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Did COVID-19 Lockdowns Crowd Out Interest in Voluntary Health Measures?

Evidence from Google Trends

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Abstract

Government and individual responses to the coronavirus disease 2019 (COVID-19) pandemic have had significant health and economic consequences. Governments imposed measures, including lockdowns, designed to suppress transmission and alleviate the burden on health systems, while private individuals exercised voluntary social distancing, compliance with government-imposed measures and exhibited increased health concerns. Using Google Trends data, I take advantage of variation in the timing of lockdowns as well as the seasonality and predictability of search interest in health-related topics, to investigate the effect of government-imposed lockdowns on voluntary motivation. I show that lockdowns are associated with decreased private interest in health, specifically health interventions perceived to protect against COVID-19 infection, providing support for a crowding out effect of lockdowns. That the efficacy of government-imposed measures is compromised by reduced voluntary motivation has important implications for policy design in the context of the ongoing COVID-19 pandemic, future pandemics and other crises.

Keywords: *COVID-19, coronavirus, lockdowns, public policy, Google Trends, crowding out effect, health*

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1. Introduction

Pandemics have been occurring with increased frequency since the turn of the millennium.[1] Coronavirus disease 2019 (COVID-19) represents the most serious public health threat posed by a respiratory virus since the 1918 Spanish flu pandemic,[2] which claimed an estimated 50 million lives globally.[3] The World Health Organization declared COVID-19 a pandemic on 11 March 2020, whereupon it had claimed 4,291 lives from 118,000 cases across 114 countries.[4] As of 24 May 2021, it had claimed 3.5 million lives from 167.5 million cases.[5]

Governments and individuals responded to COVID-19 in myriad ways. Guided by epidemiological modelling,[6] governments imposed safer-at-home measures including lockdowns, designed to restrict mobility to suppress COVID-19 transmission and "flatten the curve", alleviating the burden on health systems and saving as many lives as possible in the short- to medium-term. In addition to government-imposed policies, private individuals, driven largely by mortality rates,[7] responded with voluntary measures including self-isolation, compliance with government-imposed measures and increased health concerns[8]. Voluntary and government-imposed responses to COVID-19 continue to have significant health and economic consequences. The interaction between voluntary and enforced measures has important implications for guiding policy in the context of the ongoing COVID-19 pandemic as well as potential future pandemics and other crises. While government-imposed non-pharmaceutical interventions have successfully suppressed COVID-19 transmission,[9] research has found that they are compromised via a crowding out of voluntary behaviour.[10] This suggests that in addition to enforced measures such as lockdowns, optimal policy should include measures designed to encourage voluntary measures, for example via campaigns to disseminate important information.

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[1] Brodeur, Gray, Islam and Bhuiyan (2020a)
[2] Ferguson, Laydon, Nedjati-Gilani, Imai, Ainslie, Baguelin, Bhatia, Boonyasiri, Cucunubá, Cuomo-Dannenburg, Dighe, Dorigatti, Fu, Gaythorpe, Green, Hamlet, Hinsley, Okell, van Elsland, Thompson, Verity, Volz, Wang, Wang, Walker, Walters, Winskill, Whittaker, Donnelly, Riley and Ghani (2020)
[3] Centers for Disease Control and Prevention (2021)
[4] World Health Organization (2020)
[5] Worldometer (2021)
[6] Ferguson et al. (2020); Lourenço, Paton, Thompson, Klenerman, and Gupta, (2020)
[7] Goolsbee and Syverson (2021)
[8] Binder (2020)
[9] Anderson, Heesterbeek, Klinkenberg and Hollingsworth (2020); Hsiang, Allen, Annan-Phan, Bell, Bolliger, Chong, Druckenmiller, Huang, Hultgren, Krasovich, Lau, Lee, Rolf, Tseng and Wu (2020); Askitas, Tatsiramos and Verheyden (2021); Islam, Sharp, Chowell, Shabnam, Kawachi, Lacey, Massaro, D'Agostino and White (2020)
[10] Chernozhukov, Kasahara and Schrimpf (2021); Yan, Malik, Bayham, Fenichel, Couzens and Omer (2021); Schmelz (2021)

Due to the inherent unpredictability of COVID-19, implementation of lockdowns coincided with that of household surveys designed to assess their impact. Furthermore, lockdowns resulted in the cessation of many previously established household surveys.[11] The resulting lack of data precludes comparison before and after lockdowns, resulting in gaps in the research into the effects of lockdowns. In contrast, internet search data is available continuously throughout the implementation of lockdowns. This paper takes advantage of the availability of Google Trends data to investigate the effect of government-imposed lockdowns on private interest in health, specifically in voluntary measures perceived to protect against the likelihood and severity of COVID-19 infection. Google Trends provides an index of search interest that reflects the relative number of searches for a particular topic or keyword based on internet search queries conducted by users of Google Search.

A difference-in-differences (DiD) regression design and an event study are employed to investigate the effect of lockdowns on interest in health-related search topics. Variation in the timing of the introduction of lockdowns across jurisdictions represents a natural experiment that can be used to estimate the effects of lockdowns, however, COVID-19's pervasiveness has resulted in relatively little timing variation. As such, this paper takes further advantage of the seasonality and predictability of Google Search data,[12] using data from the corresponding period in 2019, one year prior to lockdowns, to build the counterfactual case. Extrapolation of findings to the broader population relies on the extent to which the population of Google Search users accurately reflects the broader population. Such analysis is therefore best suited to developed countries,[13] such as those in Western Europe and the United States, which form the sample used in this paper.

