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Mutual bird-human benefits during a global pandemic

Michael Brock
Jacqueline Doremus
Liqing Li

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Michael Brock[*], Jacqueline Doremus[†], and Liqing Li[‡§]

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Abstract

Feeding backyard wildlife has impure public good characteristics – it can satisfy specific human motivations whilst also improving bird populations. We document a surge in human interest in connecting with wild birds during lockdowns to address the Covid-19 pandemic. Using an event-study design at two scales and data representing three different population types, we find large increases in bird engagement that begin very soon after lockdown. The response is global: increases occur across 60 countries on six continents. However, people are sensitive to their environment, with evidence from the US showing a larger increase in engagement in states with more important bird habitat. Moreover, investments appear sustained, beginning with first bird feeders, then seed, then baths. Our work offers evidence of widespread benefits of human-wildlife interaction for humans and birds alike. We point to potential long-term effects of the Covid-19 pandemic on global bird populations and future support for bird habitat conservation.

JEL: Q26, Q57, H41

Keywords: Covid-19, birds, bird feeding, connectivity, impure public goods

[*]University of East Anglia, Norwich, UK. Email: Michael.Brock@uea.ac.uk

[†]Corresponding author: Department of Economics, California Polytechnic State University, San Luis Obispo, USA. Email: jdoremus@calpoly.edu.

[‡]University of Illinois at Urbana-Champaign, Department of Agricultural and Consumer Economics, USA. Email: lli40@illinois.edu

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1 Introduction

Over the last forty years, bird populations have plummeted by 30% across the North American continent, with losses concentrated among migratory birds such as finches, sparrows, warblers, and blackbirds (Rosenberg et al., 2019). Habitat degradation and pesticide use are likely causes (Stanton et al., 2018). Supplementing food for wild birds may help and the implications of higher bird engagement through feeding are large. Backyard feeding helps wild birds survive during critical periods when foraging is difficult or frequent, such as during winter, migration, and feeding chicks (Robb et al., 2008). Randomized control trials have shown that bird feeding improved the individual health of birds, including greater antioxidant levels, less stress and faster feather growth (Wilcoxen et al., 2015).[1] Although feeding habits across countries are poorly understood, it is suspected to be a widespread activity.[2] In the US and UK, about half of all households feed wild birds (Davies et al. 2012; Lepczyk et al. 2012).

Feeding and watching backyard birds have ecological and human benefits beyond bird survival and, for humans, the psychological benefits from engaging with the natural world in this way are well-documented (Keyes 2002; Dutcher et al. 2007; Yang and Na 2017). Connecting with local wildlife constitutes an 'impure public good,' a term first coined by Samuelson in 1954.[3] Impure public goods deliver a private stream of utility to the individual, whilst simultaneously contributing to the health and diversity of the local environment. Activities such as wildlife gardening and bird feeding imply a high degree of complementarity between the good's private and public aspects.

Given our framing of bird engagement as an impure public good, we posit that increases in interest in local wildlife during the Covid-19 lockdown period may not only satisfy human recreational desires, but also enhance the quality of the surrounding ecological infrastructure and the resilience of bird populations in the medium to long-run. To this end, we explore changes in human-wildlife interaction during lockdowns in early spring 2020 and discuss im-

[1] Note, however, that Wilcoxen et al. (2015) also found negative effects, including greater infectious disease prevalence, e.g. conjunctivitis, pox, dermal disease, or clocal disease. Despite this, they conclude that "in general, birds that had access to supplemental food were in better physiological condition."

[2] The global extent of supplementary feeding of wild birds is unknown beyond certain well-studied contexts, including the UK, US, and Australia.

[3] Beyond Cornes and Sandler (1994), others assess conditions under which private contributions will be sufficient whilst paying special attention to spatial implications (Linster 1993; Corazzini and Gianazza 2008), contribution mechanisms and incentives (Vicary 1997; Lefebvre et al. 2020) and the role of offsets in environmental settings (Kotchen, 2009).

plications for biodiversity conservation.[4] For the period 2015-2020, we use an event study design to measure changes in bird engagement during lockdown. We define 'bird engagement' as bird watching effort by people enrolled in a feeding program, seeking information on habitat engagement through Google searches, and downloading an app related to bird identification. We explore bird engagement across different scales, including a subnational analysis and a global analysis, as well as whether responses vary by the quality of bird habitat.

We find that bird watching effort by bird feeders increases by 3-33%. Search intensity for "bird feeders" by Google users increases by 17 points, out of 100, immediately after lockdowns begin, with searches for "bird bath" and "bird seed" increasing two weeks later. In the United States, increases in interest are larger in areas with more important bird habitat, suggesting a degree of human sensitivity to variation in the marginal benefit of bird watching.[5] Increases in engagement with backyard birds occur at both subnational and global levels. The latter considers 60 countries, offering new evidence on the global scope of bird feeding.

Our findings suggest that the intensified connection between people and birds during lockdown might not only help offset species survival problems, but simultaneously deliver specific humans welfare benefits. In light of the social distancing Covid-19 creates, we conjecture that bird feeding offers a platform from which humans can display actions of responsibility and guardianship. This may be particularly vital given we are deprived of many alternatives to evoke such feelings during periods of social isolation. The consistent response around the globe hence suggests that bird feeding offers meaningful benefits to humans during Covid-19 lockdowns that may also help global bird populations for years to come.

2 Bird Engagement as an Impure Public Good

As outlined above, engaging with backyard wildlife has both private and public good attributes. Bird feeding and wildlife gardening derive private benefits, such as the utility from engaging with nature, whilst at the same time delivering a bundle of public goods, such as ecosystem services and existence value. Understanding the interaction between these is essential if we

[4] We call the suite of policies that restricted public access to public and private areas 'lockdowns.'

[5] Public understanding of biodiversity is quite poor. A study in Switzerland found that people overestimated the number of species in their country by a factor of 30 (Lindemann-Matthies and Bose, 2008). Though we cannot identify the mechanism, we speculate that this is due to higher returns to bird watching effort from a greater diversity of birds visiting feeders and baths in these regions.

are to fully recognise the wider implications of a surge in proactive human interest regarding their local wildlife. In a study of bird feeders, Brock et al. (2017) find that the most common motivation for feeding is enjoyment from looking at them. The second most common is to help bird populations (see Table 5).

Whilst, (as Cornes and Sandler (1994) suggest as necessary), the degree of complementarity between these public and private components therefore seems high, declining bird populations might suggest that motives driving private engagement have until now been insufficient to keep pace with habitat destruction. At the same time, there is increasing evidence that bird feeding is shaping bird populations and increasing their resiliency, something particularly important as our climate changes (Plummer et al., 2015).

Other complementarities include potential spill-over effects from people taking an initial interest in their local wildlife. For example, people are more interested in bird species that visit feeders (Schuetz and Johnston, 2019), and may be more inclined to support conservation efforts that affect them through membership in conservation organisations, donations to wildlife charities or a desire to learn more about other local environments disparate from their own.

2.1 Changes from Covid-19 lockdowns

By definition, lockdowns change the share of time people spent in their homes with immediate effect. For example, in the US the time spent at home between March 15 and May 15, 2020 rose by approximately 15% (See Figure A1).

Lockdowns may pique people's interest in birds through several channels. First, and most obviously, forced time at home reduces the opportunity cost of wildlife viewing in one's backyard. Second, human benefits gained from bird engagement may also be affected. Human-wildlife interactions, particularly with birds, are known to be soothing and relieve stress (Ratcliffe et al., 2013). Given increased stress and required isolation from other humans during lockdown (Brodeur et al., 2020), people may seek out connections to birds and birdsong. With fewer human interactions, birdsong may be particularly valuable given genetic relationships between human and bird vocalisations (Vargha-Khadem et al., 2005; Haesler et al., 2007; Lange-Küttner, 2010). Decreased noise pollution during lockdowns may also enhance benefits from bird engagement.[6] Qualitatively, there is evidence for this: 91% of survey respondents in the UK stated they were reluctant to fully return to their pre-lockdown lifestyle, mainly due to the enjoyed reductions in pollution and the increased interactions with wildlife (Binding, 2020).

If people who are impurely altruistic allocate more time to bird engagement during Covid-19, we would expect an increase in total provision of public goods related to birds (Andreoni, 1990). Furthermore, the warm-glow from contributing to impure public goods may have particular appeal during lockdowns in response to the pandemic. A further discussion of the channels by which humans and birds benefit from this intriguing relationship is offered in Section 6.

3 Data

To assess changes in bird engagement after Covid-19 lockdowns, we use data from three different sources:[7] bird feeder enrolment data from Cornell University's Project Feeder Watch, search interest data from Google Trends, and app download data from a bird identification app company. We link these data to lockdown timing by US state and by country, as well as data on important bird habitat, by US state.

Project FeederWatch (PFW): PFW is a national citizen science program run by Cornell University in the United States. Participants sign up in fall and commit to recording bird feeder visitors for up to two consecutive days per week. PFW bird feeders enter bird identification data from November to about the first week of April for each season, creating a series of six month panels.[8] We use a five-year panel of daily bird feeding effort, from 1/1/2015 to 4/10/2020.[9] Raw data are at the session level, where a session is a dedicated period of time during which the PFW participant records all birds that visit their feeder. Users enter the

[6] In Guildford, UK, ambient noise reportedly fell by eight decibels during the Covid-19 lockdown (Randall, 2020).

[7] Populations covered by these three data may overlap.

[8] Participants sign up before November through the PFW website and receive a kit to help them identify birds. Link: https://feederwatch.org/

[9] Typically, the PFW season ends around April 8-10. For the 2019-2020 season, PFW extended the season to the end of April. We are not sure the reason for the extension nor the timing of the announcement, but it may have affected bird watching effort. For our analysis, we truncate the 2019-2020 season to the same week of the year that previous seasons ended.

effort they spent on bird identification for their session, classifying their effort into one of four categories: Less than an hour, between one and four hours, between four and eight hours, and more than eight hours. We create three outcome variables, each of which is a dummy equal to one if the user watched birds for more than one, four, or eight hours in that session. From Table 1, we see that the vast majority of users spend at least an hour formally identifying birds. About one-fifth of users spend more than four hours and about 5% spend more than eight hours.

