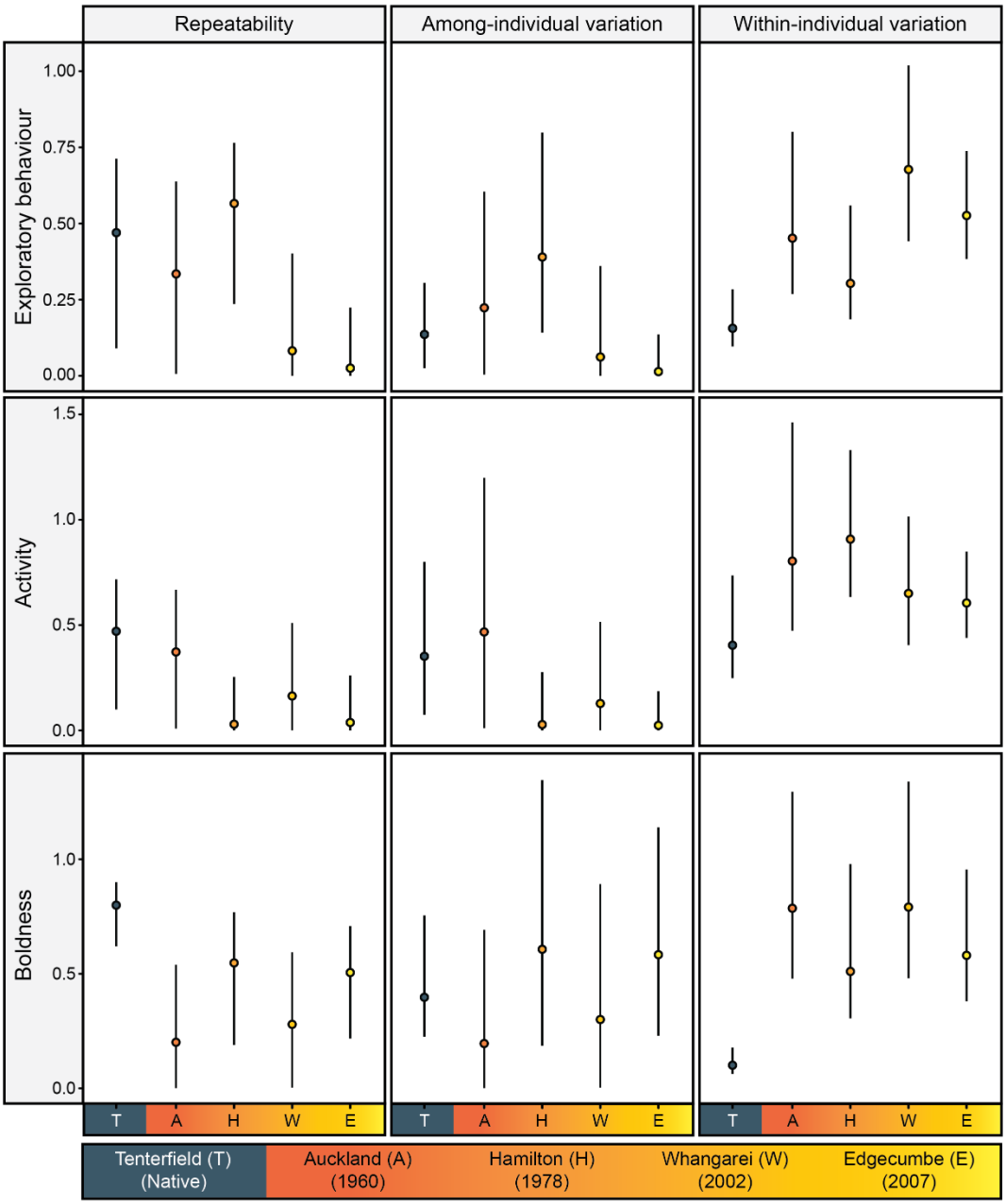
Supplementary Information for

Biological invasions as a selective filter driving behavioral divergence

David G. Chapple[1,#]*, Annalise C. Naimo[1]*, Jack A. Brand[1]*, Marcus Michelangeli[1,2,3], Jake M. Martin[1,3], Celine T. Goulet[1], Dianne H. Brunton[4], Andrew Sih[2], and Bob B.M. Wong[1].