I first provide DiD estimates showing that lockdowns are associated with an increase in interest in health-related topics including *health*, *immunity*, *vitamin C* and *exercise*, and decreased interest in *weight loss*. This is largely consistent with a public goods theory of responses to COVID-19. Transmission suppression depends on individuals' willingness to cooperate via compliance with government-imposed policies and voluntary measures. Total well-being is maximised via universal cooperation, however the cost of cooperating creates an incentive to free ride. Experimental research has found that in the absence of punishment for free riders,

[11] Brodeur, Clark, Fleche and Powdthavee (2021a)
[12] Shimshoni, Efron and Matias (2009)
[13] Carneiro and Mylonakis' (2009)

cooperating participants become frustrated and cooperation declines.[14] As a corollary, participants are more likely to cooperate when they believe that other participants will also cooperate.[15] In the context of COVID-19, strictly enforced government policies should precipitate expectations that others will cooperate, resulting in greater cooperation, including adoption of voluntary measures such as collecting information pertaining to improving health and immunity to protect against infection. Another possible explanation is that certain individuals, relatively unconcerned by the risk of infection due to a low degree of risk aversion or perceptions of their own susceptibility, might be less likely to pursue voluntary measures. Perceptions that governments might repeal lockdowns for "healthy" individuals but not those deemed to be at-risk, effectively quarantining those who are at-risk, might provide added impetus for such individuals to implement health-related measures in response to lockdowns.

An event study is employed to investigate the dynamics of search interest around lockdowns, revealing that interest in most health-related topics begins to increase prior to lockdowns, raising concerns over the validity of the parallel trends assumption implicit in the DiD regression design. This increase in pre-lockdown trends in 2020 represents a deviation from the trends in the corresponding period in 2019. The 2019 trends therefore underestimate the 2020 pre-lockdown trends and the counterfactual, resulting in overestimation of the lockdown effect. While the use of data from 2019 may not provide a strong counterfactual case for studying the effect of lockdowns, it facilitates identification of pre-lockdown increases in search interest. Furthermore, the event study reveals that lockdowns are associated with a reversal in the mostly positive pre-lockdown trends, suggesting that lockdowns are associated with decreased interest in health. This is consistent with research stemming from self-determination theory in psychology[16] and adapted by behavioural economists,[17] that has found evidence for control aversion or a crowding out effect, whereby external enforcement and incentives reduce intrinsic motivation. Under a crowding out effect, the efficacy of government-imposed policies is compromised by a corresponding decrease in voluntary measures. Controlling for mortality rates rules out the possibility that decreased interest in voluntary health measures is driven by decreased mortality rates as a result of lockdowns, although it is possible that a reduction in the

[14] Herrmann, Thöni and Gächter (2008)
[15] Dawes (1980); Fischbacher, Gächter and Fehr (2001); Shinada and Yamagishi (2007)
[16] Lepper, Sagotsky, Dafoe and Greene (1982); Deci (1971)
[17] Bowles (2008); Bowles and Polanía-Reyes (2012)

risk of infection as a result of lockdowns might reduce the incentive to pursue voluntary measures.

The results suggest that government-imposed policies crowd out voluntary efforts to collect health-related information to protect against COVID-19 infection. This trade-off has important implications for guiding policy in the context of the ongoing COVID-19 pandemic as well as potential future pandemics and other crises. In addition to government-imposed measures such as lockdowns, optimal public health policy should encourage voluntary health interventions, for example via public health campaigns and, to the extent that it exists, dissemination of information concerning health interventions that are medically shown to improve COVID-19 outcomes.

This paper contributes to the rapidly growing literature on the impact of COVID-19. Private, voluntary responses to COVID-19 have been driven by the perceived risk of infection and mortality rates,[18] while government responses, including lockdowns, restriction of non-essential businesses, school and university closures, restrictions on international travel, public awareness campaigns, restrictions on mass gatherings, encouraging voluntary social distancing, health monitoring and testing, encouraging development of vaccines, curfews, quarantine and face masks, have been guided by epidemiological studies,[19] although political factors have also played a role.[20] Epidemiological studies have found that while government-imposed policies have in general been effective in suppressing COVID-19 transmission,[21] private, voluntary measures have also played a significant role.[22] Meanwhile, COVID-19 has had significant economic effects[23] via three primary mechanisms:[24] directly, via reduced consumer confidence and consumption,[25] indirectly, via financial markets and the effect on the real economy, [26] and via supply-side disruptions to supply chains, labour demand and employment.[27] Coibion, Gorodnichenko and Weber (2020b) find that lockdowns, rather than the pandemic itself, are

[18] Goolsbee and Syverson (2021)
[19] Ferguson et al. (2020); Lourenço et al. (2020)
[20] Baccini and Brodeur (2020); Barrios and Hochberg (2020); Murray and Murray (2020)
[21] Anderson, Heesterbeek, Klinkenberg and Hollingsworth (2020); Hsiang, Allen, Annan-Phan, Bell, Bolliger, Chong, Druckenmiller, Huang, Hultgren, Krasovich, Lau, Lee, Rolf, Tseng and Wu (2020); Askitas, Tatsiramos and Verheyden (2021); Islam, Sharp, Chowell, Shabnam, Kawachi, Lacey, Massaro, D'Agostino and White (2020)
[22] Chernozhukov, Kasahara and Schrimpf (2021); Yan, Malik, Bayham, Fenichel, Couzens and Omer (2021); Schmelz (2021)
[23] Baker, Bloom, Davis and Terry (2020)
[24] Carlsson-Szlezak, Reeves and Swartz (2020)
[25] Baker, Bloom, Davis and Terry (2020); Binder (2020)
[26] Elenev, Landvoigt and Van Nieuwerburgh (2020); Céspedes, Chang and Velasco (2020)
[27] Bonadio, Huo, Levchenko and Pandalai-Nayar (2020); Céspedes, Chang and Velasco (2020)

responsible for many of the effects of COVID-19. Further research has focused on the socio-economic effects of COVID-19, including the effects on labour markets, mental health and wellbeing, racial inequality and gender roles.[28]

