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Harsh climate promotes harsh governance (except in cold-dry-wealthy environments)

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ABSTRACT: Human societies are usually thought to adapt culturally to mean climatic temperature. Here we alternatively propose that cultural adaptations are fine-tuned, using monetary means as tools, to harsh deviations from optimally livable winter and summer temperatures around 22°C. We test for the first time the interactive impacts of cold demands, heat demands, precipitation, and income on the autocracy of central government. Eight regression analyses across 173 nations, with R^2 ranging from 0.29 to 0.55, show that political cultures vary from maximally autocratic in poor countries threatened by demandingly cold and dry climates, to maximally democratic in rich countries challenged by demandingly cold and dry climates. Moreover, demandingly hot and dry climates appear to promote autocracy everywhere, irrespective of the country's level of income. The best documented rival explanations, including human-to-human transmitted diseases, ethnic diversity, and low average intelligence of the population, could not account for the findings. This kind of evidence may lead climate-culture scholars to move away from climatic determinism toward climato-economic theory building on the origins of cultures.

KEY WORDS: Cold · Heat · Precipitation · National income · Autocracy · Democracy

1. INTRODUCTION

Cold winters and hot summers are unkind to human societies for a number of reasons. All warm-blooded species have evolved to thrive in climates with temperate seasons, and come under stress in colder-than-temperate and hotter-than-temperate environments (Hill et al. 2013, Li et al. 2013). Thermoregulation also implies that humans must drink and eat a lot, with the consequence that it is stressful when arctic-like or desert-like conditions threaten safe drinking water, flora, and fauna. Relatedly, navigating between being frozen and being burnt to death, societies have to take more bold steps in protecting public health against more extreme temperatures. In short, harsher winters and summers require greater cultural adjustments to meet existential needs for thermal comfort, nutrition, and health.

It has been suggested that dangerous climates can be better managed autocratically than democratically. Milgram (1974, p. 123–124), for example, argued that 'the formation of hierarchically organized groupings lends enormous advantage to those so organized in coping with dangers of the physical environment.' Tellingly, during the fourth millennium BCE, societies in cooling and drying habitats located alongside major rivers in the Near East (e.g. the Tigris, the Nile, the Indus) restrained their freedoms by tightly organizing agricultural labor and centralizing power in the hands of kings and priests (Nissen 1988). Five millennia later, when the Little Ice Age replaced the Medieval Warm Period, essen-

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tially the same adaptational processes of formalization and centralization following climatic deterioration seem to have pushed Norse communities in medieval Greenland toward extinction (Diamond 2005, Dugmore et al. 2007).

Renewed interest in the relationship between harsh climate and harsh governance is driven by the finding that the prevalence of parasitic diseases promotes political autocracy (Schaller & Murray 2011, Fincher & Thornhill 2012). Following up on this research, it has been shown that a country's non-zoonotic and zoonotic disease burdens do not account for any variation in autocratic governance once the interactive impacts of climatic demands and income have been accounted for (Van de Vliert & Postmes 2012). Rather, autocratic governance is more prevalent in poorer societies threatened by more demanding climates.

Some inaccuracies in how climatic demands were entered into this debate in the literature are addressed here. Specifically, no distinction was made between cold and heat, and no attention was paid to potentially cross-cutting influences of precipitation. In the next section, we argue that cold demands, heat demands, and precipitation should be treated as separate yet intertwined roots of autocratic governance, and that income must be factored in to prevent simplistic climatic determinism. The methodological section then describes the measures used for climatic demands, income, and autocratic governance. The results section compares the predictive power of a purely climatic model and 3 climato-economic models predicting autocracy in 173 countries. Finally, the discussion section highlights the need for appropriate explanatory complexity and accuracy in studies of cultural adaptations to climatic conditions.

2. CLIMATO-ECONOMIC THEORIZING

2.1. Basic influences of cold and heat

Because our species has to maintain a constant level of body temperature, humans have evolved a U-shaped dependence of body heat production and rates of metabolism on ambient temperature (Scholander et al. 1950, Parsons 2003, Hill et al. 2013). In an intermediate range of ambient temperatures, termed the thermoneutral zone, the metabolic rate required for the body to maintain a core temperature is both minimal and independent of the ambient temperature. Below the thermoneutral zone, metabolism increases to generate enough heat (e.g. by shivering) for the body to maintain its temperature. Above the thermoneutral zone, metabolism increases to support active cooling (e.g. by sweating or panting). Thus, the bio-energetic costs of maintaining body temperature and integrity increase on both sides of the thermoneutral zone.

The U-shaped dependence of heat production on ambient temperature specifies our needs for thermal comfort, nutrition, and health (Rehdanz & Maddison 2005, Van de Vliert 2009). Climates with temperate seasons are relatively undemanding by offering pleasant temperatures, abundant nutritional resources owing to the rich flora and fauna, and relatively healthy habitats. But colder winters and hotter summers require more and better clothing, shelter structures, warming or cooling systems, and increasing investments of time and effort in the pursuit of water, food, and health. Because acclimatization has negligible compensating effects (Parsons 2003), more and more measures have to be taken in increasingly colder or hotter conditions to safeguard societal sustainability.