Google Trends: Google Trends data provides an unfiltered sample of search requests made to Google. It supplies an index for search intensity of a search term over the requested time period in a geographical area. This index is scaled from 0 to 100, where 100 is the week with the most searches for that search term, relative to total searches in that period, and 0 indicates that a given week did not have sufficient search volume for the specific term.[10]

We use a five-year panel (5/18/2015 to 5/17/2020) of weekly indexed search frequency data from Google Trends. In the subnational analysis, the unit of observation is at a state-week level. There, we search for terms related to bird feeding, including "bird feeder", "bird seed" and "bird bath." Using search terms on Google Trends show exact matches for an search term in the language given.

To create our sample for the global analysis, we use search *topics* related to bird feeding, instead of search terms, to accommodate different languages. Topics on Google Trends are a group of terms that share the same concept in any language. Our topics include "bird feeder", "bird food",[11] and "bird bath".[12] The set of countries with sufficient search volume varied across topics. As shown in Table A1, 60 countries had sufficient volume for the "bird feeder" topic, 49 for "bird seed", and 34 for "bird bath".[13] For our global analysis, an observation is

[10]If the search volume is very low throughout the period, Google Trends fails to report data for that geographical area for the whole period.

[11]Since "bird seed" is not a topic defined on Google Trends, we use "bird food" instead. The definition of "bird food": Bird food is food eaten by birds. While most bird food is fed to commercial fowl, people also use bird food to feed pet birds or wild birds.

[12]As a robustness check, we used these topics instead of terms for the subnational analysis. Results are consistent with using the three search terms mentioned above.

[13]In our main analysis, we use these populations for our analysis. As a robustness check, we restrict to the the 34 countries that had sufficient volume in all three topics. Results are consistent with our main analysis.

country-week.

App Data: To supplement our main analyses, we present descriptive graphs of user downloads of a suite of global bird identification apps produced by Spiny Software. We use data on change in year-over-year downloads for a suite of apps that include Birds of Britain, among others.[14] Consequently, our data covers a period spanning January 2020 to May 2020.[15]

Lockdown Timing: The Covid-19 pandemic emerged on a global scale in February and March. In response, policymakers issued "shelter in place" and "safer at home" policies, which we call lockdowns, that restricted public access to public and private areas that could facilitate disease transmission. For our subnational analysis, we use data from Raifman et al. (2020) on the initiation of lockdown timing by state.[16] In our preferred specification, we use the timing of the first lockdown in the United States, which was March 19, 2020 in California, for all states.[17] Americans reduced their mobility in concert, even though the timing of formal state-level lockdowns varied by as much as 19 days. Figure A1 shows the average percentage change in mobility in the United States, which has a steep change in the week of March 15th, 2020. Figure A2 shows the change in mobility for each state. For our global analysis, we use data from the University of Oxford on the timing of lockdown initiation by country.[18]

Important Bird Areas (IBA): BirdLife International has mapped areas critical to bird habitat, creating Important Bird Areas.[19] To explore whether changes in bird engagement vary with the quality of bird habitat, we extracted the count and size of IBAs for each state in the US from the Audubon website.[20] We linked the count of IBAs to each state in the Google

[14]Spiny Software specialises in mobile apps that encourage human-wildlife interaction. In addition to Birds of Britain, their apps include Chirp and Chirpomatic, which helps with birdsong recognition. They also have a suite of apps, Nature Guides, to help users identify birds, butterflies, and other organisms.

[15]Note that Spiny Software launched a new version of some of their apps in early March. This may have affected app downloads; for example, users seem to prefer to download recently updated apps (Nayebi et al., 2016). For this reason, we interpret changes in app downloads cautiously.

[16]We supplemented Raifman et al. (2020) with news searches for the timing of lockdowns with weaker restrictions, ending up with 43 states with a lockdown of some kind.

[17]March 19th, 2020 was in the week of March that began on March 15th, 2020.

[18]The Oxford COVID-19 Government Response Tracker: https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker

[19]IBAs can be of local, national, or global conservation importance. We include all types of IBAs in our analysis. See BirdLife's website: http://datazone.birdlife.org/site/ibacritglob for details on criteria.

[20]We used each state's page on Audubon's website, https://www.audubon.org/important-bird-areas, accessed 5/20/2020, and counted all types of IBAs. Thus we included those pending, delisted, potential, identified, etc. as well as those recognised.

Trends and PFW datasets.

4 Methods

We use an event study to estimate changes in bird engagement within the United States and across countries. Our specifications differ slightly across the two geographical scopes: we use a single event design for the subnational analysis and a staggered event design for the global analysis.

4.1 Subnational Analysis of the United States Specification

We identify changes in bird engagement within the United States, and how they differ by bird habitat quality, by comparing bird engagement before and after Covid-19 lockdowns while adjusting for seasonality. We characterise the lockdown as a national event using a simple estimator:[21]

$$Y_{ist} = \alpha + \beta Post_t + \Gamma_{ist} + \epsilon_{ist} \tag{1}$$

where $Post_t$ is a dummy equal to one for the period after March 15th, 2020. First, we use the PFW data to examine how people's bird watching effort is affected by the national lockdown. The outcome Y_{ist} measures a user i's bird watching effort in year - week t of state s. It is a binary variable equal to one if the user exceeded the effort threshold and zero otherwise. Γ_{ist} includes individual, month, state, and year fixed effects.

Second, we utilise the state-by-week Google Trends data to explore how people's search interests change regarding bird engagement. The outcome measures the search intensity of a search term in year - week t of state s. The data are first-differenced at a lag equal to the period to address seasonal effects in the search intensity in google trends data,[22] State fixed effects and year fixed effects are included in the regression. Standard errors are clustered at the state level for both analyses.

In addition to estimating the average change in bird engagement after the first lockdown in the United States, we estimate how the response varies across areas with more and less

[21] We also examine the dynamic treatment effects of the lockdown on bird engagement based on Equation 3. Results are reported in Table A2 in the Appendix.

[22] We set lag equal to 52 here because the data is at weekly level.

important bird habitat. We interact the post-event dummy with binary variables for the tercile of important bird area, IBA_s:

$$Y_{ist} = \alpha + \beta Post_t + \phi_1(Post_t * IBA1_s) + \phi_2(Post_t * IBA2_s) + \Gamma_{ist} + \epsilon_{it} \tag{2}$$

where the omitted category is the lowest tercile of the count of important bird areas and $IBA2_s$ is the highest tercile.[23] The coefficients ϕ_1 and ϕ_2 associated with the interaction term indicate if, compared to states in the bottom tercile, bird engagement is higher in states with more bird habitats.

4.2 Global Analysis

For our global analysis, we identify changes in bird engagement by comparing before and after Covid-19 lockdowns and exploit variation in lockdown timing across countries (see Figure A3).[24] Our specification to estimate the dynamic treatment effect is as follows:

$$Y_{ct} = \alpha + \sum_{k=0}^{K} \tau_k Z_{ct}^k + \Gamma_{ct} + \epsilon_{it} \tag{3}$$

Where the variable Z_{ct}^k is an indicator for the number of k weeks relative to country c's initial treatment ($k = 0$ is the week of initial treatment). Y_{ct} measures the outcome variable in country c in year-week t. Γ_{ct} includes country fixed effects and year fixed effects that capture annual differences in relative search frequency across countries. The primary coefficients of interest are the τ_k terms, which measure changes in search interests in each of the weeks following the beginning of the country's lockdown.[25][26] Standard errors are clustered at the country level.

4.3 Testing for Pre-trends

We conduct independent tests for pre-trends by extending our baseline specification with leads of treatment associated with relative-weeks before the first lockdown. In the staggered event design in Equation 3, the leads of treatment are associated with relative-weeks before the

[23] Results are qualitatively the same when using quantiles.

[24] This approach, modelling the lockdown as a single event within a country, is consistent with our subnational analysis in the United States. There we used the first lockdown in the week of March 15th, 2020.

[25] Due to the staggered design, there are few observations for $\tau > 10$. To address this, we estimate the average effect across weeks for $\tau > 10$.

[26] For our analyses of the PFW and subnational Google Trends data, these τ_k terms reflect the weeks following the week of March 15th.

lockdown in each country:

$$Y_{it} = \alpha_0 + \sum_{k=-K}^{-2} \sigma_k Z_{it}^k + \sum_{k=0}^{K} \tau_k Z_{it}^k + \delta_y + \gamma_i + \epsilon_{it} \quad (4)$$

If coefficients associated with periods preceding treatment are not jointly statistically different from zero, we fail to reject the parallel trends assumption.

4.4 Limitations

The event study design has been used in other contexts when evaluating changes in information-seeking in response to Covid-19 lockdowns (e.g. Bento et al. 2020). The main limitations are the external validity of the estimates and our inability to tease out the mechanisms behind estimated effects. Although these limitations also apply to our context, we feel they are less problematic given the research objective is to simply document the unexpected yet exceptional change to bird feeding in response to Covid-19 lockdowns. Regardless of the mechanism, this dramatic change in feeding through spring will affect future bird populations and support for environmental policy as well as shed light on the relationship between bird feeding and subjective wellbeing around the globe.

5 Results

5.1 Results for Subnational Analysis of the United States

We begin with our analysis using the simple event study design, where we compare bird identification effort and search behaviour before and after the first lockdown in the US, controlling for seasonal variation and state-level differences. We then investigate differential changes in bird engagement across states with varying intensity of important bird areas.

5.1.1 Bird Engagement After Lockdown

Table 2 reports estimates from Equation 1 using two sources of data. The three columns on the left report estimates from PFW, where the outcome is a binary variable equal to one if the user recorded bird feeder visits for at least one, four, or eight hours in a week.[27] The

[27]The omitted category of bird identification effort is less than one hour.

three columns on the right report estimates from Google Trends, where the outcome is the relative search index for the search terms “bird feeder,” “bird seed,” and “bird bath.” These two datasets reference two distinct populations that may overlap: existing bird feeders in PFW and internet users in Google Trends.