This paper is closely related to research that investigates the relative effects of voluntary versus government-imposed measures. Chernozhukov, Kasahara and Schrimpf (2021), Yan, Malik, Bayham, Fenichel, Couzens and Omer (2021), and Schmelz (2021) investigate the effects of voluntary and government-imposed measures on social distancing and COVID-19 transmission, with Schmelz (2021) finding evidence that forced compliance may crowd out voluntary motivation. Goolsbee and Syverson (2021) find that government-imposed policies are responsible for only a modest share of the decline in consumer activity, with the majority attributable to voluntary measures. It is also closely related to the work of Martela, Hankonen, Ryan and Vansteenkiste (2021), who develop communication guidelines founded in self-determination theory, designed to encourage voluntary compliance with policies introduced in response to national crises such as COVID-19. This paper fills a gap by investigating the effect of lockdowns on private interest in health and voluntary measures to improve health to protect against COVID-19 infection. Private behaviour as it pertains to improving health and resistance to disease has important implications for public health policy in the context of the ongoing COVID-19 and potential future pandemics, especially in the face of the increased frequency of pandemics since the turn of the millennium. This paper is also closely related to the literature that uses Google Search data to investigate the effects of COVID-19 and associated lockdowns (Fetzer, Hensel, Hermle & Roth, 2020; Brodeur, Clark, Fleche & Powdthavee, 2021a; Kong & Prinz, 2020).

The remainder of this paper is organised as follows: Section 2 reviews the relevant literature; Section 3 provides a discussion of the data used; Section 4 details the identification strategies employed, including the DiD regression model and the event study, the results of which are presented and discussed in Section 5; and Section 6 concludes with a summary of key findings, limitations and potential topics for further research.

[28] Brodeur et al. (2020a)

2. Literature review

This paper contributes to the rapidly growing literature documenting the effects of COVID-19 and safer-at-home measures, and the literature that uses internet search data to gain insight into large-scale decision-making and behaviour.

2.1. COVID-19

This paper is most closely related to research that investigates the relative effects of voluntary versus government-imposed responses to COVID-19. Research has found that private, voluntary measures play a significant role in suppressing transmission. Chernozhukov, Kasahara and Schrimpf (2021) find that while government-imposed policies are effective in reducing COVID-19 case and death growth rates, substantial declines are attributable to private behavioural responses, driven by new information about transmission risks. Yan, Malik, Bayham, Fenichel, Couzens and Omer (2021) find that safer-at-home orders have the same effect as an additional 29 local COVID-19 cases, alluding to the possibility of a crowding out effect. Schmelz (2021) investigates the extent to which policymakers rely on voluntary versus enforced compliance, finding further evidence for a crowding out effect, which is found to vary across individuals and the nature of the intervention. Frey, Chen and Presidente (2020) find that democratically accountable governments are 25% more effective in reducing mobility despite implementing less stringent lockdowns than autocratic regimes. Reduced mobility is related to trust in government (Bargain & Aminjonov, 2020; Brodeur, Grigoryeva & Kattan, 2020b) and civic values (Durante, Guiso & Gulino, 2021; Brodeur, Grigoryeva & Kattan, 2020b). Martela, Hankonen, Ryan and Vansteenkiste (2021) develop communication guidelines founded in self-determination theory, designed to encourage voluntary compliance with policies introduced in response to national crises such as COVID-19. Goolsbee and Syverson (2021) find that voluntary responses had a far greater economic effect, with government-imposed policies accounting for only seven percentage points of the 60% overall decline in consumer traffic. They find that consumer traffic began to decline prior to the imposition of lockdowns due to voluntary measures driven by the number of COVID-19 deaths reported locally. Chetty, Friedman, Hendren and Stepner (2020) also find that lockdowns and repeals had modest economic effects relative to voluntary measures. Driven by infection concerns, higher-income individuals reduced voluntary spending on businesses that rely on person-to-person interaction, such as restaurants, affecting their disproportionately low-wage employees in a trickle-down effect with implications for the entire economy. Importantly in the context of this paper, they

allude to the importance of addressing health concerns in the economic recovery from the COVID-19 pandemic.

Related research has investigated compliance with government-imposed policies. Fan, Orhun & Turjeman, 2020 investigate the determinants of individual attitudes towards COVID-19 and safer-at-home measures. Briscese, Lacetera, Macis and Tonin (2020) investigate the relationship between citizens' intentions to comply with government-imposed social distancing measures to the duration of hypothetical extensions to restrictions. They find that a hypothetical extension that is longer than expected (a negative surprise) is associated with a decrease in intentions to comply while a positive surprise has no effect. They also find that intentions to comply deteriorate with the duration of the lockdown. Their findings highlight the importance for governments of managing the expectations of their constituents to encourage compliance and optimise COVID-19 outcomes. Intentions to comply have also been found to be positively related to income (Coven & Gupta, 2020) and high-speed internet access (Chiou & Tucker, 2020).

A number of studies have used Google Search data to investigate the effects of COVID-19 and associated safer-at-home measures. Fetzer, Hensel, Hermle and Roth (2020) find an increase in economic anxiety. They argue that belief formation during COVID-19 may differ substantially from that in conventional economic shocks and that employing contemporaneous data such as Google Search data, provides value above and beyond relying on historical accounts. Brodeur et al. (2021a) find that mental health is negatively impacted by lockdowns with an increase in searches for mental health-related topics such as *boredom*, *loneliness*, *worry* and *sadness*. Barrios and Hochberg (2020) use search volume for certain keywords as a proxy for risk perceptions associated with COVID-19 to investigate the effects of political partisanship. Kong and Prinz (2020) use daily search interest in claiming unemployment insurance, as a proxy for unemployment insurance claims, for which data is only available weekly, to provide a more contemporaneous estimation of the differential effects of non-pharmaceutical interventions on employment in the United States.