[#]Correspondence to: David.Chapple@monash.edu



Supplementary Fig. 1. Adjusted repeatability and variance estimates (among- and within-individual) for exploratory behavior (i.e. time spent exploring the barrier), activity (i.e. the number of transitions between grid squares), and boldness (i.e. re-emergence latency; axis inverted) of skinks from the native Tenterfield source population (grey; n = 30 skinks), and invasive New Zealand skinks from Auckland (red; n = 31), Hamilton (orange; n = 43), Whangarei (light-orange; n = 33), and Edgecumbe (yellow; n = 36). For each graph, filled circles represent the median variance/repeatability estimates extracted from linear mixed-effects models, while vertical error bars denote 95% credible intervals. Source data are provided as a Source Data file.

Supplementary Table 1. The number of lizards collected from each population across the species native (i.e., Australia) and invasive (i.e., Hawaii, Lord Howe Island, and New Zealand) ranges.

Region	Population	Establishment date	Number of skinks in each population	Number of skinks in each region
Australia	Brisbane	Native	27	167
Australia	Coffs Harbour	Native	81	
Australia	Sydney	Native	29	
Australia	Tenterfield	Native	30	
Hawaii	Koke'e	~1960	39	118
Hawaii	Honolulu	1905	37	
Hawaii	Volcano	~1960	42	
Lord Howe Island	Boardwalk	~1980	26	92
Lord Howe Island	Middle Beach	~1980	30	
Lord Howe Island	North Bay	~1980	36	
New Zealand	Auckland	~1960	31	143
New Zealand	Hamilton	1978	43	
New Zealand	Whangarei	2002	33	
New Zealand	Edgecumbe	2007	36	

Supplementary Table 2. Experimental timeline of behavioral trials. Skinks underwent two trials of activity, exploratory behavior, and boldness, each four days apart. Note: some lizards performed behavioral tests seven days apart due to logistical constraints.

	Experimental day						
Week	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
1	Activity trial 1				Activity trial 2		
2		Exploration trial 1				Exploration trial 2	
3			Boldness trial 1				Boldness trial 1

Supplementary Table 3. Model comparison table comparing the relative fits of four models investigating differences in exploration among both native and invasive regions.

Model	WAIC	Se WAIC	Δ WAIC	LOO	Se LOO	Δ LOO
Both variance	2403.0	63.1	0	2432.8	64.9	0
Within model	2403.9	60.3	–0.9	2433.1	62.0	–0.3
Null model	2430.8	59.7	–27.8	2451.3	60.7	–18.5
Among model	2442.4	61.3	–39.4	2461.0	62.1	–28.2

Supplementary Table 4. Model comparison table comparing the relative fits of four models investigating differences in activity rates among both native and invasive regions.

Model	WAIC	Se WAIC	Δ WAIC	LOO	Se LOO	Δ LOO
Both variance	2505.6	47.7	0	2550.2	50.1	0
Within model	2518.2	46.3	–12.6	2561.3	48.3	–11.1
Among model	2532.8	48.4	–27.2	2569.5	50.0	–19.3
Null model	2538.8	47.1	–33.2	2578.8	49.0	–28.6

Supplementary Table 5. Model comparison table comparing the relative fits of four models investigating differences in boldness among both native and invasive regions.

Model	WAIC	Se WAIC	Δ WAIC	LOO	Se LOO	Δ LOO
Both variance	2177.4	43.0	0	2232.1	45.1	0
Within model	2183.0	42.9	–5.6	2234.4	44.9	–2.3
Null model	2272.1	42.2	–94.7	2311.0	43.7	–78.9
Among model	2277.9	42.9	–100.5	2313.7	44.4	–81.6

Supplementary Table 6. Model summary of average differences in exploratory behavior between Australia (i.e. intercept; *n* = 167 skinks), and Hawaii (*n* = 118) Lord Howe Island (*n* = 92), and New Zealand (*n* = 143).

Term	Estimate	SE	Lower 95% CI	Upper 95% CI
Intercept	**–0.644**	**0.165**	**–0.955**	**–0.293**
Hawaii	**1.099**	**0.248**	**0.573**	**1.563**
Lord Howe Island	**0.606**	**0.252**	**0.076**	**1.077**
New Zealand	**0.954**	**0.233**	**0.465**	**1.398**

Estimates in bold are those with 95% CI's that did not include zero.

