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Re-examining adaptation theory using Big Data: Reactions to external shocks

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35 **Abstract**

36 During the global response to COVID-19, the analogy of fighting a war was often used. In 2022, the
37 world faced a different war altogether, an unprovoked Russian invasion of Ukraine. Since 2020 the
38 world has faced these unprecedented shocks. Although we realise these events' health and economic
39 effects, more can be known about the happiness effects on the people in a country and how it differs
40 between a health and a war shock. Additionally, we need to investigate if these external shocks do affect
41 wellbeing, how they differ from one another, and how long it takes happiness to adapt to these shocks.
42 Therefore, this paper aims to compare these two external shocks for ten countries spanning the Northern
43 and Southern hemispheres to investigate the effect on happiness. By investigating the aforementioned,
44 we also re-examine the adaptation theory and see whether it holds at the country level. We use a unique
45 dataset derived from tweets extracted in real-time per country. We derive each tweet's underlying
46 sentiment by applying Natural Language Processing (machine learning). Using the sentiment score, we
47 apply algorithms to construct daily time-series data to measure happiness (Gross National Happiness
48 (GNH)). Our Twitter dataset is combined with data from Oxford's COVID-19 Government Response
49 Tracker. We find that in both instances, the external shocks caused a decrease in GNH. Considering
50 both types of shocks, the adaptation to previous happiness levels occurred within weeks. Understanding
51 the effects of external shocks on happiness is essential for policymakers as effects on happiness have a
52 spillover effect on other variables such as production, safety and trust. Furthermore, the additional
53 macro-level results on the adaptation theory contribute to previously unexplored fields of study.

54

55 **1. Introduction**

56 During the global response to COVID-19, the analogy of fighting a war was often used. COVID-19
57 severely impacted world health (loss of life), damaged the world economy and negatively impacted
58 wellbeing. In 2022, the world faced a different war altogether, an unprovoked Russian invasion of
59 Ukraine. The invasion displaced over 14 million people (at the time of writing this paper), caused a
60 significant loss of life and damaged world economies (severe effects on oil prices, sunflower oil, wheat
61 etc., which led to higher inflation levels). Additionally, the world experienced the threat of nuclear war

62 and the possible outbreak of World War III. Although we realise the health and economic effects of
63 these external shocks, more can be known about external shocks' effect on people's happiness in
64 countries and how it differs between health- and war-related shocks. Additionally, information is
65 needed on how severe these effects are, compared to one another and how long it takes people to adapt
66 to these shocks.

67 To this end, our primary aim is to compare these two external shocks (a health and war shock) for ten
68 countries spanning the Northern and Southern hemispheres to determine how quickly countries'
69 happiness levels adapt. We will determine (if) and how external shocks affect happiness to achieve the
70 aforementioned. Additionally, we will use an event study to determine whether the adaptation theory
71 holds at the macro-level (similar to studies conducted at the micro-level). Lastly, we also draw
72 comparisons between countries in the Northern and Southern hemispheres.

73 We define an external shock as an unexpected event that changes emotions, happiness levels, and
74 economic and other social factors. The shocks we are investigating are the COVID-19 pandemic and
75 the Ukrainian war. However, these shocks have vast differences, including how they affect countries.
76 In the panel under investigation, the shock of COVID-19 directly impacted the countries. In contrast,
77 the Ukrainian war indirectly impacted these countries, as the war did not take place in these countries,
78 though the negative effects affected all countries worldwide. These shocks create upheavals in
79 emotions, for example, anger and fear. It increases instability in resources, food and other markets,
80 leading to weaker economic growth, higher unemployment, higher inflation rates and increased poverty.

81 In our analysis, we take the first lockdown as the date of the COVID-19 shock and the invasion as the
82 date of the Ukrainian war shock. We equate these negative shocks to negative life events used in micro-
83 level studies and see these shocks as an ailment and analyse the intervention effect. In the instance of
84 the COVID-19 health shock, the intervention is the first lockdown; in the case of the Ukrainian war, it
85 is the invasion of Ukraine.

86 Previous studies explored adaptation patterns of individuals for one single event at the micro-level
87 (Brickman et al. [1], Silver [2]) and did not necessarily inform us about adaptation patterns across

88 events. Studies such as Clarke et al. [3], Clarke and Georgellis [4], Frijters et al. [5], and Rudolf and
89 Kang [6] went further than single events by providing standardised information on how individuals'
90 wellbeing develops in the approach to and aftermath of major life events. Clarke et al. [3] investigated
91 marriage, divorce, widowhood, the birth of a child, and layoff. Frijters et al. [5] used marriage, divorce,
92 childbirth, injury/ illness, death of spouse or child, being a victim of crime, redundancy, change in
93 financial situation, and change in residence. Rudolf and Kang [6] investigated marriage, divorce,
94 widowhood, unemployment, first job entry, and the shift from the six- to five-day working week.
95 However, all of these studies were conducted at the micro-level (individual level) using survey data
96 such as the Korean Labor and Income Panel Study (KLIPS), Household Income and Labour Dynamics
97 in Australia (HILDA), German Socio-Economic Panel (GSOEP) and British Household Panel Survey
98 (BHPS).

99 Following the above, our study makes three main contributions to the existing literature. First, no other
100 study has investigated two different types of external shocks, such as COVID-19 and the Ukrainian
101 war, on happiness at a macro-level. Second, no other study has tested whether adaptation theory holds
102 at the country level across events using a cross-country analysis. Third, this is the first study to use real-
103 time information from Big Data instead of survey data to re-examine adaptation theory.

104 Our analyses use a unique dataset, which we construct from tweets extracted in real-time at a country
105 level. Natural Language Processing (machine learning) is used to code (score) the tweets' underlying
106 sentiment, and algorithms are applied to the sentiment scores to derive a happiness score per tweet. We
107 derive the mean scores per day to develop our daily happiness time-series data per country, i.e., the
108 Gross National Happiness index (GNH). Thus, we use sentiment analysis, analysed over time to derive
109 time-series data. The GNH, our variable of interest, measures wellbeing/happiness and has been well-
110 established in previous studies (see Greyling and Rossouw [7], Greyling et al. [8] and [9], Rossouw et
111 al. [10] and [11], Morrison et al. [12] and Sarracino et al. [13] and [14]).