2.2. Cross-cutting influences of precipitation

Precipitation complicates the picture. Climates are often classified using a combination of temperature and precipitation (e.g. tropical humid, desert, maritime, continental). Using such a typological approach to investigate climate–culture links has the advantage that climate is correctly treated as a whole of integrated components. But it also has the disadvantage that the impact of climate cannot be accurately attributed to either temperature or precipitation. Take the finding that uncertainty avoidance is stronger in tropical and subtropical climates than in maritime and continental climates (Sully de Luque & Javidan 2004). Should one explain this finding in terms of temperature or precipitation? Or does a combination of temperature and precipitation account for it? Therefore, temperature and precipitation are construed in this study as dimensions with influences on autocratic governance that can be assessed separately.

2.3. Conditioning influences of income

Money complicates the picture further because owning, saving, earning, buying, and selling can help prevent and dispel thermal discomfort, hunger, thirst, and illness. Thus, the greater bio-energetic costs of keeping alive and well on both sides of the

thermoneutral zone can be replaced with monetary costs by buying goods and services that alter the effects of adverse winters and summers. Both cash and capital can serve climate-compensating functions by meeting basic needs. This is a far from trivial change in perspective, as it helps us move beyond the myopic explanation of societal culture offered by unconditional climate determinism.

Climato-economic theorizing (Van de Vliert 2009, 2013a,b) posits that monetary resources play a vital role in culturally coping with harsh climate. As a rule, necessities of life needed to secure thermal comfort, nutrition, and health are for sale and have a price. In consequence, cold winters and hot summers can be managed through purchases of clothing, housing, transportation, meals, medical cure and care, and so forth. Families in richer nations spend up to 50% of their household income on such climate-compensating goods and services, a figure that rises up to 90% in poorer nations (Parker 2000).

The burgeoning climato-economic explanation of culture has been criticized for collapsing cold and heat demands into climatic demands, and for neglecting the different functions of income in cold and hot climates (Murray 2013, Terracciano & Chan 2013). Indeed, money is primarily used for heating and food in colder regions and months, while it is primarily used for preventing and recovering from infectious diseases in hotter regions and months. Overall, as reflected in the World Bank's poverty lines and in city-level studies of thermoregulatory costs (e.g. Hill et al. 2013), life is more expensive in colder climates. As a further shortcoming, climato-economic research so far has exclusively focused on the temperature-compensating function of income without paying attention to the potentially complicating role of precipitation. This is a serious defect because cash and capital can be especially instrumental in coping with droughts or floods. In response to these criticisms, this is the first study ever to report the interactive effects of cold demands, heat demands, precipitation, and income on an aspect of societal functioning.

2.4. Hypotheses

The present study was undertaken to retest the existence of a relationship between harsh climate and harsh governance, this time taking better account of the complexity of climatic demands. Echoing results of previous research on this topic (Van de Vliert & Postmes 2012), we expected cold demands (Hypothesis 1) and heat demands (Hypothesis 2) to be positively related to autocratic governance, especially where low precipitation reinforces the threatening thermal demands (Hypothesis 3). Additionally, climato-economic theorizing predicts that greater income turns the effect of threatening climatic demands causing autocratic governance in poorer countries into an effect of challenging climatic demands causing democratic governance in richer countries (Hypothesis 4).

3. METHODS

3.1. Sample

We used a sample of 173 countries for which we have data on climate (temperature and precipitation), income, and autocracy. One-sample *t*-tests revealed no evidence that cold demands (t = 1.39, p = 0.17), heat demands (t = 0.86, p = 0.39), and precipitation (t = −0.03, p = 0.97) were not representative of climates across all of the world's 232 independent and dependent territories (source: Van de Vliert 2013b).

3.2. Cold and heat demands

The basic influences of cold and heat, introduced in Section 2.1 above, were translated into a general axiom and 2 specific research assumptions. (1) Warm-blooded humans are affected by both extreme cold and extreme heat because of their existential needs for thermal comfort, nutrition, and health. This axiom is at odds with the common use of average temperature in a country as a predictor of local culture (e.g. Hofstede 2001, Georgas et al. 2004, Vanhanen 2009). Overall country averages overlook the impact of seasonal variations in temperature (small and large differences between winters and summers may have the same average; higher latitudes have both lower averages and larger variations). An appropriate indicator of the relevance of thermal demands for humans should take account of winter and summer deviations from a biologically optimal point of reference.

