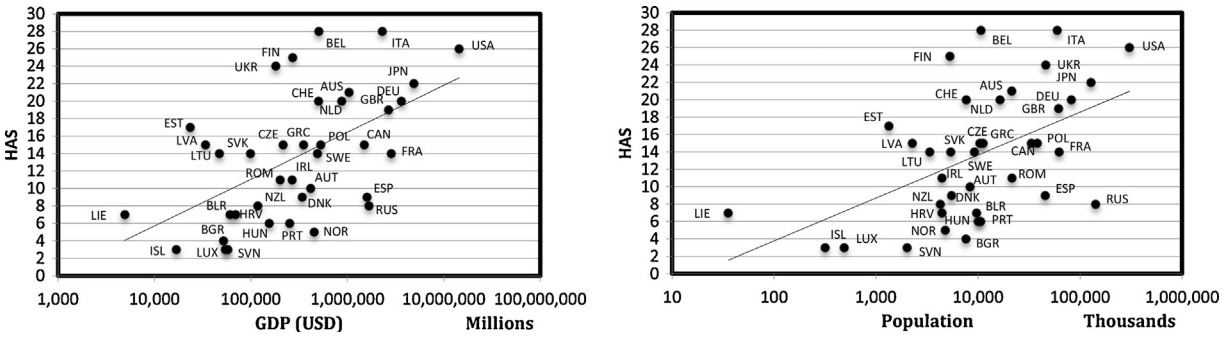

Fig. 2. Health areas scores. Black line indicates best-fit linear trendline.

4. Discussion

The results of this analysis provide a foundation to begin identifying national characteristics that differ among high and low adaptors. Here we find that adaptation response scores are significantly related to participation in international environmental treaties and national environmental governance, as well as population size and GDP. Health areas scores are found to be significantly related to population size and GDP. Several countries are outliers to these trends. Finland received a high ARS and HAS, yet has a population and GDP below median levels. Russia, on the other hand, received a very low ARS and HAS, and yet has one of the largest populations and GDPs of the Annex I group. It is worth noting that in measurements of participation in international treaties and national environmental governance, however, Finland received significantly higher scores than Russia. This indicates that while some theoretical determinants like GDP are highly associated with adaptation action, how they intersect with other contextual factors impacts adaptation outcomes. These results support hypotheses found in the adaptive capacity literature that availability of resources impacts a country's ability to engage in adaptation (Berrang-Ford et al., 2011; Ebi et al., 2006), but also point to other institutional and regulatory factors that affect how fully they result in adaptation actions (Kovats et al., 2003).

This study provides preliminary indication that countries with strong institutional frameworks for environmental governance and/or incentives structures are also likely to be higher adaptors to climate change. This research indicates no evidence of commitment to mitigation and commitment to adaptation being significantly correlated. The study determined that GDP is significantly related to health adaptation, but at the same time weaker performance among some of the world's wealthiest countries indicates that resource availability alone may be insufficient to provoke high levels of adaptation in the absence of policy commitments. This suggests that barriers to adaptation exist within high-income countries that limit how much adaptive capacity is being translated into health adaptation action. Longitudinal research is needed to more fully understand what leads to more or less health adaptation.

The methodology employed in this study is derived from, and advances in a new direction, approaches used in vulnerability and adaptation scholarship that allow systematic assessments of the complex factors affecting environmental health outcomes (Ford et al., 2013; Hambling et al., 2011; Lesnikowski et al., 2011; Berrang-Ford et al., 2011; Füssel, 2010b; Tompkins et al., 2010; Brooks et al., 2005). Significant correlations provide a preliminary indication of contextual factors associated with national adaptation outcomes, but cannot be used to infer causality due to the absence of longitudinal data. Furthermore, the current study is limited by the sample size of UNFCCC Annex I countries, which prevents the use of a multivariate analysis and limits statistical power to detect significant associations. Strong associations were nevertheless found between both ARS and HAS and population and GDP, and between ARS and international treaty participation and domestic environmental governance. These results indicate that testing a wider number of factors with a larger sample of countries would be fruitful, and can provide a basis from which to develop more complex hypotheses regarding drivers of adaptation. Further testing is required to better understand these roles and identify other factors relevant to adaptation.