Beginning with the PFW data, we see increases in the likelihood a user spends time in bird identification for each of the thresholds. The coefficients report the percentage point change, which is not monotonically increasing across the thresholds, unlike the percent change. The likelihood a bird feeder spends at least one hour increases by 3.1 percentage points or 3.7%. For more than four hours, the change is greater: an increase of 4.3 percentage points or 19.5%. For eight hours or more, the change in percentage points is smaller, at 1.6, but this corresponds to a 33% increase because the share of bird feeders who spend more than eight hours watching their feeder is very low.

Moving to Figure 2, we see that changes in each threshold are not driven by pre-trends and do not reflect the dynamics of the response to lockdown. Changes in effort begin in the very first week, suggesting that our simple event study design is adequately capturing a behavioural response across states in the United States. The response doubles in week two, increases further in week three, and then appears to stabilise (see Table A2 for dynamic treatment effect). Results hold with a staggered event study design, where lockdown timing varies across states (see Table A3). These responses suggest that people who already fed birds increased their bird engagement once their mobility was restricted.

Next, we turn to data from Google Trends to assess changes in bird engagement among a broader, more diverse group of people: internet users. Focusing on column 4 of Table 2, we see that the relative frequency of the search term “bird feeder” jumps by 17 points within the 100 point Google index after the first lockdown. The other search terms also increase, albeit by a smaller magnitude: “bird seed” increases by 5.4 points and “bird bath” by 8.5 points. This suggests a greater relative interest in products associated with providing supplementary amenities for birds after Covid-19 lockdowns. Figure 3 suggests that the parallel trends assumption is satisfied for all three search terms.

Our results suggest that the relative frequency of bird-related search terms increased dramatically during the lockdown period. Because Google Trends includes all Google users, these data also include people who did not previously feed birds, something we could not capture using PFW. Thus we interpret our two sets of results as suggesting increases in bird feeding effort along both the intensive (PFW) and extensive (Google Trends) margins, although we acknowledge an inability to test the latter claim directly.

5.1.2 Differential Response Near Important Bird Areas

Next, we investigate how changes in bird engagement differ for areas with high and low important bird habitat using the specification described in Equation 2. The top panel of Table 3 shows changes in bird identification effort among bird feeders in PFW and the bottom shows changes in relative search frequency among Google users. Focusing first on the top panel, we see evidence that identification effort by feeders increases more in areas with more important bird habitat. The coefficient on the interaction term for the middle tercile is positive and statistically significant at the 10% level for all effort thresholds. The coefficient on the interaction term for the top tercile is also positive, however we only reject the null for the lowest effort threshold, one hour.

Moving to the second panel of Table 3, we fail to find an increase in search interest among Google users in the middle tercile of bird habitat. The coefficient for each search term is negative and the standard errors are large. However, for "bird feeder" we find a somewhat large, precise increase for Google users living in states in the highest tercile of important bird area.

Together, this evidence suggests a greater increases in bird engagement among people who live in areas with more important bird habitat. This effect may be stronger for people on the margin, in terms of bird engagement. We see a larger effect within the one hour threshold for bird feeders and we only see effects among people searching for "bird feeder" and not those searching for seed or baths. Standard, low quality bird seed is sold at grocery stores, mass merchandisers, and hardware stores, while specialty seed is sold at specialty retailers. Searches for seed may thus represent a desire for deeper engagement with birds. We interpret this pattern as to suggest that habitat, and its implied higher quality birding, pushes people marginally interested in birds to invest more during the pandemic.[28]

[28]We also acknowledge that people who choose to live in states with more IBAs may be more likely to be keen wildlife enthusiasts.

5.2 Results for Global Analysis

We use a staggered event study design as described in Equation 3 to look at the global picture. Using Google Trends data from the 60 countries listed in Table A1, we report the coefficients for the ten weeks after the start of lockdown, as well as a dummy for those weeks beyond week ten, in Table 4. Focusing first on the column for "bird feeder," we see a pattern similar to results in the subnational analysis with coefficients of a similar magnitude, albeit a bit smaller. This is comforting given that we used a more basic empirical specification for the subnational analysis of the United States.

There is very little information on the scale of global bird feeding.[29] Though, birds play an important role in cultures around the world and across history,[30] it is still unclear where and why bird feeding is happening. Based on the historical development of bird feeding devices, the market size for bird seed and the current ornithological literature regarding how bird feeding affects birds, one might expect feeding to be concentrated across the United States, Canada, the UK, Germany, and Australia. Jones (2017) lists these countries as having a robust bird feeding culture. Many of these regions also have low population density, potentially increasing the returns to bird feeding. Thus, one might expect only to find a response regarding bird feeding there. However, our results assert that bird feeding is occurring at a global scale.

Our list of countries in Table A1 is not representative – these countries emerged because they had a shelter-in-place order before May 15th 2020 and they had sufficient interest in bird-related search queries – but it is sufficiently diverse to show that an interest in bird feeding is not unique to the contexts described above. Indeed, Figure 6 highlights our 60 sample countries, which span six continents.

Moving across the columns of Table 4, we see that increases in relative search frequency for "bird seed" and "bird bath" increase about two weeks after the lockdown. This behavior would be consistent with people increasingly adopting a "guardian" perspective on their backyard, adding specialty seed and baths to initial investments in feeders to make habitat enjoyable for birds. More generally, our international analyses offer some basic evidence for global interest

[29]To quote ornithologist Darryl Jones in his book *The Birds at my Table*, "After more than a decade of an unhealthy obsession with this topic... I feel confident in stating that no one has yet attempted a comprehensive bird feeding survey of the countries of the world" (2017: 64-65).

[30]The earliest recorded reference to bird feeding is likely in Hindu writings of the Vedic era, from over 3,500 years ago (Jones 2017: 39).

in bird feeding that has implications for the world's bird populations and that the action of feeding birds could improve human wellbeing across a range of cultures and environments.

5.2.1 Bird App Usage

To further assess increases in global bird engagement, we solicited data from an important bird app developer, Spiny Software, based in the UK. Spiny Software shared with us data on year-over-year changes in app purchases spanning January to May 2020. The change in app purchases is plotted against the cumulative number of countries with a shelter-in-place policy in grey in Figure 5. The UK's lockdown began March 23rd, 2020. We can see that prior to the start of global lockdowns the app had modest growth, as compared to 2019. Yet after March 23rd, as lockdowns became more common in the UK and elsewhere, app purchases spiked, and then stabilised. These data offer further evidence to suggest that the lockdown pushed a set of people with a marginal interest in birds to increase their birding effort after spending a week or two at home. One possible explanation for the two week delay in response relates to our Google Trends results: people may buy a feeder, install and fill it, birds take a few days to discover it, and once the birds arrive, people are interested in identifying them and purchase the app. Unlike with the Google Trends data, for the app purchases we can be reasonably sure that each purchase roughly corresponds to a person and that multiple purchases by an individual are unlikely.

6 Implications

Our results show a substantial increase in avian interests in the Covid-19 lockdown periods. However, readers may question the wider significance of such an increase. To us, the implications from people's raised awareness of and engagement with 'backyard wildlife' fall into two broad categories, benefits to birds and benefits to humans, although we appreciate that things do not always neatly fall into one category or the other. Nevertheless, this section describes the streams by which engaging with birds on your back doorstep can accentuate one's utility and contribute to public goods.

6.1 Bird Benefits

Enhancing the quality of the local environment may not always be the primary driver for people when they decide to undertake an activity like bird watching or bird feeding. Indeed, Table 5, taken from Brock et al.'s 2017 study of 200 respondents' motivation to feed birds in the UK, shows that the anthropocentric utility one derives from seeing birds constitutes the primary objective there. However people clearly value the fact that they can sustain or even improve the local populations of species. This concern seems to bear out with ornithological research on the impact of bird feeding, which appears to help wild birds (Wilcoxen et al., 2015).

More broadly, wildlife gardening and bird feeding offer large complementarities across public goods and private utility. Google users appear invested in making their backyards more wildlife-friendly to improve odds of seeing more wildlife. These investments during pandemic lockdowns not only satisfy their own recreational desires, but also add quality to the surrounding ecological infrastructure, and do so during a critical time for birds, as they migrate and raise families.

Beyond habitat and food provision, interest in local wildlife and investments during lockdown may lead to spill-overs for habitat conservation more broadly. Examples include a rise in membership in conservation organisations, donations to wildlife charities or a desire to learn more about other local environments disparate from their own. An example of this is the behaviour of UK 'twitchers.' This is a community whose common hobby is to visit national and international sites in pursuit of rare or vagrant birds. This activity in itself has few (if any) links to domestic or indigenous wildlife conservation, and instead revolves around the thrill of seeing species out of context and alien to its surroundings. Yet, in a survey conducted with 224 'twitchers' in 2018, nearly 80% of respondents were also members of the RSPB, Britain's biggest avian conservation charity (Fraser et al., 2020). This shows that, over time, people can derive a 'portfolio' of interests connected with wildlife. Each different interaction with wildlife delivers a slightly different type of benefit and together the set of interactions enables a far wider network of environmental benefits.

6.2 Human Benefits

Engagement with backyard nature exhibits many of the qualities identified as beneficial to long-lasting life satisfaction by the literature on subjective wellbeing. ‘Interconnectedness’ is a good example of this, and is an emotion common to many of the subjective wellbeing enhancing actions such as involvement with religion (Frey and Stutzer, 2010), community (Dutcher et al., 2007) and wider society. Furthermore, the repetition associated with ‘everyday wildlife’ interactions can induce positive feelings of responsibility (Rappe et al. 2005; Jacobsen et al. 2008), routine (Diener and Biswas-Diener, 2011) and the achievement of success under uncertainty (Dolan et al., 2008).