112 To achieve the study's aims, we first conducted a Difference-in-Difference (DiD) estimation for the
113 whole panel to establish whether the two external shocks caused the observed effect on happiness
114 (GNH). Subsequently, we also conducted a DiD estimation for both the Northern and Southern

115 hemispheres. Second, we perform an event study to determine the effect of the external shocks on the
116 GNH from 3 weeks pre-event (lockdown for COVID-19 and the invasion of Ukraine) to 9 weeks post-
117 event. Therefore, also measuring the adaptation of GNH levels compared to the reference week, three
118 weeks before the shock.

119 Our results show that COVID-19 and the Ukrainian war caused a decrease in happiness. However, after
120 3 weeks post-event, adaptation to previous happiness levels (reference week is three weeks before the
121 event) occurred. Four- and five weeks post-event, happiness was higher than 3 weeks pre-event.
122 Therefore, we found strong evidence of adaptation and show that for both events, there is a rapid return
123 to a baseline level of happiness.

124

125 Regarding the comparison between the hemispheres, we found similar results for the Northern
126 hemisphere than for the entire panel. With both the COVID-19 and the Ukrainian war shock, adaptation
127 is already evident in week 3 and week 2, respectively and gains statistical significance by weeks 4 and
128 5. In the Southern hemisphere, it seems that adaptation is somewhat slower. In the instance of lockdown
129 only from week 7 after the event week, whereas with the invasion adaptation occurred in week 4 after
130 the event.

131

132 The rest of the paper is structured as follows. The next section contains a brief discussion on studies
133 related to adaptation theory. Section 3 describes the data and the selected variables and outlines the
134 methodologies used. The results and discussion follow in section 4, while the paper concludes in section
135 5.

136 **2. Literature review**

137 **2.1 Adaptation at micro-level**

138 Since the primary aim of this study is to determine whether adaptation occurs at the macro-level, our
139 literature review will focus on adaptation studies. The literature on adaptation theory is vast; however,

140 we limit our discussion to a few seminal and across-life events' studies at a micro-level that investigated
141 adaptation.

142 Subjective wellbeing (SWB) research has been significantly affected by the hedonic treadmill theory
143 (see, for example, Mancini et al. [15], Diener et al. [16], Kahneman et al. [17]). Lykken and Tellegen
144 [18] used the hedonic treadmill theory to conclude that adaptation is quick, complete, and inevitable
145 and that genetic predispositions and personality rather than life events accounted for nearly all of the
146 long-term stable variance in SWB. According to this idea of a hedonic treadmill, people have happiness
147 'set-points' to which they inevitably return following major life events (Brickman & Campbell [19],
148 Headey & Wearing [20], Larsen [21], Williams & Thompson [22]).

149 However, studies conducted by Diener et al. [16], Lucas [23] and [24], Lucas et al. [25] and Lucas et
150 al. [26], although not refuting the happiness set-point model, concluded that even though happiness
151 levels are relatively stable over time, this stability does not preclude large and lasting changes.
152 "*Happiness levels do change, adaptation is not inevitable, and life events do matter*" (Lucas [27: p 78].

153 Most evidence for adaptation comes from single-life event cross-sectional studies. Brickman et al. [1]
154 investigated the SWB of people with spinal cord injuries and lottery winners in one of the most cited
155 studies. They found that individuals with spinal cord injuries were happier than expected, and lottery
156 winners were less happy than expected. However, due to limitations such as the lottery winners being
157 marginally happier than the control group (but not significantly happier), individuals with spinal cord
158 injuries going against the adaptation theory expectations (by being significantly less happy than the
159 comparison group, even if they were not quite as unhappy as they expected) and not using longitudinal
160 data to compare pre-and post-events Brickman et al. [1] could not offer strong support for adaptation.

161 Subsequent studies provide stronger evidence that some form of hedonic adaptation does occur after
162 improving on Brickman et al.'s [1] research design. Silver [2] also investigated people with spinal cord
163 injuries; however, individuals were followed from one to eight weeks after the disability-causing
164 accident. One week after the major life event, negative emotions were stronger than positive emotions.
165 Over the subsequent 7 weeks, happiness increased while negative emotions steadily decreased. By the

166 8th week, there was some adaptation with positive emotions stronger than negative emotions. However,
167 it is unclear whether these individuals returned to their pre-event baseline levels of SWB.

168 Studies such as Clarke et al. [3], Clarke and Georgellis [4], Frijters et al. [5], and Rudolf and Kang [6]
169 went further than single-life event studies such as Brickman et al. [1] and Silver [2] by providing
170 standardised information on how individuals' wellbeing develops in the approach to and aftermath of
171 major life events. Clarke et al. [3] and Clarke and Georgellis [4] use unemployment, marriage, divorce,
172 widowhood, the birth of a child, and layoff. Frijters et al. [5] use marriage, divorce, childbirth, injury/
173 illness, death of spouse or child, being a victim of crime, redundancy, change in financial situation, and
174 change in residence. Rudolf and Kang [6] use marriage, divorce, widowhood, unemployment, first job
175 entry, and the shift from the six- to the five-day working week. Using survey data collected at the micro-
176 level from KLIPS, HILDA, GSOEP and BHPS, all the abovementioned studies suggest that the
177 adaptation phenomenon may be general. These studies surmise that people initially react strongly to
178 both positive and negative events, but then their emotional reactions diminish. People return to a
179 positive rather than a neutral happiness baseline, and life circumstances are necessary to understand
180 long-term SWB; happiness is not completely determined by personality.