Supplementary Table 7. Model summary of average differences in activity rates between Australia (i.e. intercept; *n* = 167 skinks), and Hawaii (*n* = 118) Lord Howe Island (*n* = 92), and New Zealand (*n* = 143).

Term	Estimate	SE	Lower 95% CI	Upper 95% CI
Intercept	–0.173	0.165	–0.501	0.165
Hawaii	0.364	0.258	–0.152	0.868
Lord Howe Island	–0.205	0.258	–0.724	0.314
New Zealand	0.434	0.233	–0.029	0.895

Supplementary Table 8. Model summary of average differences in boldness between Australia (i.e. intercept; *n* = 167 skinks), and Hawaii (*n* = 118) Lord Howe Island (*n* = 92), and New Zealand (*n* = 143). Note: as boldness was measured as re-emergence latencies, lower scores indicate bolder lizards.

Term	Estimate	SE	Lower 95% CI	Upper 95% CI
Intercept	0.128	0.085	–0.044	0.299
Hawaii	0.030	0.129	–0.216	0.292
Lord Howe Island	0.269	0.150	–0.029	0.566
New Zealand	**–0.597**	**0.137**	**–0.864**	**–0.325**

Estimates in bold are those with 95% CI's that did not include zero.

Supplementary Table 9. Adjusted repeatability (R) and variance estimates (i.e., among-individual [V_A] and within-individual [V_W]) for exploratory behavior in Australia (n = 167 skinks), and Hawaii (n = 118) Lord Howe Island (n = 92), and New Zealand (n = 143).

Region	Estimate	Value	Lower 95% CI	Upper 95% CI
Australia	R	0.44	0.31	0.56
Australia	V_A	0.34	0.22	0.47
Australia	V_W	0.34	0.27	0.42
Hawaii	R	0.15	0.00	0.29
Hawaii	V_A	0.13	0.00	0.27
Hawaii	V_W	0.64	0.48	0.82
Lord Howe Island	R	0.09	0.00	0.24
Lord Howe Island	V_A	0.09	0.00	0.24
Lord Howe Island	V_W	0.79	0.58	1.01
New Zealand	R	0.18	0.00	0.31
New Zealand	V_A	0.15	0.00	0.26
New Zealand	V_W	0.57	0.43	0.72

Supplementary Table 10. Adjusted repeatability (R) and variance estimates (i.e., among-individual [V_A] and within-individual [V_W]) for activity rates in Australia (n = 167 skinks), and Hawaii (n = 118) Lord Howe Island (n = 92), and New Zealand (n = 143).

Region	Estimate	Value	Lower 95% CI	Upper 95% CI
Australia	R	0.44	0.32	0.57
Australia	V_A	0.38	0.26	0.52
Australia	V_W	0.37	0.29	0.45
Hawaii	R	0.44	0.28	0.58
Hawaii	V_A	0.57	0.33	0.84
Hawaii	V_W	0.62	0.46	0.80
Lord Howe Island	R	0.31	0.12	0.50
Lord Howe Island	V_A	0.32	0.10	0.54
Lord Howe Island	V_W	0.60	0.43	0.81
New Zealand	R	0.09	0.00	0.22
New Zealand	V_A	0.08	0.00	0.20
New Zealand	V_W	0.73	0.57	0.90

Supplementary Table 11. Adjusted repeatability (R) and variance estimates (i.e., among-individual [V_A] and within-individual [V_W]) for boldness in Australia (n = 167 skinks), and Hawaii (n = 118) Lord Howe Island (n = 92), and New Zealand (n = 143).

Region	Estimate	Value	Lower 95% CI	Upper 95% CI
Australia	R	0.58	0.46	0.70
Australia	V_A	0.38	0.26	0.51
Australia	V_W	0.25	0.19	0.31
Hawaii	R	0.29	0.10	0.47
Hawaii	V_A	0.23	0.07	0.40
Hawaii	V_W	0.53	0.39	0.69
Lord Howe Island	R	0.10	0.00	0.30
Lord Howe Island	V_A	0.12	0.00	0.35
Lord Howe Island	V_W	1.00	0.68	1.33
New Zealand	R	0.42	0.27	0.56
New Zealand	V_A	0.57	0.32	0.83
New Zealand	V_W	0.75	0.58	0.95

Supplementary Table 12. Model comparison table comparing the relative fits of four models investigating differences in exploratory behavior between native Tenterfield population, and individual invasive New Zealand populations (Auckland, Hamilton, Whangarei, and Edgecumbe).