When applied to feeding birds, Brock et al. (2017) describe this mix of benefits as similar to those you might receive when acting as a guardian. Whilst the classic values one receives from donating to environmental charities align more closely to pro-social conservation or existence valuation, this ‘warden effect’ satisfies a very different stream of wellbeing for the individual. In fact, this value for backyard wildlife more closely resembles the utility we derive from our domestic pets or from gardening, because it involves a repeated connectivity which delivers routine, reassurance and purpose within our lives (Clucas et al., 2015). These qualities associated with backyard wildlife may be particularly valuable during the pandemic and appear to have a global appeal.

The value of people taking a more proactive role in engaging with backyard wildlife is particularly important in an era of a global pandemic. Indeed, many of the other avenues by which connectivity, responsibility and interaction would normally be achieved are forcibly removed from the individual. This includes interaction with sports clubs, religious groups and visiting vulnerable family members. Even if only temporary, this literature would suggest that a rise in the uptake of local environmental activities not only offers a way to fill one’s leisure time, but at the same time provides the individual with a way to make them feel they have an important function within their community.

Of course, when coming out of a period of lockdown, the extent to which these habits persist is an open question and to a great extent unknown. However, given the anticipated nature of Covid-19, it is possible that nations will find themselves in a fluid state of lesser and greater social restrictions when cases of the virus rise and then fall again. Here, we feel that local wildlife play a vital role in feeding our warden desires. Due to the latent resilience of these species with or without human aid, they are analogous to a resource tap which people can turn on or off when needed.

The fluidity of our engagement with local wildlife offers one final retort to the question of ‘so what?,’ and this is again entrenched within behavioural psychology. This literature proposes that activities that make us ‘happy’ must strike a balance between offering variety yet also affording us consistency and routine. It explains why people enjoy watching sports live, or will take different routes to and from work. The beauty of our local environment is that whilst some components remain constant, such as the location of green spaces or the types of wildlife you might see there, seasonality brings a different perspective, both literally in the sights and sounds one can enjoy, and ecologically. A lockdown in the spring affords people the chance to see fledgling birds and install man-made nesting sites, in summer the requirement to refill water resources for drinking and in winter the impulse to provide vital sustenance to hungry species. In short, engagement with local wildlife through a pandemic not only fulfils the need to keep us occupied, but can deliver us with a diverse array of ways in which we can feel useful, connected and valuable to others.

We believe that this paper offers some unique insights into both the short-run and long-run implications of Covid-19 on the relationship people have with backyard wildlife. It is possible that these trends constitute no more than a short-lived mechanism to enjoy one’s leisure time in a period with fewer viable alternatives. However, we conjecture that the impact of increased affiliation runs deeper than this. Not only might this period of interaction instill a more long-term and sustained interest and interconnectivity with backyard nature, but we argue that aspects of this affiliation also afford opportunities to raise people’s wellbeing through channels such as connectivity, in turn facilitating longer-term enhancements in subjective wellbeing. Thus, we see this paper’s contribution not purely one of data examination, but also to foster discussion about positive externalities in both social and environmental domains and offer evidence of global benefits from such human-wildlife interaction.

7 Conclusion

In this paper we use an event study design to estimate changes in bird engagement within the United States and across the globe. We use data from bird feeders enrolled in a bird identification program, Google users search frequency, and mobile app users of a bird identification app to estimate changes after Covid-19 lockdowns. Across each population and scale, we find large increases in bird engagement immediately following lockdowns. Interestingly, changes in interest in the United States are stronger in areas with more important bird habitat, suggesting there is human sensitivity to wildlife diversity and the opportunity to experience variety embedded within bird feeding. Consistent with a 'guardian' mentality, people seek out additional features for their gardens and yards about two weeks after lockdowns. These include information-seeking on seed, bird baths, and the identification of species.

These trends have implications for the resilience of declining bird populations, given that investments occurred during a critical time. Lockdown periods cover when birds migrate and nest, times when extra food provision has been shown to have important impacts on bird mortality and morbidity (Robb et al., 2008). There may be indirect benefits, too, if greater awareness of and connection to wildlife may spur support for habitat conservation. We relate this back to the literature on impure public goods, and recognise that the adaptations arising from periods of lockdown have seemingly heightened the private motivation to engage with backyard wildlife. Whether consciously or subconsciously, they have intensified contributions to a public good.

However, there are even broader implications from our work. The global extent of bird feeding is poorly understood by ornithologists, despite its importance for bird populations. Our work suggests that humans feed birds all over the world, not just during the winter. Moreover, these interactions may provide important benefits to human wellbeing and offer a substitute mechanism for delivering consistency, purpose, and routine to our lives.

We see increased human-wildlife interactions like the ones we document here as a potential silver lining from lockdowns, which come with enormous mental health and economic costs. Future research should assess the persistence of such behaviours post-lockdown, as well as long-term and distributional impacts of increased human-wildlife interaction, for both humans and birds.

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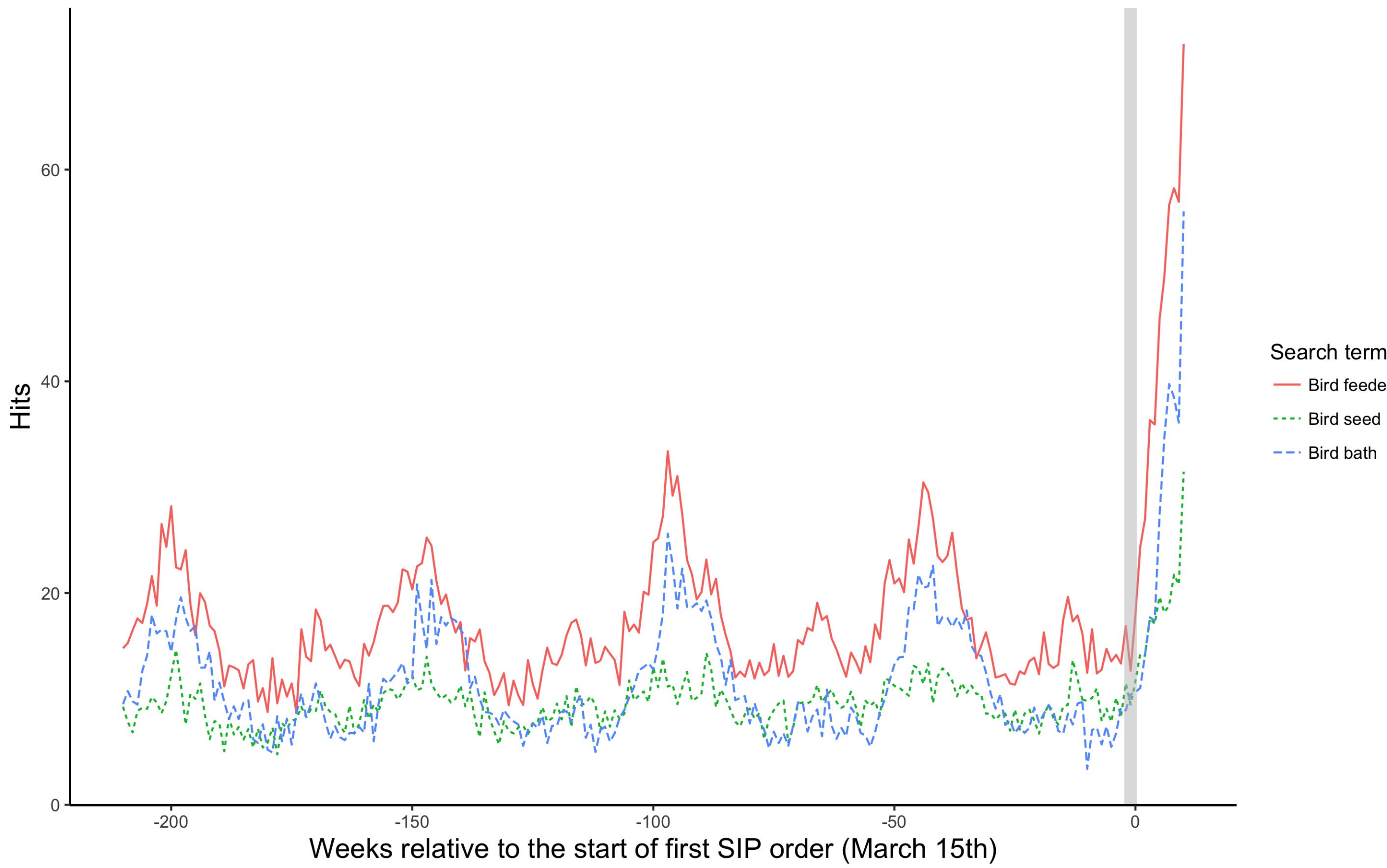


Figure 1: Raw Subnational Google Trends Search Indices

Notes: 2015-2020 Google Trends search term data by state-week for the US. Search terms include "bird feeder," "bird seed," and "bird bath." The y-axis shows the average search index for that week, across states. The maximum value is 100.