(2) The neutrality assumption holds that each individual has a slightly different thermoneutral zone, but that collectively they share the same average point of thermoneutrality. This plausible assumption replaces 0° Celsius or Fahrenheit as frames of reference from physics with a biologically optimal degree of temperature as a more appropriate frame of reference. Current climate–culture research (Van de Vliert 2009, 2013a) adopts 22°C (~72°F) as a bench-

mark from which measurements of societal livability are made. This temperature is the approximate midpoint of the individual ranges of comfortable temperatures (Parsons 2003) and the temperature preferred by tourists (Bigano et al. 2006). Also, existential needs for nutrition and health are met more easily in climates with temperatures varying around a base range of, say, 17 to 27°C (Parker 2000, Cline 2007, Van de Vliert 2009). Thus, climates are more demanding to the extent that their winter temperatures are colder than 22°C and their summer temperatures hotter than 22°C.

(3) The third and least plausible presupposition is in fact formulated to create a falsifiable null hypothesis. This symmetry assumption holds that equivalent cold and heat deviations from 22°C produce equivalent impacts on societal functioning. Accordingly, operationalized across each country's major cities, weighted for population size, cold demands are the sum of the downward deviations from 22°C for the average lowest and highest temperatures in the coldest month, and the average lowest and highest temperatures in the hottest month; heat demands are the sum of the upward deviations from 22°C for these 4 average temperatures (source: Van de Vliert 2013b, p. 505–507). In Mongolia, for example, where the lowest and highest temperatures are −44°C and 1°C in the coldest month and −6°C and 36°C in the hottest month, the cold demands are ($|-44°C - 22°C| + |1°C - 22°C|$) + $|-6°C - 22°C| = 115$, whereas the heat demands are ($|36°C - 22°C|$) = 14.

The biological validity of these measures of cold demands and heat demands is apparent from their relations with life stress. Populations appear to be unhappier, report poorer health, and commit suicide more often to the extent that they have to cope with colder winters, hotter summers, or both (Van de Vliert 2009). For example, across 75 countries, cold demands (unstandardized regression coefficient B = 2.94, $p < 0.001$), heat demands (B = 2.35, $p < 0.01$), and their interaction (B = 2.82, $p < 0.01$) account for 37% of the number of suicides per 100 000 inhabitants per year (Van de Vliert 2009). Suicide rates are highest in countries with both cold winters and hot summers irrespective of the country's level of income (e.g. Finland, Kazakhstan, Russia, Slovenia).

3.3. Precipitation

Precipitation was measured as the average over space and time of any kind of rain or snow that falls on a country (source: http://worldbank.org).

3.4. Income

National income was measured as income per capita, relative to a given set of basic goods and services (purchasing power parity in 2002, log transformed to reduce the skewed cross-national distribution; source: United Nations Development Programme 2004).

3.5. Autocratic governance

Political democracy versus autocracy combines civil liberties, free elections, party competition, and citizen participation. Mirroring this complexity, scholars from various disciplines have constructed a plethora of ratings. Because these measures have different strengths and weaknesses, Pemstein et al. (2010) used a Bayesian latent variable approach to synthesize an overarching Unified Democracy Score (UDS); their findings are available at www.unified-democracy-scores.org. We reversed the UDS and chose it over other measures because it covers more aspects of political democracy versus autocracy, has been more carefully developed, and reduces measurement error to a greater extent. Given the widely different aspects incorporated, the reliability of the UDS in terms of the 45 correlations among the subscales is impressive (r ranges from 0.60 to 0.95, and is 0.79 on average).

3.6. Analyses

Autocratic governance was regressed on standardized cold demands, heat demands, precipitation, and income. For reasons of parsimony and statistical feasibility, we did not estimate the full model with 4 main effects and 11 interactions. Instead, we compared the predictive power of a purely climatic model (cold–heat–precipitation) and 3 climato-economic models (cold–heat–income; cold–precipitation–income; heat–precipitation–income). These multiple regression models allowed us to not only test our hypotheses, but also to find the 3-factor model that best predicts autocratic governance.

In all models, attention was paid to the best documented rival predictors of autocracy. Human-to-human transmitted disease burden (B = 0.12, $p < 0.001$, Van de Vliert & Postmes 2012; source: Fincher & Thornhill 2012), ethnic diversity (B = 2.63, $p < 0.001$, Fish & Brooks 2004; source: Alesina et al. 2003), and low average intelligence of the population