Model	WAIC	Se WAIC	Δ WAIC	LOO	Se LOO	Δ LOO
Both variance	696.4	39.8	0	713.0	41.5	0
Within model	706.6	39.0	–10.2	719.7	40.7	–6.7
Among model	724.3	42.7	–27.9	729.6	42.6	–16.6
Null model	728.9	41.1	–32.5	734.2	41.6	–21.2

Supplementary Table 13. Model comparison table comparing the relative fits of four models investigating differences in activity rates between native Tenterfield population, and individual invasive New Zealand populations (Auckland, Hamilton, Whangarei, and Edgecumbe).

Model	WAIC	Se WAIC	Δ WAIC	LOO	Se LOO	Δ LOO
Both variance	873.4	25.8	0	882.5	26.4	0
Among model	878.1	25.3	–4.7	883.5	25.7	–1
Within model	889.4	26.1	–16.0	895.1	26.6	–12.6
Null model	891.5	26.3	–18.1	895.2	26.7	–12.7

Supplementary Table 14. Model comparison table comparing the relative fits of four models investigating differences in boldness between native Tenterfield population, and individual invasive New Zealand populations (Auckland, Hamilton, Whangarei, and Edgecumbe).

Model	WAIC	Se WAIC	Δ WAIC	LOO	Se LOO	Δ LOO
Within model	742.9	21.7	0	764.8	22.5	0
Both variance	749.4	21.6	–6.5	769.6	22.2	–4.8
Null model	791.0	20.3	–48.1	809.1	21.4	–44.3
Among model	799.3	19.9	–56.4	814.9	20.8	–50.1

Supplementary Table 15. Model summary of average differences in exploratory behavior between the native Tenterfield population (i.e., intercept; *n* = 30 skinks), and individual invasive New Zealand populations (Auckland [established 1960; *n* = 31], Hamilton [established 1978; *n* = 43], Whangarei [established 2002; *n* = 33], and Edgecumbe [established 2007; *n* = 36]).

Term	Estimate	SE	Lower 95% CI	Upper 95% CI
Intercept	**–1.284**	**0.085**	**–1.450**	**–1.111**
Auckland	**1.625**	**0.154**	**1.321**	**1.930**
Hamilton	**1.266**	**0.161**	**0.945**	**1.584**
Whangarei	**1.700**	**0.141**	**1.413**	**1.974**
Edgecumbe	**1.638**	**0.120**	**1.402**	**1.873**

Estimates in bold are those with 95% CI's that did not include zero.

Supplementary Table 16. Model summary of average differences in activity between the native Tenterfield population (i.e., intercept; n = 30 skinks), and individual invasive New Zealand populations (Auckland [established 1960; n = 31], Hamilton [established 1978; n = 43], Whangarei [established 2002; n = 33], and Edgecumbe [established 2007; n = 36]).

Term	Estimate	SE	Lower 95% CI	Upper 95% CI
Intercept	**–0.632**	**0.134**	**–0.895**	**–0.362**
Auckland	**0.471**	**0.217**	**0.048**	**0.899**
Hamilton	**0.542**	**0.183**	**0.179**	**0.899**
Whangarei	**0.816**	**0.176**	**0.466**	**1.161**
Edgecumbe	**1.133**	**0.161**	**0.814**	**1.445**

Estimates in bold are those with 95% CI's that did not include zero.

Supplementary Table 17. Model summary of average differences in boldness between the native Tenterfield population (i.e., intercept; n = 30 skinks), and individual invasive New Zealand populations (Auckland [established 1960; n = 31], Hamilton [established 1978; n = 43], Whangarei [established 2002; n = 33], and Edgecumbe [established 2007; n = 36]). Note: as boldness was measured as re-emergence latencies, lower scores indicate bolder lizards.

Term	Estimate	SE	Lower 95% CI	Upper 95% CI
Intercept	0.319	0.121	0.074	0.550
Auckland	–0.180	0.187	–0.544	0.188
Hamilton	**–0.617**	**0.214**	**–1.036**	**–0.189**
Whangarei	**–0.389**	**0.194**	**–0.758**	**–0.003**
Edgecumbe	**–0.389**	**0.191**	**–0.753**	**–0.009**

Estimates in bold are those with 95% CI's that did not include zero.