The broader COVID-19 literature has focused on the efficacy of non-pharmaceutical interventions in suppressing transmission of COVID-19 and the associated economic and socio-economic costs. Government responses were guided by epidemiological studies such as Ferguson, Laydon, Nedjati-Gilani, Imai, Ainslie, Baguelin, Bhatia, Boonyasiri, Cucunubá, Cuomo-Dannenburg, Dighe, Dorigatti, Fu, Gaythorpe, Green, Hamlet, Hinsley, Okell, van

Elsland, Thompson, Verity, Volz, Wang, Wang, Walker, Walters, Winskill, Whittaker, Donnelly, Riley & Ghani, 2020, who model the impact of non-pharmaceutical interventions on mortality and healthcare demand. They estimated that a policy of transmission suppression, involving a combination of population-wide social distancing, home isolation of cases, and school and university closures, would halve the number of COVID-19 deaths and reduce peak healthcare demand by 67%.

Research has confirmed that government-imposed and voluntary non-pharmaceutical interventions have successfully suppressed COVID-19 transmission (Anderson, Heesterbeek, Klinkenberg & Hollingsworth, 2020; Gupta, Montenovo, Nguyen, Rojas, Schmutte, Simon, Weinberg & Wing, 2020; Fang, Wang & Yang, 2020). Hsiang, Allen, Annan-Phan, Bell, Bolliger, Chong, Druckenmiller, Huang, Hultgren, Krasovich, Lau, Lee, Rolf, Tseng and Wu (2020) estimate that social distancing measures prevented 62 million infections in China, South Korea, Italy, Iran, France and the United States while Cho (2020) considers a counterfactual case for Sweden, which did not enforce strict lockdown measures, using a synthetic control approach to estimate that stricter policies could have reduced Swedish cases by almost 75%. Further research has estimated the differential effects of specific interventions finding that lockdowns (Islam, Sharp, Chowell, Shabnam, Kawachi, Lacey, Massaro, D'Agostino & White, 2020), restrictions on public events (Askitas, Tatsiramos & Verheyden, 2021; Islam et al., 2020), private gatherings (Askitas, Tatsiramos & Verheyden, 2021; Islam et al., 2020; Brauner, Mindermann, Sharma, Johnston, Salvatier, Gavenčiak, Stephenson, Leech, Altman, Mikulik, Norman, Monrad, Besiroglu, Ge, Hartwick, Teh, Chindelevitch, Gal & Kulveit, 2021; Sharma, Mindermann, Rogers-Smith, Leech, Snodin, Ahuja, Sandbrink, Monrad, Altman, Dhaliwal, Finnveden, Norman, Oehm, Sandkühler, Mellan, Kulveit, Chindelevitch, Flaxman, Gal, Mishra, Brauner & Bhatt, 2021), and school, university, workplace and business closures (Askitas, Tatsiramos & Verheyden, 2021; Islam et al., 2020; Brauner et al., 2021; Sharma et al., 2021) are effective in suppressing transmission, while restrictions on internal movement and public transport are not (Askitas, Tatsiramos & Verheyden, 2021). In contrast, Islam et al. (2020) find that restrictions on public transport are effective, although the effect is insignificant when school and workplace closures, restrictions on mass gatherings and public events, and lockdowns, had already been implemented.

Social distancing measures suppress COVID-19 transmission by limiting mobility. Chang, Pierson, Koh, Gerardin, Redbird, Grusky and Leskovec (2020) find that differences in infection rates among disadvantaged racial and socio-economic groups are attributable solely to

differences in mobility. Abouk and Heydari (2020) find that the combination of government-imposed and voluntary measures reduces mobility in the United States while a number of studies use cell device data to investigate the effects of safer-at-home measures on mobility (Chang et al., 2020; Nguyen, Gupta, Andersen, Bento, Simon & Wing, 2020; Brodeur, Grigoryeva & Kattan, 2020b).

Responses to COVID-19 have had significant economic and socio-economic effects. Carlsson-Szlezak, Reeves and Swartz (2020) identify three primary mechanisms via which COVID-19 and associated safer-at-home measures impact the economy: directly, via reduced consumer confidence and consumption, indirectly, via financial markets and the effect on the real economy, and via supply-side disruptions to supply chains, labour demand and employment. Baker, Bloom, Davis and Terry (2020) estimate a year-on-year contraction in U.S. GDP of 11% in the final quarter of 2020, with approximately half of this effect attributable to increased uncertainty. They find that households initially increased spending in some sectors, including retail and food, followed by an overall decrease in consumption. This finding is supported by Binder (2020), who finds a reduction in spending on travel and food as well as increased health concerns. Coibion, Gorodnichenko and Weber (2020b) find that lockdowns, rather than the pandemic itself, are responsible for reduced consumption, inflationary expectations and mortgage payments, and an increase in unemployment and uncertainty. Bonadio, Huo, Levchenko and Pandalai-Nayar (2020) estimate that one quarter of the decline in GDP is attributable to disruptions to global supply chains. Elenev, Landvoigt and Van Nieuwerburgh (2020) model the COVID-19 shock as an exogenous decline in firm productivity and labour supply resulting in a decline in revenues and an increase in corporate defaults, banking distress and a decline in corporate investment. Céspedes, Chang and Velasco (2020) also model decreased productivity due to COVID-19 via reduced labour supply and frictions in financial markets.