Table 1. Means, standard deviations (SD), and correlations of predictor variables, autocratic governance, and control variables (N = 173 countries, except for ethnic diversity [N = 170] and national IQ [N = 172]). $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Variable	Mean	SD	1	2	3	4	5	6	7
1. Cold demands	33.58	26.31							
2. Heat demands	21.80	7.88	−0.58***						
3. Precipitation	1157.62	783.34	−0.44***	−0.10					
4. Income	8.52	1.16	0.41***	−0.33***	−0.08				
5. Autocratic governance	−0.37	0.86	−0.33***	0.42***	−0.15*	−0.53***			
6. Disease burden	0.41	1.97	−0.56***	0.39***	0.17*	−0.66***	0.36***		
7. Ethnic diversity	4501.72	2552.81	−0.31***	0.29***	−0.01	−0.54***	0.40***	0.60***	
8. National IQ	83.91	11.83	0.65***	−0.43***	−0.08	0.66***	−0.42***	−0.64***	−0.50***

or national IQ ($r_s > -0.60$, $p < 0.001$, Vanhanen 2009; source: Lynn & Vanhanen 2006) were controlled for. However, tests uncontrolled for these confounders are reported first because disease burden, ethnic diversity, and national IQ could be 'bad controls' that inappropriately change the amount of true covariance in the relationship between climato-economic predictors and autocratic governance (for details, see Hsiang et al. 2013).

4. RESULTS

4.1. Descriptives

Means, standard deviations, and correlations of cold demands, heat demands, precipitation, income, autocratic governance, and control variables are provided in Table 1. As might be expected, cold demands are negatively related to heat demands ($r = -0.58$, $p < 0.001$) and precipitation ($r = -0.44$, $p < 0.001$), albeit not to an extent that there is a potential problem of multicollinearity in regression analysis. Note also that autocratic governance has strong negative associations with income ($r = -0.53$, $p < 0.001$), national IQ ($r = -0.42$, $p < 0.001$), and cold demands ($r = -0.33$, $p < 0.001$), and strong positive associations with heat demands ($r = 0.42$, $p < 0.001$), ethnic diversity ($r = 0.40$, $p < 0.001$), and disease burden ($r = 0.36$, $p < 0.001$).

4.2. Confirmatory tests

Cold demands ($B = -0.02$, $p = 0.78$), heat demands ($B = 0.31$, $p < 0.001$), and their interaction ($B = 0.16$, $p < 0.06$) account for 20% of the cross-national variation in autocratic governance. Political autocracy is more prevalent in hotter countries, and especially so in hot countries with demanding continental climates where winters tend to be relatively cold (e.g. Morocco, Saudi Arabia, Paraguay). This finding disconfirms Hypothesis 1 because harsh cold has no main effect on autocratic governance, but it simultaneously confirms Hypothesis 1 because harsh cold strengthens the impact of harsh heat. In full support of Hypothesis 2, harsh heat as such and harsh heat in conjunction with harsh cold is positively related to autocratic governance.

These results changed when precipitation was next brought into the equation. As reported in Table 2, Model 1, and illustrated in Fig. 1, precipitation increases the predictable variation in autocracy from 20 to 29%. Autocracy peaks in the most demanding climates where cold demands, heat demands, and low precipitation strengthen each other's impact

Table 2. Cold demands, heat demands, precipitation, and income predicting autocratic governance (N = 173 countries). Regression coefficients shown are unstandardized beta weights (*B*). There was no multicollinearity (variance inflation factors, VIFs < 4.26), and there were no outliers (Cook's *Ds* < 0.36). $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Predictors	Model			
	1	2	3	4
Cold demands (C)	−0.33**	0.09	−0.21**	
Heat demands (H)	0.13	0.33***		0.24***
Precipitation (P)	−0.35***		−0.26***	−0.13**
C × H	0.09	0.04		
C × P	−0.35**		−0.05	
H × P	−0.19*			−0.11*
C × H × P	−0.06			
Income (I)		−0.43***	−0.36***	−0.40***
C × I		−0.24**	−0.28***	
H × I		0.13		0.21***
C × H × I		−0.14		
P × I			−0.06	0.16**
C × P × I			−0.05	
H × P × I				−0.20***
R^2	0.29***	0.48***	0.46***	0.54***

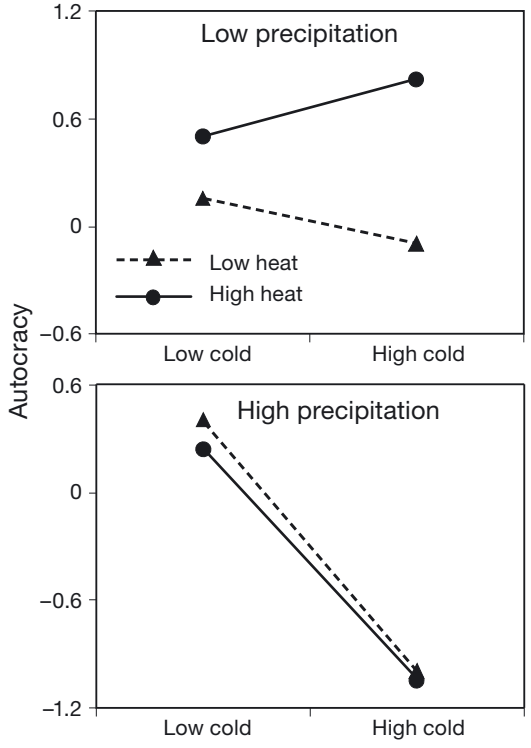

Fig. 1. Autocratic governance thrives in dry-cold-hot climates (upper panel), and withers in wet-cold climates (lower panel)