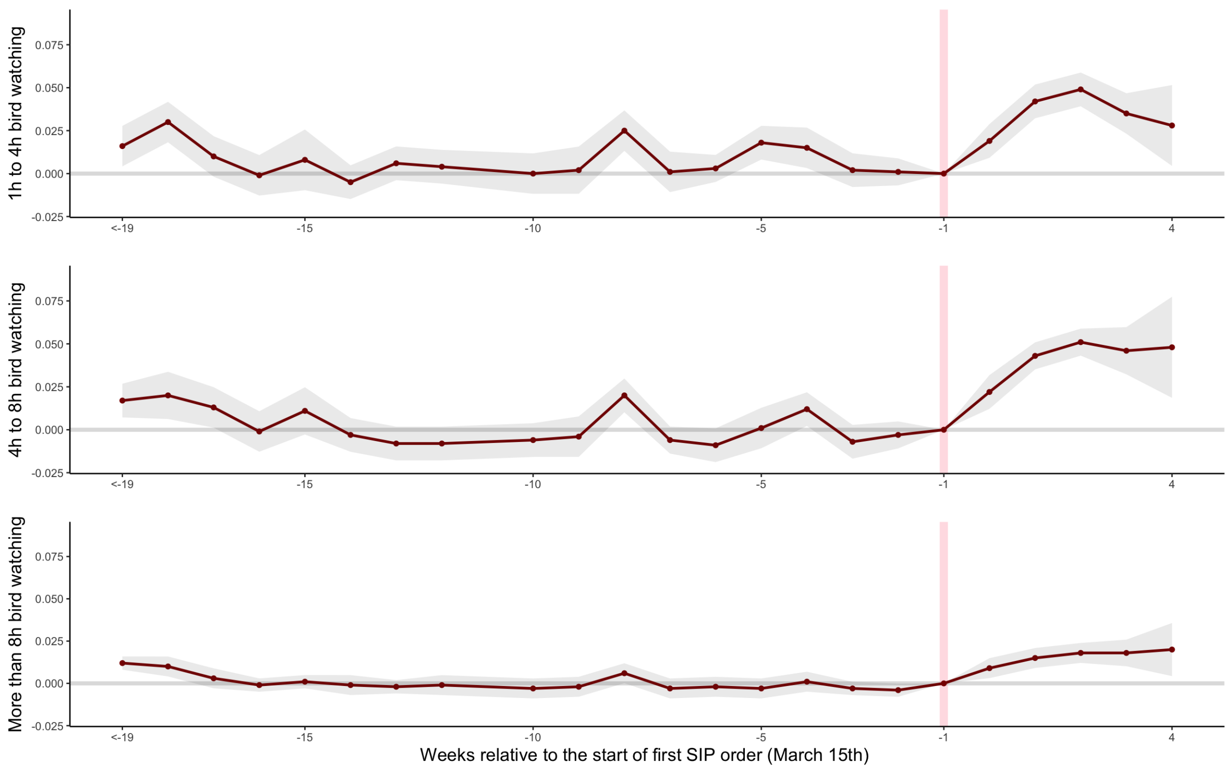


Figure 2: Change in Bird Identification Effort by Existing PFW Feeders

Notes: 2015-2020 data from Project Feeder Watch at the user-week level. Coefficients for Equation 3 plotted, showing the number of weeks relative to the start of the first shelter-in-place order. Respondents classify effort bird watching, resulting in three binary outcome variables associated with the three panels.

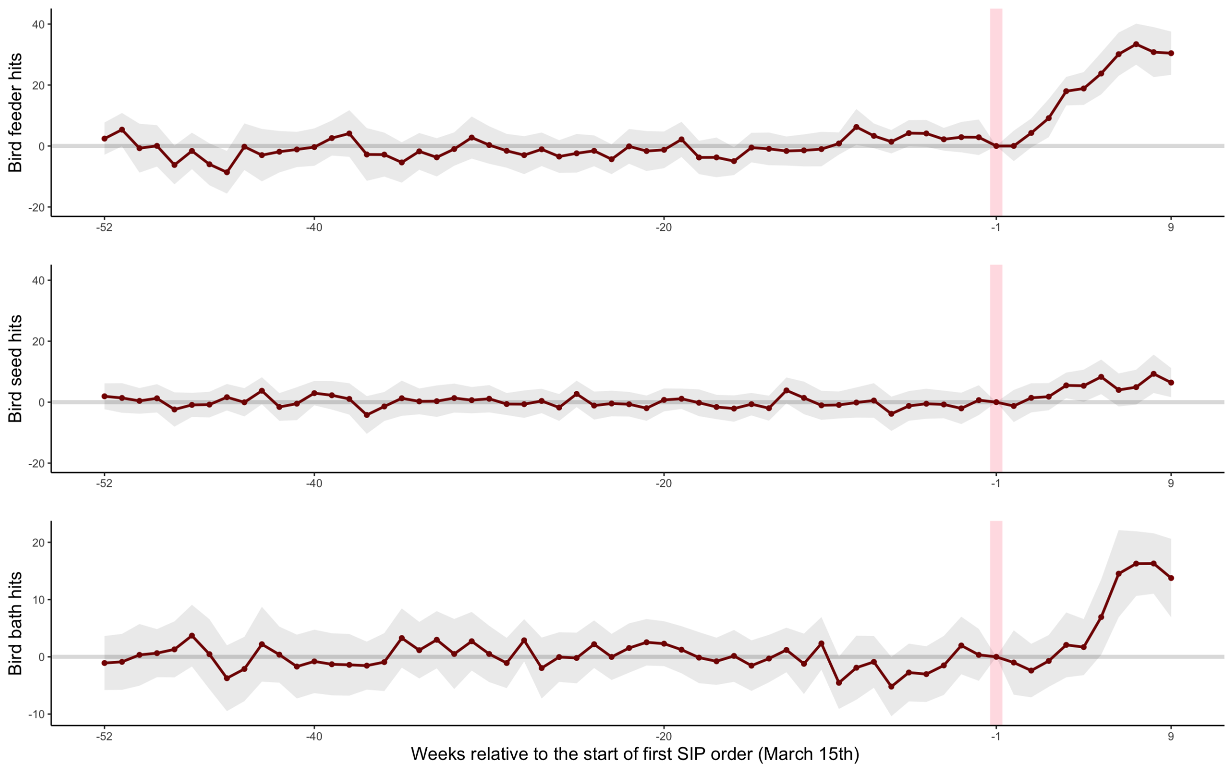


Figure 3: Subnational Event Study of Google Trends Search Index

Notes: Data from 2015-2020 at the state-week level, first-differenced to remove seasonality. Coefficients for year prior to event shown, all coefficients in Equation 3 estimated. Plots with raw data (no first differencing) and several years of pre-period are in appendix. The y-axis shows the change in Google search intensity, where the maximum value would be 100.

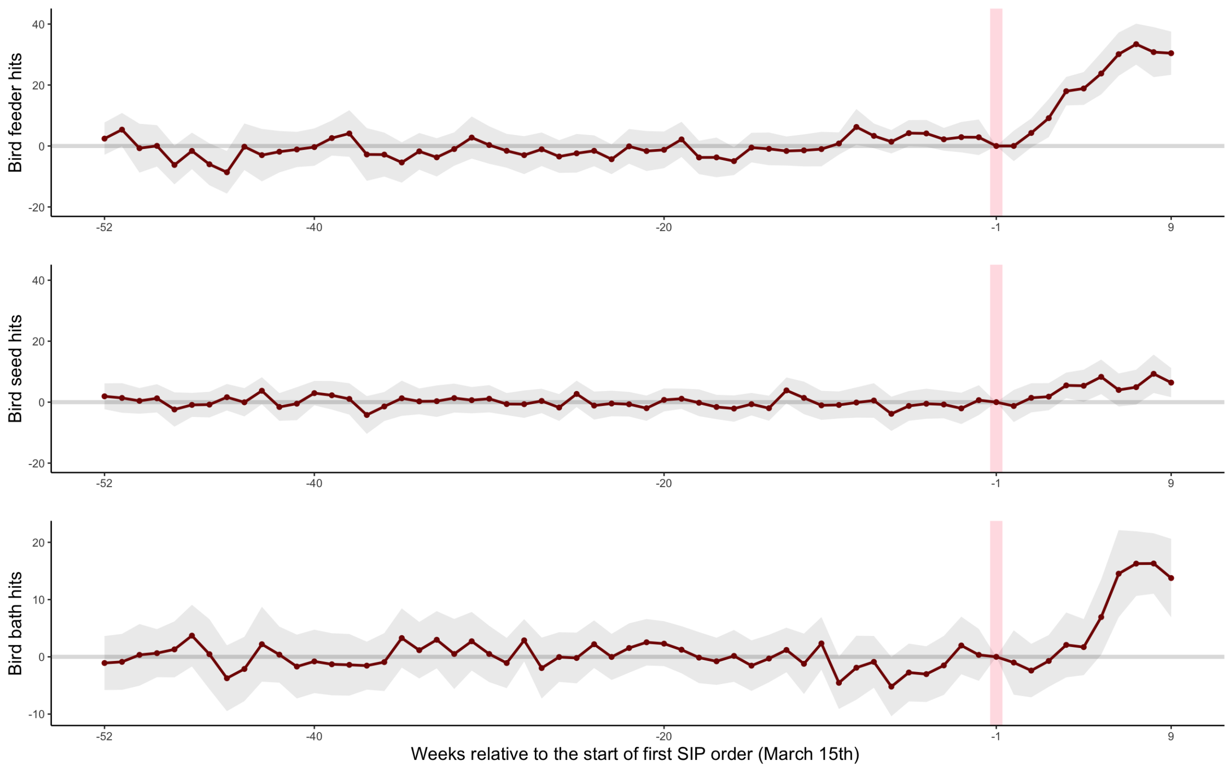
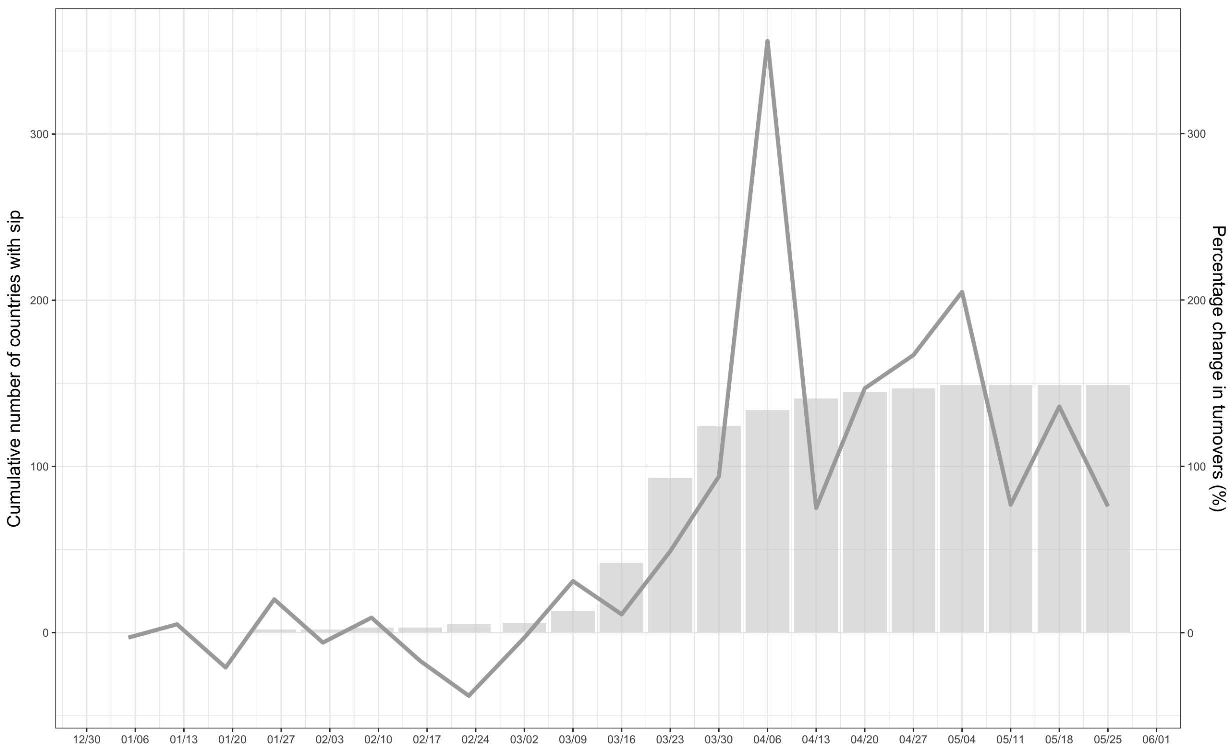