Supplementary Table 18. Adjusted repeatability (R) and variance estimates (i.e., among-individual [V_A] and within-individual [V_W]) for exploratory behavior within each population in the invasive New Zealand lineage (i.e., Tenterfield [native; *n* = 30 skinks], Auckland [established 1960; *n* = 31], Hamilton [established 1978; *n* = 43], Whangarei [established 2002; *n* = 33], and Edgecumbe [established 2007; *n* = 36]).

Region	Estimate	Value	Lower 95% CI	Upper 95% CI
Tenterfield	R	0.45	0.15	0.75
Tenterfield	V_A	0.14	0.00	0.27
Tenterfield	V_W	0.16	0.09	0.26
Auckland	R	0.33	0.00	0.60
Auckland	V_A	0.24	0.00	0.52
Auckland	V_W	0.47	0.24	0.75
Hamilton	R	0.55	0.27	0.78
Hamilton	V_A	0.41	0.12	0.77
Hamilton	V_W	0.32	0.17	0.52
Whangarei	R	0.12	0.00	0.35
Whangarei	V_A	0.10	0.00	0.30
Whangarei	V_W	0.69	0.43	0.99
Edgecumbe	R	0.05	0.00	0.18
Edgecumbe	V_A	0.03	0.00	0.11
Edgecumbe	V_W	0.54	0.37	0.72

Supplementary Table 19. Adjusted repeatability (R) and variance estimates (i.e., among-individual [V_A] and within-individual [V_W]) for activity within each population in the invasive New Zealand lineage (i.e., Tenterfield [native; *n* = 30 skinks], Auckland [established 1960; *n* = 31], Hamilton [established 1978; *n* = 43], Whangarei [established 2002; *n* = 33], and Edgecumbe [established 2007; *n* = 36]).

Region	Estimate	Value	Lower 95% CI	Upper 95% CI
Tenterfield	R	0.46	0.15	0.75
Tenterfield	V_A	0.38	0.00	0.71
Tenterfield	V_W	0.43	0.23	0.69
Auckland	R	0.36	0.00	0.63
Auckland	V_A	0.50	0.00	1.05
Auckland	V_W	0.85	0.42	1.36
Hamilton	R	0.06	0.00	0.20
Hamilton	V_A	0.06	0.00	0.22
Hamilton	V_W	0.93	0.59	1.27
Whangarei	R	0.19	0.00	0.46
Whangarei	V_A	0.16	0.00	0.43
Whangarei	V_W	0.66	0.38	0.97
Edgecumbe	R	0.06	0.00	0.22
Edgecumbe	V_A	0.04	0.00	0.15
Edgecumbe	V_W	0.62	0.43	0.83

Supplementary Table 20. Adjusted repeatability (R) and variance estimates (i.e., among-individual [V_A] and within-individual [V_W]) for boldness within each population in the invasive New Zealand lineage (i.e., Tenterfield [native; *n* = 30 skinks], Auckland [established 1960; *n* = 31], Hamilton [established 1978; *n* = 43], Whangarei [established 2002; *n* = 33], and Edgecumbe [established 2007; *n* = 36]).

Region	Estimate	Value	Lower 95% CI	Upper 95% CI
Tenterfield	R	0.79	0.65	0.91
Tenterfield	V_A	0.42	0.20	0.69
Tenterfield	V_W	0.10	0.06	0.16
Auckland	R	0.21	0.00	0.49
Auckland	V_A	0.23	0.00	0.59
Auckland	V_W	0.81	0.45	1.24
Hamilton	R	0.53	0.24	0.80
Hamilton	V_A	0.65	0.15	1.26
Hamilton	V_W	0.54	0.27	0.89
Whangarei	R	0.28	0.00	0.55
Whangarei	V_A	0.33	0.00	0.78
Whangarei	V_W	0.82	0.45	1.27
Edgecumbe	R	0.49	0.25	0.73
Edgecumbe	V_A	0.61	0.20	1.10
Edgecumbe	V_W	0.60	0.35	0.90

Supplementary Table 21. The effect size (± 95 % CI) of the magnitude difference in among-individual variation (ΔV_A), within-individual variation (ΔV_W), and repeatability (ΔR) of exploration, activity, and boldness for each population in the invasive New Zealand lineage (i.e., Tenterfield [AUS; n = 30 skinks], Auckland [AUK; n = 31], Hamilton [HAM; n = 43], Whangarei [WGI; n = 33], and Edgecumbe [EDG; n = 36]).