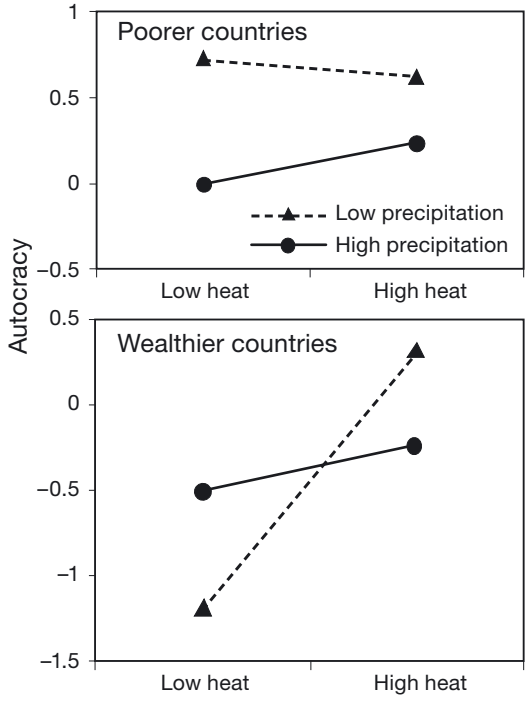

Fig. 2. Autocratic governance thrives in cold-dry-poor and hot-dry-poor countries (upper panel), and withers in cold-dry-wealthy countries (lower panel)

(Fig. 1, top). By contrast, autocracy is minimal in cold climates with high precipitation irrespective of summer temperatures (Fig. 1, bottom). This pattern of results confirms Hypothesis 3 and adds the extra insight that low precipitation has an especially strong effect on autocratic governance in continental climates.

This may be useful information for a better ecology-based understanding of autocracy. Nonetheless, those models in Table 2 that take account of income to cope with demanding climates provide even better predictions of autocracy than the purely climatic model does (R^2 increases from 0.29 in Model 1 to 0.54 in Model 4). Model 4 provides the most accurate description of the ecology of political systems reflected in 3 main effects (ΔR^2 = 0.37), three 2-way interaction effects (ΔR^2 = 0.13), and a 3-way interaction effect (ΔR^2 = 0.04) of heat demands, precipitation, and income. A plot of these interactions is presented in Fig. 2.

The left side of the Fig. 2 (top) shows that the relatively high levels of autocracy in poorer countries are especially high in cold-dry compared to cold-wet climates (simple slope test: $B = -0.37$, $p < 0.01$). In striking contrast, the lower panel shows that the relatively low levels of autocracy in richer countries are especially low in cold-dry compared to cold-wet climates (B = 0.34, $p < 0.001$). These observations support Hypothesis 4, that greater income turns the effect of threatening climatic demands causing autocratic governance in poorer countries into an effect of challenging climatic demands causing democratic governance in wealthier countries. Similar comparisons of hot-dry and hot-wet climates in poorer ($B = -0.19$, $p < 0.05$) and wealthier (B = −0.28, $p < 0.01$) countries reconfirm the idea that greater heat demands reinforced by lower precipitation increase autocracy.

4.3. Disconfirmatory tests

Care was taken to rule out the rival explanations inherent in the correlations documented in Table 1. As can be seen in Table 3, a larger disease burden, greater ethnic diversity, and lower national IQ as significant predictors of autocratic governance cannot nullify the findings. On the contrary, Model 4 shows that disease burden, ethnic diversity, and national IQ do not explain any variation in political culture once the significant interactive impacts of heat demands, precipitation, and income have been accounted for. Further care was taken to ensure that exclusion of the largest countries with multiple climatic regions (Argentina, Australia, Brazil, Canada, Chile, China,

Table 3. Cold demands, heat demands, precipitation, and income as predictors of autocratic governance after controlling for rival predictors (N = 169 countries). Regression coefficients shown are unstandardized beta weights (*B*). There was no multicollinearity (variance inflation factors, VIFs < 5.83), and there were no outliers (Cook's *Ds* < 0.29). $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$

Predictors	Model			
	1	2	3	4
Disease burden	0.02	−0.01	−0.02	−0.02
Ethnic diversity	0.01*	0.01	0.01	0.01
National IQ	−0.01	−0.00	0.01	0.00
Cold demands	−0.11	0.12	−0.24**	
Heat demands (H)	0.14	0.32***		0.24***
Precipitation (P)	−0.28**		−0.26***	−0.11*
C × H	0.12	0.07		
C × P	−0.35**		−0.05	
H × P	−0.18*			−0.12*
C × H × P	−0.09			
Income (I)		−0.39***	−0.35***	−0.41***
C × I		−0.27***	−0.27***	
H × I		0.11		0.20***
C × H × I		−0.16*		
P × I			−0.06	0.15**
C × P × I			−0.04	
H × P × I				−0.19***
R^2	0.40***	0.50***	0.48***	0.55***

India, Russia, and the United States) did not alter the findings. The robustness of the results was also verified by excluding all members of the Organization of Petroleum Exporting Countries (Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela).