COVID-19 has also had significant socio-economic effects, including negative effects on labour markets, including employment, wages and work hours (Layard, Clark, De Neve, Krekel, Fancourt, Hey & O'Donnell, 2020; Kong & Prinz, 2020; Béland, Brodeur & Wright, 2020b; Béland, Brodeur, Mikola & Wright, 2020c; Adams-Prassl, Boneva, Golin & Rauh, 2020; Coibion, Gorodnichenko and Weber, 2020a; Kahn, Lange & Wiczer, 2020; Rojas, Jiang, Montenovo, Simon, Weinberg & Wing, 2020; Gupta et al., 2020; Aum, Lee & Shin, 2020; Yasenov, 2020; Alstadsæter, Bratsberg, Eielsen, Kopczuk, Markussen, Raaum & Røed, 2020), mental health (Brodeur et al., 2021a; Davillas & Jones, 2020; de Pedraza, Guzi & Tijdens,

2020; Tubadji, Boy & Webber, 2020; Lu, Nie & Qian, 2020; Béland et al., 2020c; Etheridge & Spantig, 2020; Armbruster & Klotzbücher, 2020; Layard et al., 2020), domestic violence (Béland, Brodeur, Haddad & Mikola, 2020a; Leslie & Wilson, 2020), racial inequality (Fairlie, Couch & Xu, 2020; Borjas & Cassidy, 2020; Montenovo, Jiang, Rojas, Schmutte, Simon, Weinberg & Wing, 2020; Schild, Ling, Blackburn, Stringhini, Zhang & Zennettou, 2020; Bartos, Bauer, Cahlikova & Chytilová, 2020) and gender inequality (Alon, Doepke, Olmstead-Rumsey and Tertilt, 2020; Adams-Prassl et al., 2020; Etheridge & Spantig, 2020; Forsythe, 2020). COVID-19 has also had a number of unintended positive externalities, including reductions in pollution (Brodeur, Cook & Wright, 2021b; He, Pan & Tanaka, 2020; Almond, Du & Zhang, 2020; Dang & Trinh, 2020; Le Quéré, Jackson, Jones, Smith, Abernethy, Andrew, De-Gol, Willis, Shan, Canadell, Friedlingstein, Creutzig & Peters, 2020; Layard et al., 2020), electricity consumption and personal vehicle travel (Cicala, Holland, Mansur, Muller & Yates, 2020), traffic collisions (Brodeur, Cook & Wright, 2021b), commuting times and crime rates (Layard et al., 2020) and an increase in certain forms of volunteering (Layard et al., 2020).

2.2. Internet search data

This paper also contributes to the literature that uses internet search data to gain insight into large-scale behaviour. The digital revolution of the last 15 to 20 years has had a profound effect on economic research, characterised by a shift from relying on small-sample government surveys and statistics, to large-scale, administrative and private sector data with almost universal population coverage (Einav & Levin, 2014). Hamermesh (2013) found that from 1963 to 1983, almost all articles published in top economic journals were either theoretical or empirical, based on government data or surveys conducted by the authors. The proportion of empirical papers climbed to over 70% by 2011 with a majority using data obtained by the authors or generated experimentally. New types of data, such as internet search data, has spawned new research into issues that were previously considered important but for which reliable data was unavailable.

According to Simon (1955), the decision-making process begins with the gathering of information. The ubiquity of Google Search as a tool for gathering information provides economists with the ability to gain insight into large-scale behaviour and decision-making that drives economic variables. McLaren and Shanbhogue (2011) summarise how policy makers and central banks can utilise Google Search data. Furthermore, in contrast with traditional survey data, internet search data is available in real time. A significant portion of the literature

is explores the suitability of internet search data for contemporaneous forecasting or nowcasting: using internet search data to pre-empt the results of lagged survey data. Ettredge, Gerdes and Karuga (2005) first proposed using internet search data to forecast economic variables, finding that search volumes for specific terms are correlated with U.S. Bureau of Labor Statistics unemployment figures. At around the same time, Cooper, Mallon, Leadbetter, Pollack and Peipins (2005) found that search activity for specific cancers correlated with estimated incidence. Since then, internet search data has been used to predict incidence and outbreaks of diseases such as influenza (Ginsberg, Mohebbi, Patel, Brammer, Smolinski & Brilliant, 2009; Carneiro & Mylonakis, 2009; Polgreen, Chen, Pennock, Nelson & Weinstein, 2008) as well as economic variables including automobile sales, unemployment claims, travel destination planning and consumer sentiment (Choi & Varian, 2012), Swiss tourism demand (Siliverstovs & Wochner, 2018), financial returns (Preis, Moat & Stanley, 2013), house prices (Kulkarni, Haynes, Stough & Paelinck, 2009), retail sales (Bughin, 2015), inflation expectations (Guzmán, 2011) and how job searches respond to extensions of unemployment payments (Baker & Fradkin, 2011). Goel, Hofman, Lahaie, Pennock and Watts (2010) extend the literature on contemporaneous forecasting by investigating the ability of internet data to predict consumer activity in the near future. They challenge the predictive power of internet search data above and beyond baseline models, finding that its value lies in its availability, in particular its timeliness and in situations where other key indicators are unavailable.

This paper fills a gap in the literature by investigating the effect of COVID-19-related lockdowns on voluntary measures, specifically interest in voluntary, health-related interventions perceived to protect against COVID-19 infection.

3. Data

3.1. Google Trends

Google Trends provides an indexed time series of relative search interest in a particular topic or search term by geography and time period. Its ability to provide insights into the search habits of Google Search users has important implications for economists, researchers, policymakers, marketers and advertisers. Rather than absolute search volume, Google Trends provides an index of relative search volume. Data is extracted from a random sample of Google searches and *normalised* such that it reflects the number of searches for a topic as a proportion of all searches for a given time and location, thereby controlling for total search volume. Furthermore,

search interest is *indexed* on a scale from zero to 100 with the maximum search volume for the time period indexed to 100 and a search interest index of 50 representing half of the maximum. Much of the early literature relied on *Google Insights for Search*, which was absorbed by Google Trends in late 2012 due to considerable overlap in functionality.