	Exploration			Activity			Boldness		
Contrast	ΔV_A	ΔV_W	ΔR	ΔV_A	ΔV_W	ΔR	ΔV_A	ΔV_W	ΔR
AUS – AUK	-0.10	**-0.31**	0.13	-0.12	-0.42	0.10	0.19	**-0.71**	**0.57**
	(-0.44, 0.21)	**(-0.61, -0.04)**	(-0.31, 0.59)	(-0.86, 0.54)	(-1.04, 0.09)	(-0.34, 0.58)	(-0.31, 0.62)	**(-1.14, -0.33)**	**(0.25, 0.88)**
AUS – HAM	-0.27	-0.16	-0.10	0.32	**-0.50**	**0.40**	-0.23	**-0.44**	0.26
	(-0.63, 0.09)	(-0.38, 0.04)	(-0.50, 0.31)	(-0.07, 0.72)	**(-0.94, -0.06)**	**(0.04, 0.70)**	(-0.89, 0.39)	**(-0.79, -0.15)**	(-0.05, 0.60)
AUS – WGI	0.05	**-0.53**	0.34	0.22	-0.24	0.27	0.09	**-0.72**	**0.51**
	(-0.21, 0.27)	**(-0.84, -0.23)**	(-0.06, 0.67)	(-0.26, 0.69)	(-0.63, 0.17)	(-0.16, 0.65)	(-0.46, 0.61)	**(-1.16, -0.32)**	**(0.18, 0.84)**
AUS – EDG	0.12	**-0.37**	**0.40**	0.33	-0.19	**0.39**	-0.19	**-0.50**	**0.30**
	(-0.04, 0.28)	**(-0.57, -0.17)**	**(0.05, 0.69)**	(-0.02, 0.72)	(-0.51, 0.14)	**(0.03, 0.70)**	(-0.74, 0.33)	**(-0.80, -0.24)**	**(0.02, 0.59)**
AUK – HAM	-0.17	0.15	-0.22	0.44	-0.08	0.30	-0.42	0.27	-0.32
	(-0.63, 0.28)	(-0.17, 0.51)	(-0.67, 0.18)	(-0.09, 1.09)	(-0.69, 0.55)	(-0.04, 0.66)	(-1.15, 0.23)	(-0.27, 0.82)	(-0.71, 0.10)
AUK – WGI	0.15	-0.22	0.21	0.34	0.18	0.17	-0.10	-0.01	-0.06
	(-0.22, 0.53)	(-0.62, 0.18)	(-0.19, 0.60)	(-0.30, 1.03)	(-0.36, 0.83)	(-0.29, 0.60)	(-0.73, 0.50)	(-0.62, 0.61)	(-0.49, 0.39)
AUK – EDG	0.21	-0.06	0.28	0.45	0.23	0.29	-0.38	0.21	-0.28
	(-0.06, 0.54)	(-0.39, 0.27)	(-0.06, 0.62)	(-0.06, 1.07)	(-0.25, 0.82)	(-0.07, 0.63)	(-0.98, 0.22)	(-0.27, 0.75)	(-0.66, 0.09)

HAM – WGI	0.32	**-0.37**	**0.43**	-0.10	0.26	-0.13	0.32	-0.28	0.25
	(-0.06, 0.73)	**(-0.74, -0.04)**	**(0.08, 0.75)**	(-0.47, 0.20)	(-0.20, 0.74)	(-0.47, 0.16)	(-0.44, 1.05)	(-0.87, 0.25)	(-0.16, 0.68)
HAM – EDG	**0.38**	-0.21	**0.50**	0.01	0.31	-0.01	0.04	-0.06	0.04
	(0.08, 0.75)	(-0.47, 0.06)	**(0.19, 0.77)**	(-0.16, 0.23)	(-0.08, 0.74)	(-0.24, 0.19)	(-0.67, 0.80)	(-0.52, 0.41)	(-0.35, 0.41)
WGI – EDG	0.07	0.15	0.07	0.12	0.05	0.12	-0.28	0.22	-0.22
	(-0.11, 0.31)	(-0.20, 0.49)	(-0.16, 0.36)	(-0.13, 0.45)	(-0.34, 0.41)	(-0.16, 0.47)	(-0.91, 0.41)	(-0.30, 0.77)	(-0.60, 0.19)

Contrasts in bold are those with 95% CI's that did not include zero.