Another rival explanation attributes the confirmatory results to the fact that similarities between adjacent countries have violated the statistical assumption of independent observations. This problem has been examined by re-estimating Model 4 in Table 2 for countries with low and high risks of spatial dependency and spillover effects. In the low-dependency condition, 38 countries were removed from the analysis because they are part of 10 multi-country regions where adjacent countries have highly similar thermal demands and precipitation (source: Cline 2007). The interaction coefficients were essentially unaffected (N = 135; total $R^2 = 0.50$; $B = -0.106$, p = 0.056 for H × P, $B = 0.192$, p = 0.001 for H × I, $B = 0.127$, p = 0.071 for P × I, and $B = -0.193$, p = 0.002 for H × P × I, where H represents heat demands, P is precipitation, and I is income), and do not suggest that spatial dependence must be held accountable for the results.

In the high-dependency condition, the 28 island countries were removed. For each of the remaining 145 countries, we computed the average degree of autocratic governance of its land-border neighbors, which was then included as an additional predictor in Model 4. Neighbor autocracy (7% unique variance) and climato-economic predictors (10% unique variance), in additive combination (46% shared variance), accounted for 63% of the variation in own autocracy. However, neighbor autocracy ($B = 0.468$, p = 0.001) did not nullify the interaction effects of heat demands, precipitation, and income ($B = -0.089$, p = 0.065 for H × P, $B = 0.097$, p = 0.072 for H × I, $B = 0.126$, p = 0.027 for P × I, and $B = -0.158$, p = 0.012 for H × P × I). Therefore, we feel confident in concluding that even in the high-dependency condition, the similarities between adjacent countries are not offering a sufficient explanation for the observed relationship between climato-economic factors and autocratic governance.

4.4. Basic influences of cold and heat

Clearly, then, climato-economic conditions covary with autocratic governance as predicted. A remaining question is to what extent the evidence also supports the underlying assumptions from Section 3.2. The neutrality assumption posits that societal functioning unfolds around a thermoneutral point (22°C) rather than a thermoneutral zone (e.g. 19° to 25°C). To bolster this assumption, we repeated the analyses with cold demands as the sum of the downward deviations from 19°C, and heat demands as the sum of the upward deviations from 25°C. These supplementary analyses yielded virtually identical results because only 6 countries fall in the investigated thermoneutral zone on the cold side below 22°C (Comoros, Guyana, Seychelles, Yemen) or on the hot side above 22°C (Colombia, Iceland).

In agreement with our falsifiable null hypothesis, the confirmatory tests reported in Section 4.2 show that the symmetry assumption must be rejected. Cold demands are a worse predictor of autocratic governance than are heat demands. Not only does Hypothesis 1 receive less support than Hypothesis 2, the cold demands in Model 3 also have less predictive power than the heat demands in Model 4. Confirming findings reported by Hill et al. (2013) and Li et al. (2013), it is thus possible to conclude that the impact slope is generally steeper for heat demands than for cold demands. However, the specifics of the level and steepness of these impact slopes cannot be

given. As detailed in Table 2, the impact of cold demands on autocratic governance is dependent upon income (Model 3), whereas the impact of heat demands on autocratic governance is dependent upon the interactive combination of precipitation and income (Model 4 and Fig. 2).

5. DISCUSSION

For more than 25 centuries, scholars have been trying to relate the mean temperature of a territory to societal functioning (for recent examples, see Georgas et al. 2004, McCrae et al. 2007, Vanhanen 2009). But that is a suboptimal approach given that all warm-blooded species on Earth have a U-shaped relationship with ambient temperature. As a consequence, climates with colder-than-temperate winters, hotter-than-temperate summers, or both, offer less thermal comfort, nutrition, and health. Moreover, low precipitation makes already harsher winters or summers even more demanding. The present study is innovative in its use of downward and upward deviations from a thermal optimum (22°C) and levels of precipitation as interacting predictors of political culture.

Climate–culture research also has a long history of overemphasizing straightforward main effects of climatic demands on societal functioning (for overviews, see Feldman 1975, Sommers & Moos 1976, Jankovic 2010). For example, in a meta-analysis of 60 studies about the influences of temperature and precipitation on the prevalence of social conflict, Hsiang et al. (2013) assumed that climatic demands only have unconditional main effects on conflict — that is, effects unmoderated by economic development. Additionally, Hsiang et al. (2013) did not model income per capita for reasons based on the isomorphic assumption that income, too, only has unconditional main effects on conflict — that is, effects independent from climatic demands. The common assumptions are that climatic demands promote conflict, whereas income per capita promotes harmony and cooperation.