Figure 4: Global Event Study of Google Trends Search Index

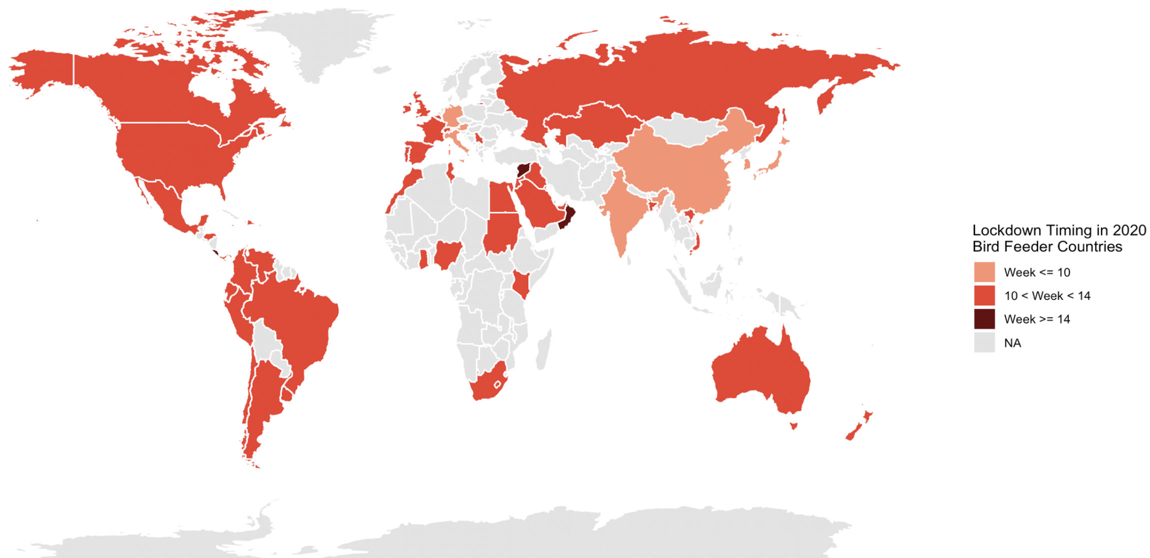
Notes: Data from 2015-2020 at the country-week level, first-differenced to remove seasonality. Coefficients for year prior to event shown, all coefficients in Equation 3 estimated. Plots with raw data (no first differencing) and several years of pre-period are in appendix. The y-axis shows the change in Google search intensity, where the maximum value would be 100.

Figure 5: Change in Year-Over-Year Bird App Purchases



Notes: Though Spiny Software creates bird apps for several areas, including North America and Europe, it is based in the UK. The grey bars represent the cumulative number of countries around the globe that had initiated a shelter-in-place policy. The UK's lockdown began March 23rd, 2020. The line represents the change from the same week in 2019 in downloads.

Figure 6: Map of Countries with Bird Feeder Search Data



Notes: Countries in grey did not have sufficient search for "bird feeder" on Google Trends between 2015-2020. Among the 61 countries that did, we show variation in the timing of their national lockdown by week of year in 2020. The list of countries with sufficient search volume is in Table A1 in the Appendix.

Table 1: Summary Statistics

	N	Mean	St. Dev.	Min	Max
Panel A: Subnational, Project Feeder Watch					
1 hour	712,027	0.845	0.362	0	1
4 hours	712,027	0.218	0.413	0	1
8 hours	712,027	0.049	0.216	0	1
Panel B: Subnational, Google Trends					
Feeder	13,050	17.57	15.207	0	100
Feeder (first differenced)	10,400	1.004	16.545	-100	96
Seed	13,050	9.683	10.54	0	100
Seed (first differenced)	10,400	0.503	13.244	-97	97
Bath	13,050	11.334	12.518	0	100
Bath (first differenced)	10,400	0.8	13.742	-86	86
Panel C: Global, Google Trends					
Feeder (60 countries)	15,660	17.414	22.342	0	100
Seed (49 countries)	12,789	19.204	22.791	0	100
Bath (34 countries)	8,874	12.489	19.764	0	100

Notes: Data from 2015-2020. PFW data begin in November and end in April each season. Subnational Google Trends data first differenced due to seasonality in search.

Table 2: Subnational Analysis of Change in Bird Engagement After Lockdown in US

	Project Feeder Watch			Google Trends		
	(1)	(2)	(3)	(4)	(5)	(6)
	1 hour	*4 hours*	*8 hours*	*Feeder*	*Seed*	Bath
Post	0.031***	0.043***	0.016***	17.074***	5.400***	8.492***
	(0.003)	(0.004)	(0.002)	(1.652)	(0.823)	(1.121)
FE	M+S+Y	M+S+Y	M+S+Y	S+Y	S+Y	S+Y
Clustered SE	State	State	State	State	State	State
Observations	712,027	712,027	712,027	10,400	10,400	10,400
R-squared	0.005	0.007	0.005	0.012	0.055	0.018

Notes: Data from 2015-2020. Google Trends data first differenced. Includes constant term (not reported). Standard errors reported in parentheses below coefficient. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Table 3: Variation in US Response by Important Bird Area

	post		postxIBA1		postxIBA2		FE	SE	R^2
Panel A: Project Feeder Watch, N=712,027									
1 hour	0.020***	(0.005)	0.015*	(0.008)	0.018***	(0.007)	M+S+Y	State	0.005
4 hours	0.034***	(0.006)	0.014*	(0.008)	0.012	(0.008)	M+S+Y	State	0.007
8 hours	0.012***	(0.004)	0.008*	(0.004)	0.002	(0.006)	M+S+Y	State	0.005
Panel B: Google Trends (first differenced), N=10,400									
Feeder	15.548***	(1.417)	-1.364	(1.826)	5.693***	(1.766)	S+Y	State	0.012
Seed	6.753***	(1.161)	-2.254	(1.496)	-1.99	(1.447)	S+Y	State	0.056
Bath	8.615***	(1.201)	-0.48	(1.547)	0.06	(1.497)	S+Y	State	0.018

Notes: Data from 2015-2020. Each line is a separate regression. IBA1 and IBA2 are binary variables for the second and third tercile of the count of BirdLife International's important bird areas, by state. The omitted category is the lowest tercile. Google Trends data first differenced. Each row is a separate regression and includes a constant term (not reported). Standard errors reported in parentheses next to coefficient. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Table 4: Global Dynamic Response to Lockdowns

	(1) Feeder		(2) Seed		(3) Bath	
t=0	0.86	(2.116)	4.149	(3.051)	-1.072	(3.379)
t=1	8.727***	(2.904)	8.272**	(3.426)	1.458	(3.854)
t=2	6.410**	(2.640)	7.149***	(2.746)	-0.425	(3.100)
t=3	6.694**	(3.253)	10.945***	(3.351)	3.634	(3.629)
t=4	11.860***	(3.397)	4.966*	(2.856)	7.075*	(4.136)
t=5	10.877***	(2.927)	14.496***	(3.688)	14.281***	(5.266)
t=6	9.195***	(3.265)	9.313***	(3.495)	11.458**	(4.838)
t=7	8.534**	(3.532)	7.585**	(3.272)	13.017**	(5.938)
t=8	7.797**	(3.533)	10.958***	(3.817)	17.311***	(5.409)
t=9	13.190***	(3.945)	12.569***	(4.143)	19.463***	(6.967)
t=10	10.763**	(4.622)	14.479***	(4.635)	11.467	(7.336)
t>10	0.053	(4.631)	10.352*	(5.963)	11.833*	(6.678)
FE	C+Y		C+Y		C+Y	
SE	Country		Country		Country	
N	15,660		12,789		8,874	
Countries	60		49		34	
R2	0.264		0.279		0.207	

Notes: Data from 2015-2020. Raw Google Trends (no first differencing). Standard errors reported in parentheses to the right of coefficient. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Table 5: Motivations to Feed Birds

Rank	Description	Score Average
1	Enjoyment from looking at them	4.37
2	Helps bird populations	4.18
3	Feel the birds need the food	3.97
4	Good feeling from helping	3.55
5	Throwing food in the bin is a waste	2.90

Notes: Data in response to a survey of 200 respondents in East Anglia, UK, by Brock et al. (2017). Score Average based on a Likert response from 1 (not important) to 5 (extremely important)