Google Search data represent a number of advantages over traditional survey data. In contrast to traditional survey data, which suffer from an inherent lag, Google search data are available in real time. Google Search data have proven more successful in predicting disease outbreaks than conventional Centers for Disease Control and Prevention surveillance systems (Carneiro & Mylonakis, 2009). Unlike traditional survey data, which can be costly to collect, and data collected by other companies operating in the private sector, Google Search data are freely available via Google Trends. Notwithstanding, the Google Trends interface can prove limiting. It is only possible to view or download search volumes for up to five search terms or topics at a time, proving prohibitively time consuming for many study designs. There exist application programming interfaces (APIs) that can expedite data collection, however the number of requests that can be made in a certain time period is limited, with the user being temporarily blocked from making further requests in the event that the limit is exceeded.

Rather than being self-reported, Google Search data are generated via random sampling of search queries drawn from the total number of Google Search queries. In addition to ameliorating small sample bias (Baker & Fradkin, 2017), inasmuch as Google Search users perceive anonymity, it avoids any observer-expectation effect or interviewer bias: how an observer's perceived expectations might influence a subject's behaviour. Even if Google's sampling is truly random, use of Google Search data can potentially introduce selection bias if a country or state's population of Google Search users does not accurately represent the broader population. For example, younger members of the population might be more likely to have better access to the internet or to rely on the internet to gather health-related information compared to the elderly, who might rely on more traditional sources of information such as medical professionals. Furthermore, demographic information is not available, meaning that it is not possible to investigate heterogeneous variation. Google Search data captures the search activity of a sample of the population of Google Search users in aggregate and care must be taken when extrapolating findings to the wider population. Using Google Trends data to gain insight into human behaviour should result in more accurate analyses when applied to developed countries, which are more likely to have larger populations of Google Search users, which more accurately reflect the wider populations (Carneiro & Mylonakis, 2009).

Brodeur et al.'s (2021a) interpretation of search volume for mental health-related topics as a proxy for incidence or severity of mental health problems illustrates an important limitation of Google Search data. People might search for mental health-related terms for reasons other than a deterioration in mental health. Care must be taken in interpreting the results of any analysis based on Google Search data and accordingly, this paper interprets Google Search data as the aggregate level of interest in the topics under consideration.

3.2. Sample selection

The sample of 9 Western European countries and 43 U.S. states considered in this paper is based on Carneiro and Mylonakis' (2009) observation that any analysis of Google Search data requires a large population of Google Search users and is therefore best suited to developed countries. Furthermore, only countries and states that implemented full lockdowns are included, although this requirement is relaxed for the purpose of testing the robustness of the results of the DiD regression. The requirement of full lockdowns ensures a degree of homogeneity in the set of lockdown measures imposed by governments, avoiding the need to adjust for the stringency of government measures and concerns over the reliability of such stringency measures. The number of Western European countries expands to 12 when the requirement of a full lockdown is relaxed for the robustness check. Lists of the Western European countries and U.S. states, including the dates upon which they announced and implemented lockdowns, are presented in the Appendix in Table 4 and Table 5.

The time period under consideration in this paper represents a delicate balancing act. It must be long enough to provide sufficient information to establish trends and accurately estimate the effect of lockdowns. However, a time period that is too long risks capturing extraneous effects that could introduce bias into the estimation of the counterfactual and effect of lockdowns. Furthermore, it is important that the time period captures any potential pre-lockdown effects to facilitate investigation into the dynamics of how search interest evolves around lockdowns and to assess the validity of the parallel trends assumption implicit in the DiD regression design. The time period considered is from 1 January 2019 to 10 April 2020, which is further supported by the literature (Brodeur et al., 2021a).

3.3. Re-scaling Google Trends data

The empirical techniques employed in this paper utilise daily data from 1 January to 10 April in both 2019 and 2020, henceforth referred to as *period 1* and *period 2* respectively.

Unfortunately, while Google Trends provides daily data for time periods up to nine months, it returns weekly data for time periods between nine months and five years. It is possible to run two separate queries, each less than nine months, to return daily data for both periods, however daily search intensities from disjoint periods are, in general, not comparable since they are indexed using different maximum search volumes. The data needs to be adjusted to make it comparable, which is achieved by downloading daily data for both periods and using weekly data, available continuously spanning the entire period, to re-scale the daily data. For a query with a length greater than nine months, Google Trends returns weekly data where each data point represents the daily search volumes aggregated over each week from Sunday to Saturday. In order to re-scale the daily data accurately, the daily data must align with the weekly data. The first step is to download daily search volumes for period 1, however to ensure that the daily data aligns with the weekly data, the period over which daily data is downloaded must begin on a Sunday and end on a Saturday. Daily data is downloaded for the period 30 December 2018 (a Sunday) to 13 April 2019 (a Saturday), encapsulating the entirety of period 1. Daily search interest in a given keyword on day d in region r for period 1, is denoted $D_{d,r,1}$. These are aggregated over Sunday to Saturday of each week (w) to give weekly search volumes: $\dot{W}_{w,r,1}$, where $\dot{}$ denotes the aggregation of daily data. The average over period 1 is denoted $\overline{\dot{W}_{r,1}}$. This procedure is repeated for period 2 (29 December 2019 (Sunday) to 11 April 2020 (Saturday)), giving $\overline{\dot{W}_{r,2}}$.

Weekly search interests for week w in region r, denoted $W_{w,r}$, spanning the entire period (30 December 2018 to 11 April 2020) are used to calculate the average weekly search volumes for periods 1 and 2, denoted $\overline{W_{r,1}}$ and $\overline{W_{r,2}}$ respectively. Weekly search interest weights for periods 1 and 2 are given by equations (1) and (2) respectively.

$$w_{r,1} = \frac{\overline{W_{r,1}}}{\overline{\dot{W}_{r,1}}} \tag{1}$$

$$w_{r,2} = \frac{\overline{W_{r,2}}}{\overline{\dot{W}_{r,2}}} \tag{2}$$

Daily search volumes are re-scaled by multiplying by the appropriate weights according to equation (3) for period 1 and equation (4) for period 2, giving re-scaled daily search volumes, denoted $\widetilde{D}_{d,r}$, that are comparable across both periods.