Climate–culture researchers might be advised to move away from such overly simple perspectives. It seems more realistic to view cash and capital as tools for turning detrimental effects of winters or summers into beneficial effects (cf. Hill et al. 2013). One might rightly notice that this approach leaves aside to what extent climate helps generate income, but that is not a very helpful observation. The scientific virtue of parsimony makes it a strong rather than a weak proposition that climate and income influence each other's impact on daily life independent of preceding impacts of cold, heat, and precipitation on income. Moreover, no interaction effect of thermal demands, precipitation, and income on daily functioning can be estimated without taking into account the historically developed common variance between climate and income.

In line with the climato-economic perspective (Van de Vliert 2009, 2013a,b), the interactions of climatic demands and income predict autocratic governance better than do the purely climatic interactions of cold demands, heat demands, and precipitation (an increase from 29% to 54%). Conversely viewed, the interaction of income and climate predicts autocratic governance better than does income in and of itself (an increase from 28% to 54%). Demandingly cold-dry climates appear to promote autocracy in poor countries (e.g. Afghanistan, Belarus) but democracy in rich countries (e.g. Canada, Germany). Moreover, demandingly hot-dry climates appear to promote autocracy everywhere, irrespective of the country's level of income.

Perhaps more than anything else, our analyses highlight the merit of incorporating more complexity into investigations of the cultural consequences of climate. Even after controlling for disease burden, ethnic diversity, and national IQ, multiple interactions among thermal demands, precipitation, and income contributed to the prediction and clarification of more autocratic rule (see Table 3). Thus, in and of themselves, disease burden, ethnic diversity, national IQ, thermal demands, precipitation, and income all sketch an insufficiently accurate picture of the political expression of societal structures and processes in major world niches.

As a major shortcoming, adaptation of political culture to climato-economic conditions has been examined here in a cross-sectional manner. Yet, it is unlikely that the results are due to coincidence or to confounding spillover effects between adjacent countries. It is indeed difficult to avoid a causal interpretation of the complex covariation of climatic, economic, and political variables in Fig. 2. The present findings may well reflect causality rather than simultaneity also because the climato-economic composite cannot easily adjust itself to more or less civil liberties, free elections, healthy party competition, and citizen participation. That said, there may be reverse causality from autocracy to collective income.

Although we did not longitudinally investigate any changes, the ecology–polity links found are bound to have implications for climatic and economic changes in the long run. Specifically, the regression equation

from Model 4 in Table 2 may be used to model future changes in political cultures as a result of two threats humanity faces today: global warming and local poverty. The quality of our ability to predict culture necessarily depends on the quality of climatic and economic forecasts, with the consequence that predictions need to be made carefully and results should not be overinterpreted. Even so, it would be foolhardy not to use insights from research on the recent past to make cautious predictions of the more remote future that might help locate, diagnose, and potentially mitigate problems.

So far, investigations of links between climate change and cultural adaptation have focused on migration (e.g. Warner et al. 2009), agriculture (e.g. Parry et al. 2005, Challinor et al. 2007, Cline 2007), and large-scale conflict (e.g. Burke et al. 2009, Tol & Wagner 2010, Hsiang et al. 2013). As exemplified by the present study, climato-economic theorizing might enrich and extend this research agenda by replacing annual mean temperature with temperature deviations from a thermal optimum, by introducing the interactive impacts of precipitation and income, and by helping to explain the underlying processes in terms of existential needs for thermal comfort, nutrition, and health.

As to practical implications, the empirical findings discussed here and elsewhere (Van de Vliert 2009, 2013a,b) seem to be leaning toward the following recommendation. The transition to democracy that is typically associated with economic development holds increasingly true in more demanding climates. Regression equations such as those from Tables 2 & 3 can help simulate human development effects of different matches of climatic demands and economic growth.

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LITERATURE CITED

Alesina A, Devleeschauwer A, Easterly W, Kurlat S, Wacziarg R (2003) Fractionalization. J Econ Growth 8: 155–194

Bigano A, Hamilton JM, Tol RSJ (2006) The impact of climate on holiday destination choice. Clim Change 76: 389–406

Burke MB, Miguel E, Satyanath S, Dykema JA, Lobell DB (2009) Warming increases the risk of civil war in Africa. Proc Natl Acad Sci USA 106:20670–20674

Challinor A, Wheeler T, Garforth C, Craufurd P, Kassam A (2007) Assessing the vulnerability of food crop systems in Africa to climate change. Clim Change 83:381–399

Cline WR (2007) Global warming and agriculture: impact estimates by country. Center for Global Development, Washington, DC

Diamond J (2005) Collapse: how societies choose to fail or survive. Allen Lane, London