Online Appendix

Tables

Figures

Table A1: Global Analysis Sample and Shelter-In-Place timing

Country	Date SIP	Sample		
Argentina	3/19/2020	Feeder	Bath	Seed
Australia	3/24/2020	Feeder	Bath	Seed
Austria	3/6/2020	Feeder	Bath	Seed
Bahrain	3/18/2020	Feeder		
Bangladesh	3/19/2020	Feeder	Bath	Seed
Belgium	3/18/2020	Feeder	Bath	Seed
Brazil	3/13/2020	Feeder	Bath	Seed
Canada	3/16/2020	Feeder	Bath	Seed
Chile	3/25/2020	Feeder	Bath	Seed
China	1/23/2020	Feeder	Bath	
Colombia	3/25/2020	Feeder	Bath	Seed
Costa Rica	4/27/2020	Feeder		
Dominican Republic	3/17/2020	Feeder		
Ecuador	3/17/2020	Feeder		
Egypt	3/24/2020	Feeder	Bath	Seed
France	3/17/2020	Feeder	Bath	Seed
Germany	3/9/2020	Feeder	Bath	Seed
Ghana	3/30/2020	Feeder		Seed
Honduras	3/16/2020	Feeder		
Hong Kong	2/8/2020	Feeder	Bath	Seed
India	1/26/2020	Feeder	Bath	Seed
Iraq	3/13/2020	Feeder		Seed
Ireland	3/26/2020	Feeder	Bath	Seed
Italy	2/23/2020	Feeder	Bath	Seed
Jamaica	3/13/2020	Feeder		
Japan	2/25/2020	Feeder	Bath	Seed
Jordan	3/18/2020	Feeder		Seed
Kazakhstan	3/19/2020	Feeder		Seed
Kenya	3/27/2020	Feeder		Seed
Kuwait	3/22/2020	Feeder		Seed
Lebanon	3/16/2020	Feeder		Seed
Luxembourg	3/17/2020	Feeder	Bath	Seed
Mauritius	3/23/2020	Feeder	Bath	Seed
Mexico	3/30/2020	Feeder	Bath	Seed
Morocco	3/20/2020	Feeder		Seed
New Zealand	3/21/2020	Feeder	Bath	Seed
Nigeria	3/23/2020	Feeder		Seed
Oman	4/10/2020	Feeder		Seed
Panama	3/17/2020	Feeder		
Peru	3/15/2020	Feeder		
Portugal	3/19/2020	Feeder		Seed
Puerto Rico	3/15/2020	Feeder		
Qatar	3/17/2020	Feeder		Seed
Russia	3/30/2020	Feeder	Bath	Seed
Saudi Arabia	3/23/2020	Feeder		Seed
Serbia	3/15/2020	Feeder		Seed
Singapore	4/3/2020	Feeder	Bath	Seed
South Africa	3/26/2020	Feeder	Bath	Seed
South Korea	2/23/2020	Feeder	Bath	Seed
Spain	3/14/2020	Feeder	Bath	Seed
Sudan	3/23/2020	Feeder		
Switzerland	3/17/2020	Feeder	Bath	Seed
Syria	4/17/2020			Seed
Trinidad and Tobago	3/30/2020	Feeder		Seed
Tunisia	3/20/2020	Feeder	Bath	Seed
United Arab Emirates	3/23/2020	Feeder	Bath	Seed
United Kingdom	3/23/2020	Feeder	Bath	Seed
United States	3/15/2020	Feeder	Bath	Seed
Uruguay	3/13/2020	Feeder		
Venezuela	3/13/2020	Feeder	Bath	Seed
Vietnam	4/1/2020	Feeder	Bath	Seed

Table A2: Dynamic Treatment Effect, Subnational, Single Event, PFW and GT

	(1) 1 hour	(2) 4 hours	(3) 8 hours	(4) Feeder	(5) Seed	(6) Bath
t=0	0.012***	0.022***	0.010***	-2.788	-0.438	0.746
	0.004	0.003	0.002	(1.978)	(1.692)	(2.122)
t=1	0.035***	0.043***	0.017***	1.472	2.242	-0.654
	0.003	0.004	0.002	(1.935)	(1.643)	(1.849)
t=2	0.043***	0.051***	0.019***	6.332**	2.622*	1.026
	0.003	0.005	0.003	(2.517)	(1.439)	(1.863)
t=3	0.028***	0.046***	0.019***	15.172***	6.322***	3.826*
	0.005	0.006	0.003	(2.020)	(1.798)	(2.002)
t=4	0.021*	0.048***	0.022***	16.052***	6.202***	3.446*
	0.012	0.015	0.008	(2.153)	(1.738)	(2.006)
t=5				20.972***	9.122***	8.686***
	0.000	0.000	0.000	(3.200)	(2.007)	(2.601)
t=6				27.312***	4.822***	16.266***
				(3.463)	(1.858)	(3.201)
t=7				30.592***	5.742***	18.026***
				(3.027)	(1.949)	(2.273)
t=8				27.992***	10.122***	18.046***
				(3.865)	(2.140)	(2.159)
t=9				27.632***	7.242***	15.506***
				(3.492)	(1.896)	(2.928)
FE	M+S+Y	M+S+Y	M+S+Y	S+Y	S+Y	S+Y
SE (clustered)	None	None	None	state	state	state
Observations	712,027	712,027	712,027	10,400	10,400	10,400
R2	0.005	0.007	0.005	0.078	0.014	0.032

Notes: 2015-2020, data at the state-week level for the US. Estimates include a constant term (not reported). Google Trends data first differenced.$*p < 0.1; **p < 0.05; ***p < 0.01$.

Table A3: Dynamic Treatment Effect, Subnational, Staggered Events, PFW and GT

	(1) 1 hour	(2) 4 hours	(3) 8 hours	(4) Feeder	(5) Seed	(6) Bath
t=0	0.030***	0.037***	0.015***	7.411**	3.201**	1.638
	(0.004)	(0.004)	(0.002)	(2.953)	(1.249)	(1.830)
t=1	0.038***	0.045***	0.015***	13.946***	6.760***	5.080***
	(0.004)	(0.006)	(0.004)	(2.402)	(1.713)	(1.670)
t=2	0.032***	0.048***	0.019***	16.202***	5.178***	3.126*
	(0.008)	(0.011)	(0.004)	(2.556)	(1.952)	(1.745)
t=3	0.041***	0.020	0.023**	23.970***	5.829***	10.917***
	(0.014)	(0.017)	(0.011)	(2.887)	(1.835)	(2.910)
t=4				23.923***	6.713***	15.894***
				(3.956)	(2.231)	(2.983)
t=5				29.691***	6.271***	15.824***
				(3.592)	(2.027)	(2.540)
t=6				28.329***	9.970***	19.099***
				(4.086)	(1.913)	(2.016)
t=7				28.772***	9.575***	14.660***
				(3.778)	(2.250)	(3.957)
t>=8				40.417***	6.211**	19.983***
				(4.914)	(2.691)	(4.929)
FE	M+S+Y	M+S+Y	M+S+Y	S+Y	S+Y	S+Y
SE (clustered)	State	State	State	State	State	State
Observations	679,829	679,829	679,829	8,944	8,944	8,944
R2	0.005	0.007	0.005	0.089	0.016	0.038

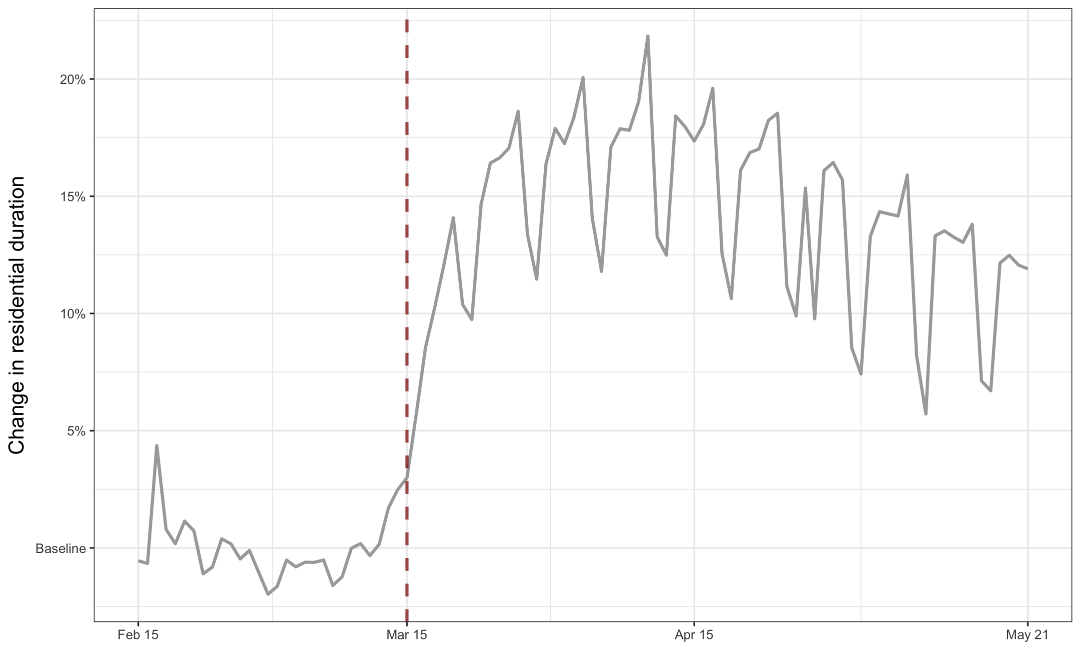
Notes: 2015-2020. Estimates include a constant term (not reported). Google Trends data first differenced. In the staggered event study, only states with lockdown policies are included in the analysis (43 states).$*p < 0.1; **p < 0.05; ***p < 0.01$.