Of note, the study design involving systematic and replicable procedures enables tracking of progress over time and should facilitate future longitudinal analyses (Ford et al., 2013). Future work for example, could compare progress on adaptation and health vulnerabilities across the Fifth and Sixth National Communications.

The statistical association between GDP and population and both ARS's and HAS's suggests that large countries and those with higher available national resources may be more willing and/or able to allocate money and attention to adaptation issues. These findings are consistent with literature suggesting that larger countries may be more likely to engage in proactive adaptation (Berrang-Ford et al., 2011), and have significant implications for considering the obligation of high income countries to conduct resource and technology transfers to low income countries. Given, however, the extremely low ARS of Russia, a country with one of the highest GDPs of the Annex I group, further analysis is needed to more fully understand how size of economy interacts with other factors to make countries more active adaptors. While GDP may reflect greater resource availability, this wealth may be insufficient to facilitate adaptation in the absence of broader policy commitments, such as treaty participation or environmental stewardship. Countries with a high GDP but low participation level in treaties and national environmental governance tended to have lower ARS's than those countries with lower GDP's but high participation levels in treaties and national governance. These trends indicate that while resource availability may be a facilitator of adaptation, environmental governance frameworks are likely a stronger predictor of adaptation levels.

Without effective policy translation, however, these governance frameworks may have negligible impacts on adaptation. Quality of governance was therefore tested to determine whether there is a relationship between transparency, legitimacy of institutions and policy-makers, and adaptation. Using the corruption perceptions index (CPI) produced annually by Transparency International, a statistically significant relationship was found between perceptions of corruption and ARS's; lower levels of perceived corruption were significantly associated with higher levels of adaptation. These findings suggest that the quality of governance may play a role in supporting adaptation.

A significant relationship was also found between participation in international treaties and adaptation response levels, but not health areas. The absence of a relationship between treaty participation and HAS may be explained by the range of treaties included in our proxy variable. None of the treaties included in the Environmental Sustainability Index measure were health-focused, indicating that adaptation issues are being addressed primarily from an environmental perspective and without a health-specific lens. International treaties such as the Montreal Protocol on Substances that Deplete the Ozone Layer have been shown to successfully reduce negative environmental impacts (Mader et al., 2010), but these findings suggest further study is needed as to whether environmental treaties are being underutilized in regards to the integration of health considerations into actions addressing environmental degradation, and more specifically climate change. Wider inclusion of health issues in treaties and reporting mechanisms may be an appropriate mechanism for better engaging health policy-makers and encouraging higher prioritization of health issues on climate change policy agendas. Current studies indicate that prioritization and allocation of resources to climate change and health topics is low (Ford et al., 2011; Kovats, 2010; Ebi, 2009b; Jessup et al., 2013), limiting the development of a more nuanced understanding of emerging climate change challenges for the public health sector and, beyond this, the development of effective adaptation responses.

Reductions of CO_2 emissions between 1990 and 2007 were used as a proxy for measuring commitment to mitigation as an indicator of likelihood to commit to adaptation. No significant relationship was found between emissions reductions and ARS or HAS. Countries with the largest emissions reductions over this period were former-Soviet states transitioning to a market economy, which can be at least partially attributed to economic turmoil

throughout the 1990s that characterized this process and not to dedicated efforts to reduce GHGs (Ciais et al., 2010). These countries also tended to score lower on the ARS. However, given that these emissions reductions were not derived from planned mitigation policy, these countries should be considered outliers when measuring commitment to emissions reductions (interpreted as a broader commitment to addressing climate change) as a driver for adaptation; in the case of the former-Soviet economies, these unplanned reductions of CO_2 emissions cannot be considered a true proxy for commitment to mitigation. When statistical tests were run without former-Soviet countries, however, commitment to mitigation remained statistically insignificant. Qualitative results indicate that the higher adaptors identified in this study varied in regards to emissions reduction, and by extension commitment to mitigation. A handful of non-Soviet countries demonstrated high adaptation scores as well as reductions in emissions: Belgium, Switzerland, and the UK. Some countries that scored in the top 25% on ARS and HAS, however, also experienced significant increases in emissions between 1990 and 2008, notably Australia, Finland, and the US. These results suggest that national motivations to mitigate greenhouse gas emissions may differ from motivations to engage in adaptations. Notably, no clear regional trends were identifiable in the data to explain these differences.