181

182 **2.2 Adaptation at macro-level**

183 As far as the authors know, only two studies investigate *adaptation theory at the macro-level*. The first
184 study focuses on countries involved in civil conflict, and the second investigates one external shock and
185 does not involve a cross-country analysis. However, no studies investigate adaptation theory *across*
186 *external shocks* involving a *cross-country analysis using Big Data*.

187 In a study of 44 countries actively involved in civil conflict and using average happiness by country
188 from representative surveys (World Database of Happiness from Veenhoven [28]), Welsch [29] found
189 that the current number of conflicts significantly reduced the wellbeing of people in civil wars.
190 However, Welsch [29] concluded that the change in the number of victims (the number of victims per
191 1000 inhabitants), rather than their absolute number, reduces wellbeing in civil wars, suggesting that

192 there is some, but no complete, adaptation to the conditions of a war shock. Additionally, he calculated
193 that, on average, the compensating variation for one fatality is about 108,000 US dollars. This means
194 that income must increase by 108,000 US dollars to have happiness at constant levels when one
195 additional person dies. The direct effects in terms of suffering, fear and agony are larger than the indirect
196 effects due to the smaller income brought about by premature death.

197 The idea that some adaptation occurs could be that people get used to the horrors of war to some extent.
198 When one experiences that many persons die, then the fact that one's son, husband, father or other
199 relative has died may be more bearable because the people affected are aware that they are no exception
200 to the rule. That other persons have had to come to terms with similar grief. On the other hand, one can
201 well argue that experiencing the death of many others has a cumulative negative effect on one's own
202 happiness.

203 Morrison et al. [12] used the GNH and Plutchik's [30] wheel of emotions to investigate the response to
204 the COVID-19 pandemic in New Zealand. The authors found distinct reactions to the pandemic using
205 the period 14 February – 14 June 2020. There was an initial strong decrease in wellbeing in response to
206 COVID-19, and this decrease was brought on by a decrease in the emotions' joy', 'anticipation' and
207 'trust'. However, this initial decrease in wellbeing was short-lived and recovered relatively quickly.
208 Thereby finding evidence of hedonic adaptation.

209 **3. Data**

210 **3.1 Data and countries**

211 In the analyses, we use two external shocks, namely COVID-19 and the Ukrainian war and compare the
212 days pre- and post-event. We use a panel dataset spanning the period 25 February – 23 May 2020
213 (COVID-19) and 1 February – 30 April 2022 (Ukrainian war). The following ten countries are included
214 in our analyses; seven Northern hemisphere countries; Belgium, Germany, Great Britain, France, Italy,
215 the Netherlands, and Spain and three Southern hemisphere countries; Australia, New Zealand and South
216 Africa.

217 We have a total of 890 observations, thus 89 observations for ten countries for both the COVID-19
 218 shock and the Ukrainian war shock time period. Primarily the choice of countries is determined by data
 219 availability. However, future studies can extend the dataset to include more countries. The current
 220 selection of countries from both hemispheres provides unique insights into the effect of two external
 221 shocks (external to the countries under investigation) on happiness and the time needed to adapt to these
 222 shocks. Table 1 summarises key statistics for each country used in the current study.

223 **Table 1. Key summary facts of countries in this study.**

Country	Total population	Average happiness levels** (2020)	Date of announcement	Date of first lockdown (2020)	Date of Ukraine invasion (2022)
Australia	25.5 million	7.09	15 March	17 March*	24 February
Belgium	11.6 million	6.98	17 March	18 March	24 February
France	66.99 million	6.66	16 March	17 March	24 February
Germany	83.02 million	7.08	22 March	22 March	24 February
Great Britain	66.65 million	7.17	23 March	23 March	24 February
Italy	60.36 million	6.39	8 March	9 March	24 February
Netherlands	17.28 million	7.73	14 March	15 March [†]	24 February
New Zealand	5.5 million	7.14	23 March	26 March	24 February
South Africa	57.7 million	6.32	23 March	27 March	24 February
Spain	46.94 million	6.40	13 March	14 March	24 February

224 * Australia never officially went into a complete lockdown like that in other countries. We used the day when the closure of
 225 international borders was announced as a proxy for "lockdown."

226 [†]The Netherlands started a so-called 'intelligent lockdown' on this date.

227 ** The happiness scores cited here reflect the average for the period in 2020 before the first COVID-19 case was announced.
 228 Source: Greyling et al. [31], Hale et al. [32].

229

230 **3.2 Twitter data: *GNH.today project***

231 The outcome variable, the Gross National Happiness index (GNH), which measures wellbeing, was
 232 sourced from the *GNH.today project*, launched in April 2019 (Greyling et al. [31]). This project
 233 measures the evaluative mood of a country's citizens over time. The GNH, as a measure of mood,
 234 captures the more volatile part of wellbeing, generally referred to as happiness (Diener et al. [16]).

235 However, the evaluative qualification indicates tweets reflect individuals' conscious decisions - they
236 evaluate what they want to say. Since the GNH has been well-established and validated in previous
237 studies, we will only provide a brief discussion here (see Greyling and Rossouw [7], Greyling et al. [8]
238 and [9]), Rossouw et al. [10] and [11], Morrison et al. [12] and Sarracino et al. [13] and [14]).

239 To construct the GNH index, a live feed of tweets is extracted from the voluntary information-sharing
240 social media platform Twitter (see Rossouw and Greyling [33] for a detailed discussion). Using Natural
241 Language Processing, sentiment analysis, which is the process of determining whether a piece of writing
242 (product/movie review, tweet, etc.) is positive, negative or neutral, is applied to every tweet. It can
243 identify the follower's attitude towards an event through tone, context etc. Sentiment analysis is driven
244 by an algorithm and is better than text analysis since it helps you understand an entire opinion and not
245 merely a word from the text. For our sentiment analysis, we use the Sentiment140 lexicon;
246 subsequently, every tweet is labelled as having either a positive, neutral or negative sentiment.