Table A4: Dynamic Treatment Effect, Global, Balanced Panel (34 countries)

	Feeder	Seed	Bath
t=0	2.265	2.738	-0.991
	(3.114)	(3.286)	(3.469)
t=1	8.235**	8.374**	1.615
	(3.920)	(3.802)	(3.948)
t=2	8.477**	10.284***	-0.324
	(3.509)	(3.520)	(3.170)
t=3	12.841***	14.314***	3.858
	(4.859)	(4.029)	(3.716)
t=4	14.174***	9.223**	7.403*
	(4.969)	(3.600)	(4.222)
t=5	13.841***	17.556***	14.828***
	(4.286)	(4.316)	(5.376)
t=6	15.568***	9.253**	11.918**
	(4.928)	(3.886)	(4.939)
t=7	8.841	9.738**	10.494*
	(5.394)	(3.897)	(5.515)
t=8	14.598***	14.677***	17.949***
	(5.271)	(4.903)	(5.519)
t=9	16.973***	14.215***	20.216***
	(5.932)	(5.056)	(7.125)
t=10	9.759	10.116**	12.094
	(6.378)	(4.944)	(7.571)
t>10	1.565	9.607	15.394**
	(6.687)	(6.561)	(7.419)
FE	C+Y	C+Y	C+Y
SE (clustered)	country	country	country
Observations	8,613	8,613	8,613
R2	0.259	0.321	0.201

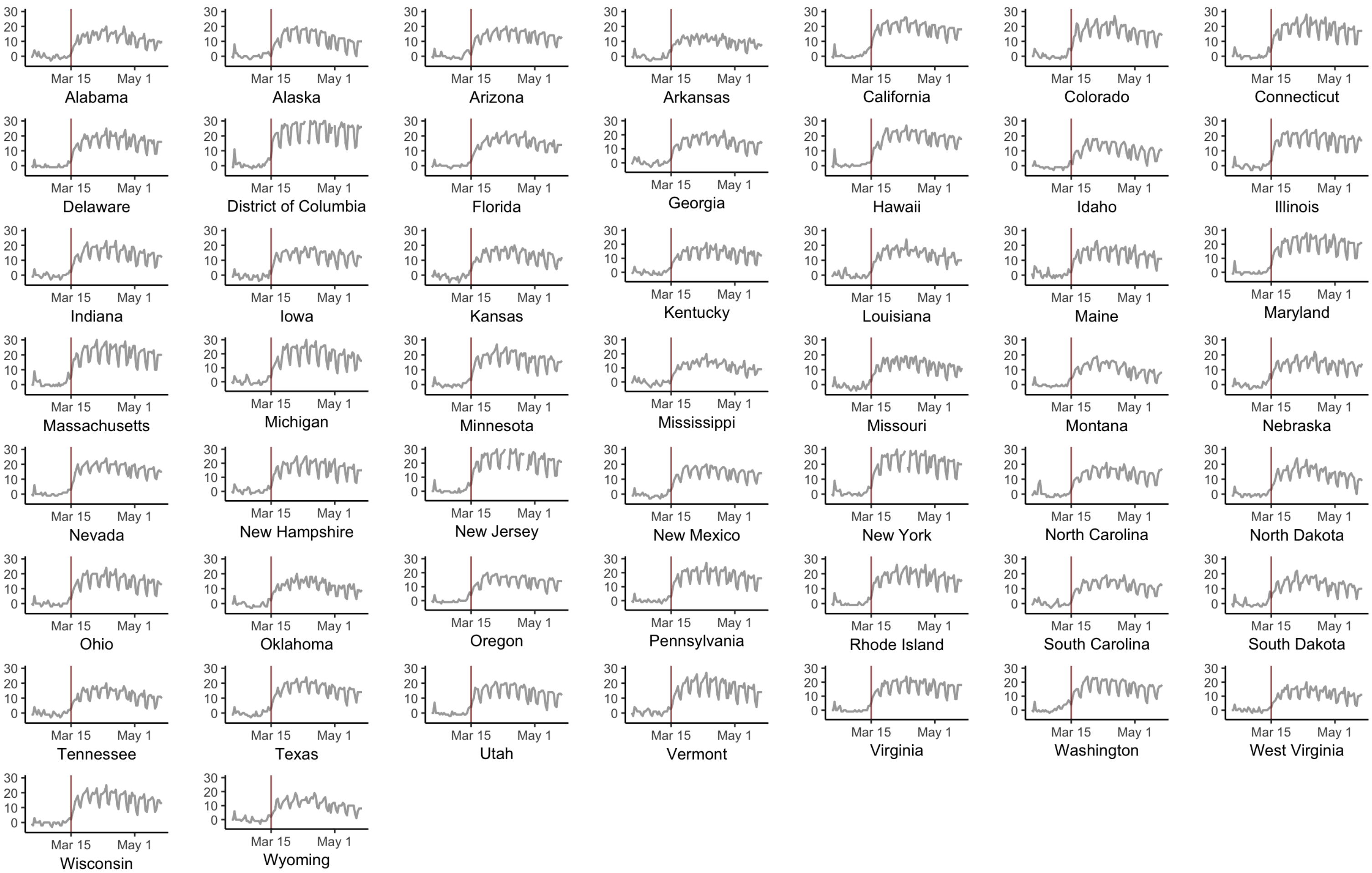
Notes: Data from 2015-2020 at the country-week level. Raw Google Trends (no first differencing). Fixed effects by country and year. Standard errors reported in parentheses below coefficient. $*p < 0.1; **p < 0.05; ***p < 0.01$.

Figure A1: Community Mobility in the US, National



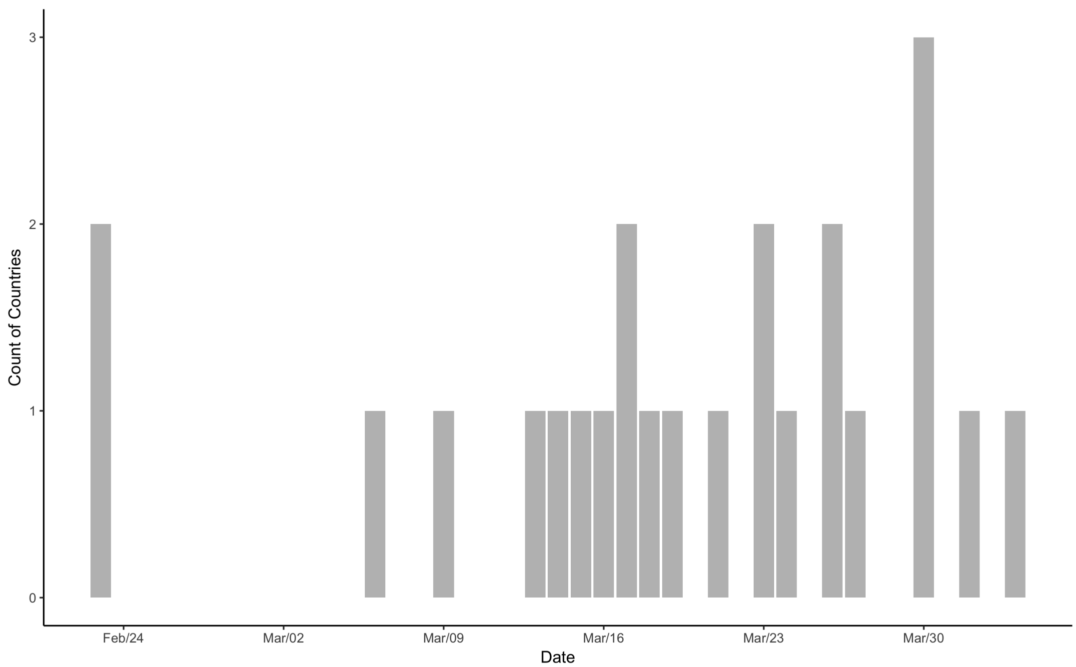
Notes: Data from Google Community Mobility Reports, created using datafrom users who turn on Location History: https://www.google.com/covid19/mobility/.

Figure A2: Community Mobility in the US, by State



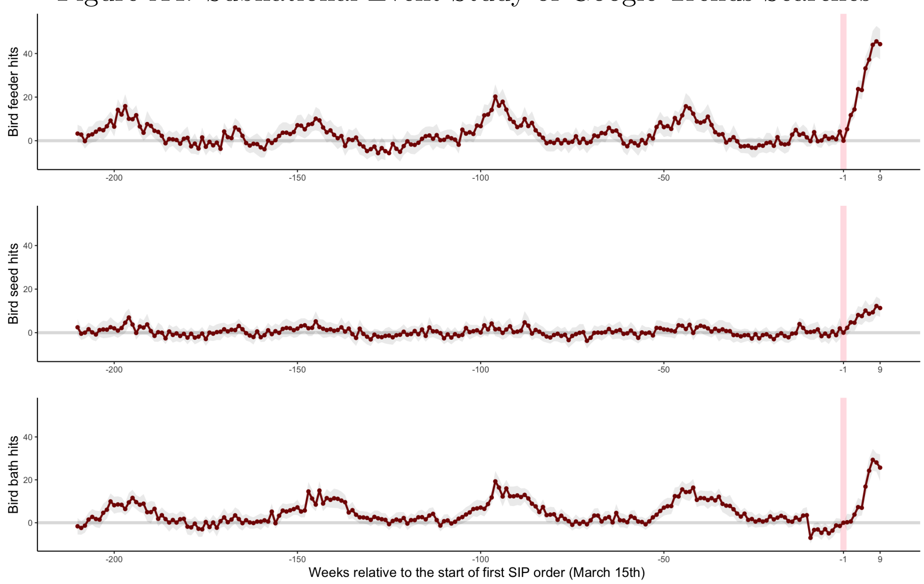
Notes: Data from Google Community Mobility Reports, created using datafrom users who turn on Location History: https://www.google.com/covid19/mobility/.

Figure A3: Variation in Timing of Global Policies



Notes: This figure shows the variation in start dates of the lockdowns policies for the 60 countries we used in the global level analysis.

Figure A4: Subnational Event Study of Google Trends Searches



Notes: Data from 2015-2020, Google Trends, at the country-week level with no first differencing. Coefficients from Equation 3.