$$\widetilde{D}_{d,r} = w_{r,1} \cdot D_{d,r,1} \quad (3)$$

$$\widetilde{D}_{d,r} = w_{r,2} \cdot D_{d,r,2} \quad (4)$$

These are then normalised to values between 0 and 100 according to equation (5).

$$D^*_{d,r} = \frac{\widetilde{D}_{d,r}}{max\left(\widetilde{D}_{d,r}\right)} \times 100 \quad (5)$$

3.4. Search topics

The search topics considered in this paper should capture information for which people might search if they are interested in improving their health to reduce the likelihood and severity of COVID-19 infection. The inclusion of *health* serves to illustrate some important considerations in the selection of appropriate search topics. While it is possible to obtain data on specific keywords using Google Trends, it is also possible to obtain data on broader topics. Topics capture not only an exact phrase, but misspellings, acronyms and translations in all languages, which is particularly pertinent to this paper given the inclusion of non-English-speaking countries. Furthermore, Shimshoni, Efron and Matias (2009) find that search queries that aggregate queries for specific, semantically-related keywords, are more predictable 12 months ahead than search queries for specific keywords. Given that the identification strategy relies on data from 2019 to build the counterfactual case, consideration of topics as opposed to specific keywords should result in more accurate estimation of the counterfactual. The breadth of a search topic is also directly related to availability of data. Due to privacy concerns, search data is only available for topics with sufficient volume.

Guided by these considerations, this paper investigates the effect of lockdowns on search interest in the following topics: *health*, *immunity*, *vitamin C*, *exercise* and *weight loss*. Given that this paper investigates public interest in health in the context of COVID-19-related lockdowns, it is only natural to investigate the public's interest in immune health, captured by the inclusion of the topic, *immunity*, while regular *exercise* is widely understood to play an important role in a healthy lifestyle, including avoiding weight gain.

Vitamin C, also known as ascorbic acid, is often touted as a natural remedy for the common cold, although its efficacy has been a subject of controversy for many years. It has been proposed as a treatment for respiratory infections ever since being isolated in the 1930s, experiencing increased popularity in the 1970s when Nobel laureate Linus Pauling concluded

from placebo-controlled trials that vitamin C supplementation would prevent the common cold. In a comprehensive meta-analysis, Hemilä and Chalker (2013) review the findings of placebo-controlled trials to investigate whether vitamin C reduces the incidence, duration or severity of the common cold via either regular supplementation or as therapy upon the onset of cold symptoms. They find that while vitamin C supplementation fails to reduce the incidence of colds in the general population, it has been shown to successfully reduce the duration of colds, although these findings were not replicated in therapeutic trials. Nevertheless, they find that given the consistent effects of vitamin C on the duration and severity of colds, the low cost and lack of significant risk, it may be worthwhile for individuals to experiment with vitamin C as a cold remedy.

While common colds can be caused by a variety of viruses, they are often caused by coronaviruses, albeit not COVID-19. Vitamin C has been touted as a potential remedy for COVID-19 due to its antioxidant, anti-inflammatory, antithrombotic and immuno-modulatory functions (Carr & Rowe, 2020). Like the common cold, research into the efficacy of vitamin C as a treatment for COVID-19 is inconclusive, although there are several theories regarding how vitamin C might help to treat COVID-19. High levels of vitamin C may create free radicals that destroy viruses. It is also possible that vitamin C renews the body's antioxidant protection, which can become depleted by infection. Hemilä and Chalker (2020) argue for consideration of vitamin C as a possible treatment for COVID-19 on the basis of a meta-analysis that found that, while regular vitamin C supplementation of approximately one gram per day did not prevent upper respiratory tract infections, it successfully shortened and alleviated infections that occurred during the period of vitamin C administration, reducing duration by 8% and 14% in adults and children respectively. They consider this to be particularly salient given the potential severity of COVID-19 symptoms compared to the often mild symptoms of most upper respiratory tract infections. Based on these findings, it is reasonable to expect that a person seeking to voluntarily improve their resistance to COVID-19 might search for information regarding vitamin C.

According to Alberca, Oliveira, Branco, Pereira & Sato (2020), obesity exacerbates the effects of COVID-19 via its effects on immune response, nutritional factors, psychological factors and the gut-lung axis. As such, it is reasonable to assume that an individual, in particular one who is obese or overweight, might voluntarily seek information concerning weight loss in order to protect themselves against COVID-19.

It should be noted that increased interest in weight loss might not necessarily be driven by a desire for improved health as a direct result of COVID-19. Loss of income, restrictions on mobility, business closures affecting gyms, swimming pools, sports clubs etc., restrict access to quality nutrition and exercise; important factors in avoiding weight gain. Increased interest in weight loss might simply be a response to weight gain as a result of lockdowns, although one might expect considerable lag in such an effect. Another possibility is that increased interest in weight loss might be driven by an increase in free time as a result of lockdowns, especially considering obesity's prevalence, which has seen it labelled as a potential pandemic itself (Alberca et al., 2020).

While this paper investigates the effect of lockdowns on public interest in health and health-related interventions, it remains silent on their medical efficacy. It is only necessary that there exists a public perception that such interventions might improve one's resistance to COVID-19 or reduce the degree to which one is impacted by lockdowns. For interest's sake, this paper includes some discussion of specific health interventions, however a simple Google Search reveals the extent to which such interventions have entered the public's consciousness, justifying inclusion in this paper. Provided with a specific keyword or topic, Google Trends' "suggested terms" tool identifies popular, semantically-related search terms and topics, providing insight into those interventions perceived to be most effective in combatting COVID-19. Identification of the most popular topics also helps ameliorate the issue of data availability for terms with insufficient volume. As an example, curcumin, a bioactive compound found in turmeric, has been touted as a potential remedy for COVID-19 due to its antiviral properties via direct interaction with viral membrane proteins, disruption of the viral envelope, inhibition of viral proteases and inducing host antiviral responses (Rajesh, Thimmulappa, Mudnakudu-Nagaraju, Shivamallu, Subramaniam, Radhakrishnan, Bhojraj & Kuppusamy, 2021). However, curcumin as a remedy for COVID-19 has not experienced the same degree of penetration into the public consciousness as, for example, vitamin C, and as such, is not included in this study.