247 As a robustness check, we recalculate all indices using the sentiment scores from NRC (Turney and
248 Mohammad [34]) and VADER (Hutto & Gilbert [35]). If the indices using different lexicons are highly
249 correlated, we assume that the index is not sensitive to the type of lexicon used. The calculated GNH
250 using Sentiment140, NRC and VADER are highly correlated. The Pearson correlation coefficient
251 between GNH (Sentiment140) and GNH (NRC) is $r = 0.88$ ($p=0.000$) and between GNH
252 (Sentiment140) and GNH (VADER) $r = 0.96$ ($p=0.000$). Therefore, we assume the GNH index is not
253 sensitive to the type of lexicon used, and the results gained using the GNH index are robust.

254 After each tweet has been classified, a sentiment balance algorithm is applied to derive a happiness
255 score per hour. The scale of the happiness scores is between 0 and 10, with 5 being neutral, thus neither
256 happy nor unhappy. The index is available live on the *GNH.today project* website (Greyling et al. [31]).
257 To derive time-series data, we calculate the mean GNH per day. We smooth the GNH data to adjust for
258 trends using a 7-day moving average (Kelly [36], Helliwell & Wang [37]).

259 In our analysis, we compare the two external shocks of COVID-19 and the Ukrainian war. We take the
260 first lockdown as the date of the COVID-19 shock and the invasion as the date of the Ukrainian war

261 shock. The lockdown was in 2020, and the invasion in 2022. As a counterfactual period, we use the
262 year 2021, assumed to be the 'new normal' in which people have accepted that COVID-19 is a reality
263 and part of their daily lives. However, we cannot directly compare the GNH from 2020 and 2021, and
264 2021 and 2022 as the mean levels of the GNH differ markedly across the years. Thus, we need to re-
265 scale (standardise) the data to be comparable. To standardise the GNH data, we use the observation
266 minus the mean per time period (either 2020 and 2021, or 2021 and 2022, respectively) divided by the
267 standard deviation per time period. We report results using the standardised GNH time series in the
268 Difference-in-Difference estimations.

269 The use of Twitter data presents several key advantages over survey data. First, the data are not self-
270 reported by a subsample of respondents but rather capture the opinion of millions of Twitter users.
271 Second, the data does not suffer from biases such as the observer-expectation effect or interviewer bias.
272 Third, Twitter data are less vulnerable to small-sample bias. Nevertheless, Twitter data have limitations.
273 One of these is that younger individuals are relatively more likely than older individuals to tweet;
274 however, on Twitter accounts, the ages are spread from 19-65, similar to survey data. Another limitation
275 is that we cannot look at heterogenous effects of COVID-19 and the Ukrainian war by demographic
276 groups based on regions. Our results should thus be read as the average impact of COVID-19 (using
277 the date of the first lockdown) or the Ukrainian war (date of invasion) on the happiness of Twitter users
278 per geographical region. Although we cannot assume that Twitter users are representative of a country,
279 we know that a vast number of the population do have Twitter accounts, and the number of tweets
280 approximates millions per day. Therefore, biases are limited by the size of the sample.

281

282 **3.3 Oxford data and covariates**

283 To select the covariates included in the models, we are limited in our choice of variables, as we can
284 only include high-frequency close to real-time data. Furthermore, the time periods we compare are
285 relatively short. For example, the invasion in Ukraine was in February 2022 and even using real-time
286 data, the number of observations is limited, seeing that the project commenced in April 2022, thus

287 allowing us to use data until the end of April. Given the relatively short period, we are restricted in the
288 number of covariates that can be included in the estimations to avoid overfitting the models. Therefore,
289 we limit our selection of covariates, similar to Fang et al. [38] and Brodeur et al. [39], to the following:

- 290 1. The lockdown or invasion variable is the assumed date of the external shock (intervention
291 variable). We construct a dummy variable with 0 before the lockdown or invasion and 1
292 thereafter. For the external shock COVID-19, lockdown is the date specific to each country
293 (see Table 1). For the Ukrainian war's external shock, the invasion date was 24 February 2022.
294 However, in our analyses, we do not use the lockdown date or the day of the invasion itself, as
295 we believe the effects on happiness may have started when policies were announced or the
296 imminent threat of an invasion became apparent. Thus, our lockdown and invasion variables
297 are constructed on the day each country announced their first lockdowns (see Table 1) and the
298 day preceding the invasion, 23 February. In further support of our decision to use the dates of
299 the lockdown announcements and the day preceding the invasion, literature has shown that
300 wellbeing measures react to expectations rather than the event itself (see Greyling et al. [9] and
301 Morrison [12]). In subsequent analyses, where we compare the Northern and Southern
302 hemispheres, we construct the lockdown and invasion dummy variable following the same
303 method explained above. As a robustness test, we also run all regressions using each country's
304 lockdown date and the invasion's date.
- 305 2. The number of new COVID-19 cases. We use the lagged number of new COVID-19 cases per
306 million to control for the evolution of the pandemic (Hale et al. [32]).
- 307 3. Country fixed effects. We use country-fixed effects to control for countries' observed and
308 unobserved characteristics.
- 309 4. A day-of-the-week fixed effects. We control for any observed or unobserved day-of-the-week
310 effects. For example, Mondays, the first workday of the week, often has lower levels of
311 happiness than other days, whereas Friday and Saturdays, in expectation of more leisure time,
312 have higher levels of happiness.

313 5. Event-week. We transformed the daily data into weekly data. Week 0 is equal to the event
314 week. Our reference week is week -3, thus three weeks before the event. Similarly, three weeks
315 after the event is referred to as week 3.