There is no significant relationship detected between the percent of GDP spent on social expenditures and adaptation scores. Commitment to social protection, as indicated by the percentage of GDP spent, was not sufficient to predict adaptation in the absence of strong environmental governance and treaty commitment. Previous literature has suggested that national priorities, including political will, stakeholder engagement, and economic and political priorities play a significant role in determining the ability of countries to progress toward adaptation goals (Westerhoff et al., 2011; Haddad, 2005), and that understanding national values, worldviews, and culture is critical to understand why nation's choose to pursue particular policies on climate change (Adger et al., 2009; Tompkins and Adger, 2005). Our evidence suggests that general commitment to social spending may not be enough to ensure actions will be taken to reduce the health burden of climate change. Revisiting the relationship between national values and priorities, social spending, and climate change adaptation must therefore be a key part of future efforts to develop a model of adaptation drivers.

Finally, these results suggest that public awareness about climate change risks may not lead directly to adaptation. We are particularly interested in whether a higher sense of personal risk from climate change is being channeled by policy-makers into higher levels of planned adaptation. There was no significant association between public perceptions of risks of climate change and adaptation. This could be for several reasons—public views are continuing to evolve regarding the severity of risks, the current lack of policy mechanisms to translate awareness of risks into policy, or the perception that there is limited room for action on climate change. Public opinion on climate change is a challenging factor to analyze because of its relatively volatile nature. For example, data gathered by the Pew Research Center indicates that the percentage of Americans stating that climate change should be a "top priority" declined from 43% in 2005 to 29% in 2011 (Pew Research Center for the People and the Press, 2005, 2011). Likewise, the relatively high perceptions of climate change risk observed by Gallup in 2007/2008 data fell substantially in following years. The sudden drop in risk perceptions could be a result of concerns over the global economic downturn, efforts by climate change skeptics to undermine public trust in climate science and the ensuing 2009 'Climategate' scandal (Marquart-Pyatt et al., 2011), or perceived inertia in international climate change talks (Pugliese and Ray, 2011). Pielke (2010), however, argues that public opinion across countries is within a sufficient range to support action on climate change policy, indicating that political will is in fact not a barrier to action. If this is the case, then it remains to be determined whether the public realizes how much can be done to adapt, and whether public perceptions of risk are being interpreted by policy-makers as motivation to adapt or to mitigate. It is worth noting that this measure of public perception of risk only considers general attitudes toward long-term climatic change. It does not capture the relationship between public opinion, experiences with individual extreme events, and adaptation. Other findings indicate that experiences with extreme events have a positive impact on willingness to engage in adaptation (Adger et al., 2013; Biesbroek et al., 2010; Tompkins et al., 2010; Penning-Rowsell et al., 2006), providing an opening for further studies to systematically measure the relationship between adaptation and experiences with extreme events. Furthermore, this study only examines anticipatory, public adaptation and so is not able to measure private adaptive responses taken by individuals who perceive higher personal risk from climate change. It may also be worthwhile to examine the relationship between general levels of environmental literacy and private adaptation across countries.

This analysis demonstrates that it is possible to examine potential factors contributing to adaptation and test their relevance against systematically measured adaptation. The methodology developed in this study provides a valuable approach for identifying possible drivers of adaptation. It should be expanded to study middle and low income countries, which are likely to be at high risk from climate change and also exhibit poorer health profiles resulting from impacts of other social determinants of health, such as education and income, and for whom lower resource availability may present a more significant constraint. Longitudinal analysis would increase the potential to infer causal relationships and allow perspective on changes in adaptation and associated policies over time. Inclusion of both more countries and longitudinal data would give a sufficiently large dataset to allow multivariate analysis and the associated analytical nuance required to examine more fully the relationships we explore and hypothesize here. A broader comparison of likeliness to adapt will aid policy-makers in identifying those countries with greater barriers to adaptation, and so facilitate a more effective distribution of resources and tools that support those countries at greatest risk of falling behind on health adaptation.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2013.04.008.

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