Dugmore AJ, Keller C, McGovern TH (2007) Norse Greenland settlement: reflections on climate change, trade, and the contrasting fates of human settlements in the North Atlantic islands. Arctic Anthropol 44:12–36

Feldman DA (1975) The history of the relationship between environment and culture in ethnological thought: an overview. J Hist Behav Sci 11:67–81

Fincher CL, Thornhill R (2012) Parasite-stress promotes in-group assortative sociality: the cases of strong family ties and heightened religiosity. Behav Brain Sci 35:61–79

Fish MS, Brooks RS (2004) Does diversity hurt democracy? J Democracy 15:154–166

Georgas J, Van de Vijver FJR, Berry JW (2004) The ecocultural framework, ecosocial indices, and psychological variables in cross-cultural research. J Cross Cult Psychol 35:74–96

Hill RW, Muhich TE, Humphries MM (2013) City-scale expansion of human thermoregulatory costs. PLoS ONE 8:e76238

Hofstede G (2001) Culture's consequences: comparing values, behaviors, institutions, and organizations across cultures. Sage, Thousand Oaks, CA

Hsiang SM, Burke M, Miguel E (2013) Quantifying the influence of climate on human conflict. Science 341:1235367

Jankovic V (2010) Climates as commodities: Jean Pierre Purry and the modelling of the best climate on earth. Stud Hist Philos Sci B Stud Hist Philos Mod Phys 41: 201–207

Li T, Horton RM, Kinney PL (2013) Projections of seasonal patterns in temperature-related deaths for Manhattan, New York. Nat Clim Change 3:717–721

Lynn R, Vanhanen T (2006) IQ and global inequality. Washington Summit Publishers, Augusta, GA

McCrae RR, Terracciano A, Realo A, Allik J (2007) Climatic warmth and national wealth: some culture-level determinants of national character stereotypes. Eur J Pers 21: 953–976

Milgram S (1974) Obedience to authority. Tavistock, London

Murray DR (2013) Cultural adaptations to the differential threats posed by hot versus cold climates. Behav Brain Sci 36:497–498

Nissen HJ (1988) The early history of the ancient Near East. University of Chicago Press, Chicago, IL

Parker PM (2000) Physioeconomics: the basis for long-run economic growth. MIT Press, Cambridge, MA

Parry M, Rosenzweig C, Livermore M (2005) Climate change, global food supply and risk of hunger. Philos Trans R Soc Lond B Biol Sci 360:2125–2138

Parsons KC (2003) Human thermal environments: the effects of hot, moderate and cold environments on human health, comfort and performance, 2nd edn. Taylor & Francis, London

Pemstein D, Meserve SA, Melton J (2010) Democratic compromise: a latent variable analysis of ten measures of regime type. Polit Anal 18:426–449

Rehdanz K, Maddison D (2005) Climate and happiness. Ecol Econ 52:111–125

Schaller M, Murray DR (2011) Infectious disease and the creation of culture. Adv Cult Psychol 1:99–151

Scholander PF, Hock R, Walters V, Johnson F, Irving L (1950) Heat regulation in some arctic and tropical mammals and

birds. Biol Bull (Woods Hole) 99:237–258

Sommers P, Moos RH (1976) The weather and human behavior. In: Moos RH (ed) The human context: environmental determinants of behavior. Wiley, New York, NY, p 73–107

Sully de Luque M, Javidan M (2004) Uncertainty avoidance. In: House RJ, Hanges PJ, Javidan M, Dorfman PW, Gupta V (eds) Culture, leadership, and organizations: the GLOBE study of 62 societies. Sage, Thousand Oaks, CA, p 602–653

Terracciano A, Chan W (2013) Personality traits, national character stereotypes, and climato-economic conditions. Behav Brain Sci 36:501–502

Tol RSJ, Wagner S (2010) Climate change and violent conflict in Europe over the last millennium. Clim Change 99: 65–79

United Nations Development Programme (2004) Human development report 2004. Oxford University Press, New York, NY

Van de Vliert E (2009) Climate, affluence, and culture. Cambridge University Press, New York, NY

Van de Vliert E (2013a) Climato-economic habitats support patterns of human needs, stresses, and freedoms. Behav Brain Sci 36:465–480

Van de Vliert E (2013b) White, gray, and black domains of cultural adaptations to climato-economic conditions. Behav Brain Sci 36:503–521

Van de Vliert E, Postmes T (2012) Climato-economic livability predicts societal collectivism and political autocracy better than parasitic stress does. Behav Brain Sci 35:94–95

Vanhanen T (2009) The limits of democratization: climate, intelligence, and resource distribution. Washington Summit Publishers, Augusta, GA

Warner K, Ehrhart C, de Sherbinin A, Adamo SB, Onn TC (2009) In search of shelter: mapping the effects of climate change on human migration and displacement. United Nations University, CARE, and CIESIN-Columbia University, Bonn

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