316

317 **3.4 Methodology**

318 **3.4.1 Difference-in-Difference**

319 We use a Difference-in-Difference (DiD) estimation to investigate the causal effect of the two external
320 shocks (dates of first lockdowns and invasion) on happiness. The DiD estimation compared GNH for
321 pre-and post-event in 2020 (lockdown) and 2022 (invasion) to the same time periods (counterfactual)
322 in 2021, assumed to have normal happiness levels in the new "normal" era with COVID-19.
323 Specifically, we estimate the following equation:

$$324 \quad GNH_{i,c} = \alpha_0 + \alpha_1 \eta_{i,c} * Year_i + \alpha_2 X_{i-1,c} + \mu_c + \sigma_i + \epsilon_{i,c} \quad (1)$$

325 Where $GNH_{i,c}$ is the daily happiness at time i for country c . Our intervention variable is $\eta_{i,c}$. It is a
326 dummy variable denoting either $lockdown_{i,c}$ or $invasion_{i,c}$ depending on the type of shock, COVID-
327 19 (2020) or the Ukrainian War (2022). Our $lockdown_{i,c}$ and $invasion_{i,c}$ variable take on the value of
328 0 pre-lockdown or invasion and one post-lockdown or invasion in both the year of the actual lockdown
329 (2020) or war (2022) and the counterfactual year assumed to be normal (2021), thus a year in which
330 COVID-19 has been accepted as the new normal with no lockdowns.

331 $Year_i$ is a dummy variable where 1 is the year 2020 or 2022, respectively. We control for new COVID-
332 19 cases per million with a one-day lag ($X_{i-1,c}$). The model includes country and day-of-the-week fixed
333 effects (μ_c and σ_i). We report robust standard errors to address heteroscedasticity ($\epsilon_{i,c}$).

334 Our interaction term $\alpha_1 \eta_{i,c} * Year_i$ will convey the causal impact of the lockdown or invasion on
335 happiness. We admit that it is possible that the DiD estimator could conflate the true effect of the
336 lockdown and the Ukraine invasion with the broader negative economic spillover in 2020 and 2022.
337 Therefore, we conduct an additional sensitivity test, namely an event study, to gauge the robustness of

338 the negative impact of the lockdown and the invasion on happiness. To this effect, we interpret the DiD
 339 results alongside the event study.

340

341 **3.4.2 Event study**

342 We also estimate an event study model to test for any adaptation of the GNH after the negative external
 343 shocks. Additionally, the event study results also serve as a sensitivity test to confirm the robustness of
 344 the DiD results. The analysis is for the time period 3 weeks pre-event (week -3, week -2, week-1), the
 345 event week (week 0) to 9 weeks post-event (week 1 to week 9). Thus, the reference week is week -3,
 346 and we test the adaptation of happiness to the GNH levels of the reference week.

347 To compare the data across events for 2020 and 2022, we recoded the dates as numbered days from 2
 348 – 90. We start on day 2 to represent a Tuesday; thus, we assume Monday is the first day of the week.
 349 This is to compare the same day of the week between the two events since the day of the week also
 350 influences happiness– thus recognising the heterogeneity between different days of the week (normally
 351 a Monday low and a Saturday high) and addressing this heterogeneity by comparing the same day of
 352 the week across events.

353 Therefore, we estimate the following:

$$GNH_{i,c} = \sum_{k=-3}^9 \alpha_k E_{k,c} + \gamma X_{i-1,c} + \mu_i + \rho_c + \epsilon_{i,c} \quad (3)$$

354

355 $GNH_{i,c}$ is the happiness measured at time i for country c . $E_{k,c}$ Where $k=-3, -2, \dots, 9$, are dummy variables
 356 for the three-week pre-event week and nine-week post-event. The variable $X_{i-1,c}$ controls for the lagged
 357 number of new COVID-19 cases per day per million per country c . The model includes day-of-the-
 358 week fixed effects, μ_i , and country fixed effects, ρ_c . With $\epsilon_{i,c}$ the residual. The third-week pre-event
 359 week is the reference period. The estimated coefficients on the $E_{k,c}$ dummies should therefore be
 360 interpreted as the effect of being in (for example) the fourth-week post-event week compared to week
 361 three pre-event.

362 **3.4.3 Robustness checks**

363 To test the robustness of our results in the DiD analysis, we also use the lockdown date rather than the
364 announcement date of the lockdown – and the day of the invasion rather than the day before the
365 invasion. We find similar results.

366 Furthermore, we use the event study results as a robustness check for our DiD results. If we find similar
367 results from the event study, thus happiness was negatively affected after the event, we can confirm our
368 DiD results.

369

370 **4. Results**

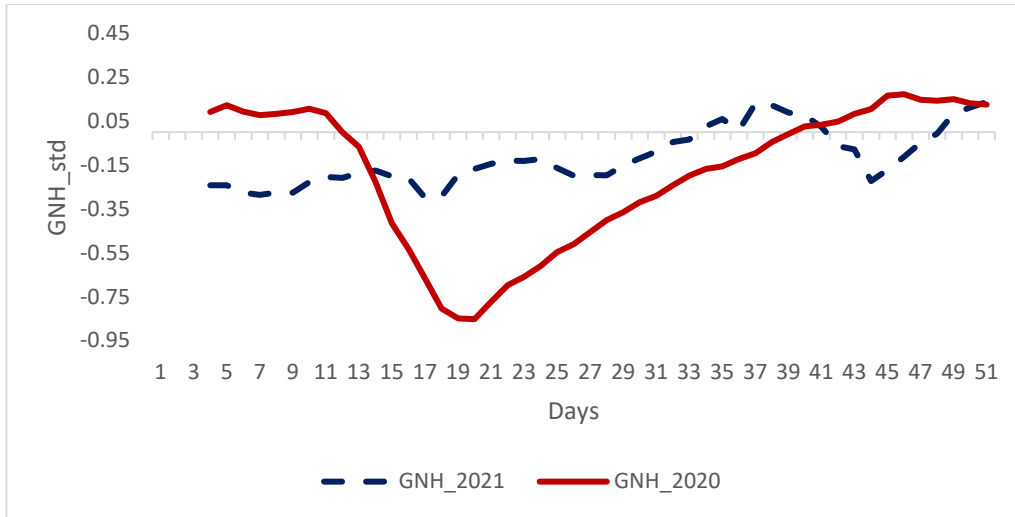
371 **4.1 Graphical analysis of the evolution of happiness across events**

372 We start our analysis by comparing the GNH pre- and post-lockdown in 2020 to the same dates in 2021.

373 We investigate the three weeks before, the event week and the three weeks after the event week. We
374 follow the same method considering the invasion of Ukraine; however, comparing the years 2022 to
375 2021.

376 Fig 1 plots daily GNH for the period pre- and post-lockdown, and Fig 2 plots GNH for the time pre-
377 and post-invasion. To make a comparison across the years, we number the days in all the years from 1
378 to 57 (see the X-axis), thus for a period of three weeks before the event, the week of the event and three
379 weeks after the event week.

380 Fig 1 shows a sharp decline in GNH (solid red line) on the approximate date on which lockdowns were
381 announced, this decrease in GNH is only seen in 2020, with no such changes in 2021. A similar pattern
382 is seen in Fig 2, with GNH (solid red line) showing a sharp decrease on the day before the invasion in
383 2022. However, this is not reflected in the pattern in 2021.



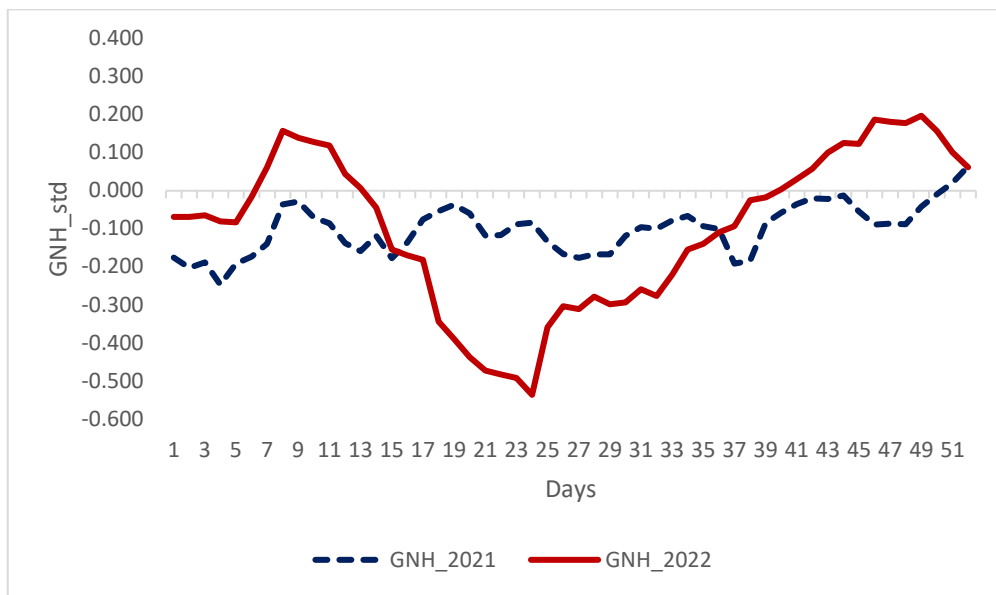
384

385 Note: The blue dotted line indicates 2021 (counterfactual) and the solid red line, 2020, the year of the external shock.
 386 Source: Greyling et al. [31]

387 **Fig 1. Standardised GNH before and after lockdown.**

388

389



390

391 Note: The blue dotted line indicates 2021 (counterfactual) and the solid red line 2022, the year of the external shock.
 392 Source: Greyling et al. [31]

393 **Fig 2. Standardised GNH before and after the invasion.**

394

395 The graphical analysis of the GNH data shows a sharp decrease in the GNH brought on by external
 396 shocks. In the absence of lockdown or the invasion, we assume the GNH would have followed a similar
 397 pattern as in the counterfactual year, thus a common trend assumption. However, this assumption was
 398 violated by the external shocks. The DiD analysis should confirm this initial insight.

399 4.2 Difference-in-Difference

400 To answer our question regarding the causal effect of the two external shocks on happiness, we turn to
 401 our results from the DiD in Table 2, which compares GNH for three weeks pre-and post-event in 2020
 402 (lockdown) and 2022 (invasion) to the same time periods (counterfactual) in 2021 for all ten countries,
 403 assumed to have new 'normal' happiness levels.

404 To determine whether the decrease in GNH was associated with the lockdown and the invasion (the
 405 intervention) specifically and not only the trend (we also control for new COVID-19 cases per million
 406 as a proxy for the evolution of the pandemic), we consider the estimated coefficient of the interaction
 407 variable " $lockdown_{i,c} * Year$ or $invasion_{i,c} * Year$," i.e., the DiD estimator. We find it statistically
 408 significant (at the 10 and 1% levels, respectively) and negative. Therefore, indicating that "lockdown
 409 or the invasion in the year of COVID-19 (2020) and the year of the Ukrainian war (2022)" had lower
 410 levels of GNH of 0.0803 and 0.249 points, respectively, compared to the counterfactual year with no
 411 lockdown or invasion. Thus, in the year when the intervention (lockdown and invasion) was applied,
 412 people were unhappier after the lockdown announcement and imminent invasion of Ukraine compared
 413 to the counterfactual year. This implies that *the lockdown and the invasion of Ukraine caused a decline*
 414 *in happiness levels*, controlling for COVID trends (COVID cases), observed and unobserved differences
 415 in the characteristics of countries and day-of-the-week effects.

416 **Table 2. The effects of COVID-19 lockdown and the invasion of Ukraine - DiD estimates for all**
 417 **countries.**

Variable	Lockdown		Invasion	
	GNH_std	SE	GNH_std	SE
Lockdown #year COVID	-0.0803*	(0.0460)		
Lagged new COVID- 19 cases per million	Yes		Yes	
Country FE	Yes		Yes	
Day of the week FE	Yes		Yes	
Invasion # year War			-0.2490***	(0.0670)
cons	-0.1651***	(0.0378)	-0.1033***	(0.0517)
N	972		972	
adj. R ²	0.046		0.026	

418 Standard errors in parentheses

419 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ Lockdown = Day when lockdowns were announced in each country, and Ukraine =23
 420 February 2022 (the day before the invasion)

421 Consequently, we split our sample between the Northern and Southern hemispheres. We see from Table
422 3 that our intervention variable 'lockdown' is significant and negatively related to happiness in both
423 hemispheres. Regarding the intervention variable 'invasion of Ukraine', we find a similar result: the
424 GNH in the year of the war after the invasion is lower than in the counterfactual year with no invasion
425 in the Northern and the Southern hemispheres.

426 These results show that even if we consider the Northern and Southern hemispheres separately, we find
427 that the "lockdown" and the "invasion" caused lower happiness levels in both hemispheres. The fact
428 that the countries in the Southern hemisphere are much further geographically removed from Ukraine
429 makes no difference to the effect of the invasion on their happiness levels. The imminent threat of a
430 nuclear or World War III, as well as all the other negative consequences of the war, affects people's
431 happiness in general, no matter how far they are geographically separated.

432 Table 3. The effects of COVID-19 lockdown and the invasion of Ukraine – DiD estimates for the Northern and Southern hemispheres.

Variable	Lockdown Northern hemisphere		Lockdown Southern hemisphere		Invasion Northern hemisphere		Invasion Southern hemisphere	
	GNH_std_sd_cov	SE	GNH_std_sd_cov	SE	GNH_std_sd_ukr	SE	GNH_std_sd_ukr	SE
Lockdown #Year COVID	-0.1386**	(0.0550)	-0.2348***	(0.0888)				
Lagged new COVID cases per million	Yes		Yes		Yes		Yes	
Country FE	Yes		Yes		Yes		Yes	
Day of the week FE	Yes		Yes		Yes		Yes	
Invasion #Year War					-0.2828***	(0.0699)	-0.2281**	(0.0982)
_cons	-0.0453	(0.0456)	-0.4026***	(0.0704)	0.0298	(0.0537)	-0.3939***	(0.0732)
<i>N</i>	448		188		448		188	
adj. <i>R</i> ²	0.027		0.295		0.173		0.532	

433 Standard errors in parentheses
434 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
435
436

437 **4.3 Event study**

438 Following the DiD results, we continue our analysis concerning the period it takes for happiness to
 439 adapt after the two different types of external shocks. We divide our time-series data into weeks. The
 440 event week is week 0, which includes the announcement of the lockdown dates (see Table 1) and the
 441 day before the invasion of Ukraine (23 February 2022). We extend our time period of analysis up to 9
 442 weeks after the event to gain better insights into adaptation to happiness levels.

443 **Table 4. Duration of the external shocks on happiness (GNH): lockdown and the invasion.**

Reference week = -3 pre-event	Lockdown		Ukraine invasion	
	GNH_ma	SE	GNH_ma	SE
Week -2	-0.0010	(0.0266)	0.0237	(0.0386)
Week -1	-0.3346***	(0.0264)	0.0379	(0.0387)
Week 0	-0.3297***	(0.0265)	-0.1097***	(0.0387)
Week 1	-0.1672***	(0.0268)	-0.1154***	(0.0388)
Week 2	-0.0489*	(0.0268)	-0.0536	(0.0387)
Week 3	0.0431	(0.0268)	0.0290	(0.0386)
Week 4	0.0350	(0.0269)	0.0889**	(0.0386)
Week 5	0.1083***	(0.0265)	0.0447	(0.0386)
Week 6	0.1135***	(0.0265)	0.0569	(0.0387)
Week 7	0.1200***	(0.0264)	0.0959**	(0.0387)
Week 8	0.1321***	(0.0264)	0.0867**	(0.0388)
Week 9	0.1863***	(0.0314)	0.1580***	(0.0402)
Lagged new COVID-19 cases per million	Yes		Yes	
Country FE	Yes		Yes	
Day of the week FE	Yes		Yes	
cons	7.1111***	(0.0237)	7.3409***	(0.0385)
N	818		830	
adj. R ²	0.686		0.316	

444 Standard errors in parentheses
 445 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
 446

447 From Table 4, we see in terms of the lockdown shock that weeks - 1 to week 2 have lower GNH levels
 448 than the reference week (week -3). However, after that, the GNH recovers, and from week 5, it is
 449 significant and higher than in week -3, thus adaptation. For the external Ukrainian invasion shock, we
 450 see that weeks 0 and 1 have lower levels of GNH compared to week -3. Even though not statistically
 451 significant, the GNH remained lower until week three post-event. This might reflect the surprise of this

452 external shock; thus, people only realised the threat the week of the invasion, whereas, with the
453 lockdown shock, people were aware of this earlier. However, in both instances, the effect of the shock
454 on happiness only lasts two weeks post-event. Therefore, it indicates a quick recovery to levels of GNH
455 compared to week -3 pre-event.

456
457 Continuing our investigation into the Northern and Southern hemisphere countries, we refer to the
458 results in Table 5. Regarding the external lockdown shock on the Northern hemisphere, we see that
459 weeks - 1 to 0 have lower GNH levels than the reference week (week -3). Even though not statistically
460 significant, the GNH remained lower until week 3. By week 5, GNH levels were higher than what was
461 experienced in week -3, gaining statistical significance. For the Southern hemisphere, we note that
462 lower levels of GNH were experienced during weeks -2 to 0 and week 2 again.

463
464 In the Northern hemisphere, we find similar results as in the analysis for all the countries. With both
465 the interventions lockdown and invasion, adaptation is already evident in week 3 and week 2,
466 respectively, after the event week and gains statistical significance by weeks 5 and 4. In the Southern
467 hemisphere, it seems that adaptation is somewhat slower. In the instance of lockdown only from week
468 7 after the event week, whereas with the invasion adaptation also occurred in week 4 after the event.
469 Though these results are not statistically significant, the coefficients are positive, implying that GNH is
470 at higher levels than the reference week.

471
472 From the event study, it seems that GNH levels adapt relatively quickly after a shock to previous levels
473 of GNH. Therefore, we conclude that adaptation at the macro-level is quick and complete for the
474 countries under investigation. This confirms that the adaptation theory holds at a macro-level for
475 negative external shocks, similar to studies focusing on life events at a micro-level as argued by Larsen
476 [21], Lykken and Tellegen [18], Williams and Thompson [22], Headey and Wearing [20] and Brickman
477 and Campbell [19].

478
479

Table 5. Duration of the external shocks (lockdown and the invasion) on happiness (GNH): A comparison between the Northern and Southern hemispheres.

Reference week = -3 pre-event	Lockdown – Northern hemisphere		Lockdown – Southern hemisphere		Invasion – Northern hemisphere		Invasion – Southern hemisphere	
	GNH_ma	SE	GNH_ma	SE	GNH_ma	SE	GNH_ma	SE
Lockdown Week -2	0.0161	(0.0211)	-0.0954*	(0.0312)				
Lockdown Week -1	-0.3672***	(0.0731)	-0.3107**	(0.0693)				
Lockdown Week 0	-0.2688***	(0.0713)	-0.5219**	(0.0699)				
Lockdown Week 1	-0.0886	(0.0781)	-0.4024	(0.1452)				
Lockdown Week 2	-0.0204	(0.0868)	-0.1635*	(0.0394)				
Lockdown Week 3	0.0536	(0.0689)	-0.0293	(0.0392)				
Lockdown Week 4	0.0434	(0.0615)	-0.0258	(0.0141)				
Lockdown Week 5	0.1339*	(0.0594)	-0.0017	(0.0046)				
Lockdown Week 6	0.1494*	(0.0692)	-0.0241	(0.0383)				
Lockdown Week 7	0.1339	(0.0837)	0.0283	(0.0268)				
Lockdown Week 8	0.1382	(0.0833)	0.0519	(0.0194)				
Lockdown Week 9	0.2001*	(0.0909)	0.0813	(0.0355)				
Invasion Week -2					0.0621*	(0.0269)	-0.0678	(0.0401)
Invasion Week -1					0.0834*	(0.0420)	-0.0734	(0.0711)
Invasion Week 0					-0.0628	(0.0541)	-0.2132*	(0.0683)
Invasion Week 1					-0.0359	(0.0582)	-0.2728**	(0.0632)
Invasion Week 2					0.0212	(0.0581)	-0.1971*	(0.0536)
Invasion Week 3					0.0642	(0.0675)	-0.0027	(0.0450)
Invasion Week 4					0.1451**	(0.0583)	0.0183	(0.0415)
Invasion Week 5					0.0857	(0.0584)	0.0100	(0.0808)
Invasion Week 6					0.0639	(0.0547)	0.0998	(0.0428)
Invasion Week 7					0.1214	(0.0769)	0.0845	(0.1150)
Invasion Week 8					0.1343*	(0.0642)	0.0171	(0.0756)
Invasion Week 9					0.1804**	(0.0652)	0.1422	(0.0636)
Lagged new COVID-19 cases per million	Yes		Yes		Yes		Yes	
Country FE	Yes		Yes		Yes		Yes	
Day of the week FE	Yes		Yes		Yes		Yes	
cons	7.2025***	(0.0572)	6.9382***	(0.0321)	7.4448***	(0.0476)	7.1139***	(0.0297)
N	579		239		581		249	
adj. R ²	0.701		0.786		0.281		0.532	

480

481 **5. Conclusions**

482 In this study, we compared two negative external shocks (health shock – COVID-19 and a war shock –
483 the Ukrainian war) for ten countries spanning the Northern and Southern hemispheres to determine how
484 quickly countries' happiness adapt. By doing the aforementioned, we contributed to literature in three
485 significant ways. First, no other study has compared two different types of external shocks on happiness
486 at a macro-level. Second, no other study has tested whether adaptation theory holds at the country level
487 across events using a cross-country analysis. Third, this is the first study to use real-time information
488 from Big Data instead of survey data to re-examine adaptation theory. This allowed us to contribute to
489 the debate on whether adaptation at a macro-level is quick and complete.

490 Our Difference-in-Difference model established that both COVID-19 and the Ukrainian war caused a
491 significant decrease in happiness. This finding holds for both the Northern and Southern hemisphere
492 countries. Similarly, the event study showed that the external shocks negatively affected the happiness
493 levels before, during and after the week of the event. The happiness levels were lower in the week
494 leading up to lockdown and stayed lower for two weeks after the event. For the invasion of Ukraine,
495 we saw that happiness levels were lower during the event week and stayed lower for two weeks post-
496 event. However, we saw that adaptation occurred three weeks post-event in both external shocks. We
497 find similar results across the Northern hemisphere countries, although, in the case of the Southern
498 hemisphere, adaptation to the COVID-19 shock seems slower.

499 Therefore, considering both external shocks, we can conclude that happiness levels adapted relatively
500 quickly to pre-event levels. Our findings are the first to confirm adaptation theory at a macro-level
501 *across events* using a cross-country analysis. Our study is also the first to confirm that the macro-level
502 adaptations of countries to happiness shocks within our sample are similar to the micro-level findings,
503 suggesting that people initially react strongly to negative events. Though, their happiness levels return
504 to previous levels.

505 It would be negligent of us not to discuss our study's limitations. Our panel of countries under
506 investigation does not include Ukraine, Russia or neighbouring countries. It is plausible that if they had

507 been included, we might not have seen a complete adaptation. Furthermore, as discussed in section 3.2,
508 there are limitations when working with Twitter data. However, we believe that despite these
509 limitations, the results contribute to understanding the adaptation to external shocks at a macro level.

510 In future studies, we would like to investigate the emotional effect of external shocks by analysing
511 Plutchik's [30] wheel of emotions and the adaptation of these emotions over time. Furthermore, we
512 would like to conduct narrative analysis and topic modelling of the tweets to understand better why we
513 see the patterns in the emotions.

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