4. Identification strategy

This paper employs a difference-in-differences (DiD) regression design and an event study to investigate the effect of lockdowns on search interest in health-related topics. These exploit variation in the timing of lockdowns across regions to ameliorate issues of reverse causality and omitted variables bias, and disentangle the effect of lockdowns from that of the pandemic itself. However, the effects of COVID-19 were universal, occurring practically simultaneously

all over the world, resulting in relatively little variation in the timing of lockdowns. Table 4 in the Appendix reveals that all 12 Western European countries (including the three that introduced only partial lockdowns) announced lockdowns within 19 days of one another, with two-thirds announcing lockdowns in the space of only six days. Meanwhile, Table 5 in the Appendix reveals that all 43 U.S. states announced lockdowns within only 18 days of one another, with all but one state announcing lockdowns within the space of only 15 days. Shimshoni, Efron and Matias (2009) find that the majority of the most popular search queries are predictable using a 12 month ahead forecast, with certain categories of search queries, including health, exhibiting a particularly high degree of predictability. As such, this paper follows the example of Brodeur et al. (2021a), taking advantage of the seasonality and predictability of Google Search data to use data from the corresponding period in 2019 to build the counterfactual case, thus controlling for seasonal changes within countries and states to investigate deviations from the 2019 trend resulting from the announcement of lockdowns in 2020.

4.1. Difference-in-differences estimation of lockdown effects

The DiD regression model for a given search topic is given by equation (6):

$$Volume_{i,t} = \alpha \cdot \left(After\ lockdown_{i,t} \times Year_t\right) + \beta \cdot After\ lockdown_{i,t} + \gamma \cdot Deaths_{i,t-1} + \mu_t + \rho_i + \varepsilon_{i,t} \quad (6)$$

where $Volume_{i,t}$ is the re-scaled index of search volume for a given topic on day t in country or state i. $After\ lockdown_{i,t}$ is a dummy variable that takes value one in the days following the date upon which lockdowns were announced and zero otherwise. This applies to observations from 2020 and 2019 such that if a country or state announced a lockdown on 15 March 2020, $After\ lockdown_{i,t}$ takes value one for every date after 15 March in both 2019 and 2020. $Year_t$ is a dummy variable that takes value one in the year in which lockdowns were imposed (2020) and zero otherwise (2019). $After\ lockdown_{i,t} \times Year_t$ is an interaction variable that takes value one in the days following the announcement of a lockdown in 2020 (the year of the lockdown) but not 2019, thereby indicating treatment status. The effect of lockdowns on search volume is therefore captured by α. The inclusion of $After\ lockdown_{i,t}$ controls for any seasonal effects associated with the announcement date. Country or state fixed effects are captured by ρ_i to control for time-invariant country or state characteristics. The model includes year, week and weekday (Monday to Sunday) fixed effects to control for

seasonal effects, captured by μ_t. $Deaths_{i,t-1}$ is the daily rate of new COVID-19-related deaths per million lagged one day. Inclusion of the lagged mortality rate is consistent with Goolsbee and Syverson's (2021) findings that voluntary measures are heavily influenced by COVID-19 deaths. Data for COVID-19 deaths was obtained from the European Centre for Disease Prevention and Control (ECDC) and the Centers for Disease Control and Prevention (CDC) for Western Europe and the United States respectively. Population data for the United States was obtained from the United States Census Bureau. Standard errors are robust and clustered at the day level.

Implicit in the DiD regression design employed in this paper is the parallel trends assumption that in the absence of COVID-19-related lockdowns, Google Search volumes would have evolved as they did in 2019. The validity of this assumption is investigated via an event study.

4.2. Event study

The event study model specified in equation (7) investigates the dynamics of the effects of lockdowns. It provides insight into pre-lockdown trends, the validity of the parallel trends assumption implicit in the DiD regression design, the persistence of the lockdown effect and the degree to which people adapt to lockdowns.

$$Volume_{i,t} = \sum_{k=-3}^{k=4} \alpha'_k \cdot \left(W_{k,i} \times Year_t\right) + \sum_{k=-3}^{k=4} \beta'_k \cdot W_{k,i} + \gamma' \cdot Deaths_{i,t-1} + \mu'_t + \rho'_i + \varepsilon'_{i,t} \quad (7)$$

where the specification is similar to that of the DiD regression design in equation (6). The key difference is that $W_{k,i}$ are dummy variables for the three weeks preceding and four weeks following lockdown announcement. If country or state i announced lockdowns on 15 March 2020, the dummy variable, $W_{3,i}$ (corresponding to three weeks prior to lockdown announcement) takes value one in the third week preceding 15 March 2020 as well as in the third week preceding the corresponding date in 2019. As before, $Year_t$ is a dummy variable that takes value one in the year in which lockdowns were imposed (2020) and zero otherwise (2019). $W_{k,i} \times Year_t$ is therefore an interaction term that takes value one in the kth week after lockdown announcement only in the year of the lockdown (2020) and α'_k captures the effect of being in the weeks surrounding lockdown announcement. As before, $Volume_{i,t}$ is the re-scaled index of search volume for a given topic on day t in country or state i, $Deaths_{i,t-1}$ is the lagged mortality rate, μ'_t captures year, week and weekday fixed effects and ρ'_i captures country or

state fixed effects. The fourth week preceding lockdown announcement is the reference period. The estimated coefficients (α'_k) are therefore interpreted as the effect of being in the kth week after lockdown announcement compared to the fourth week prior. Standard errors are robust and clustered at the day level.

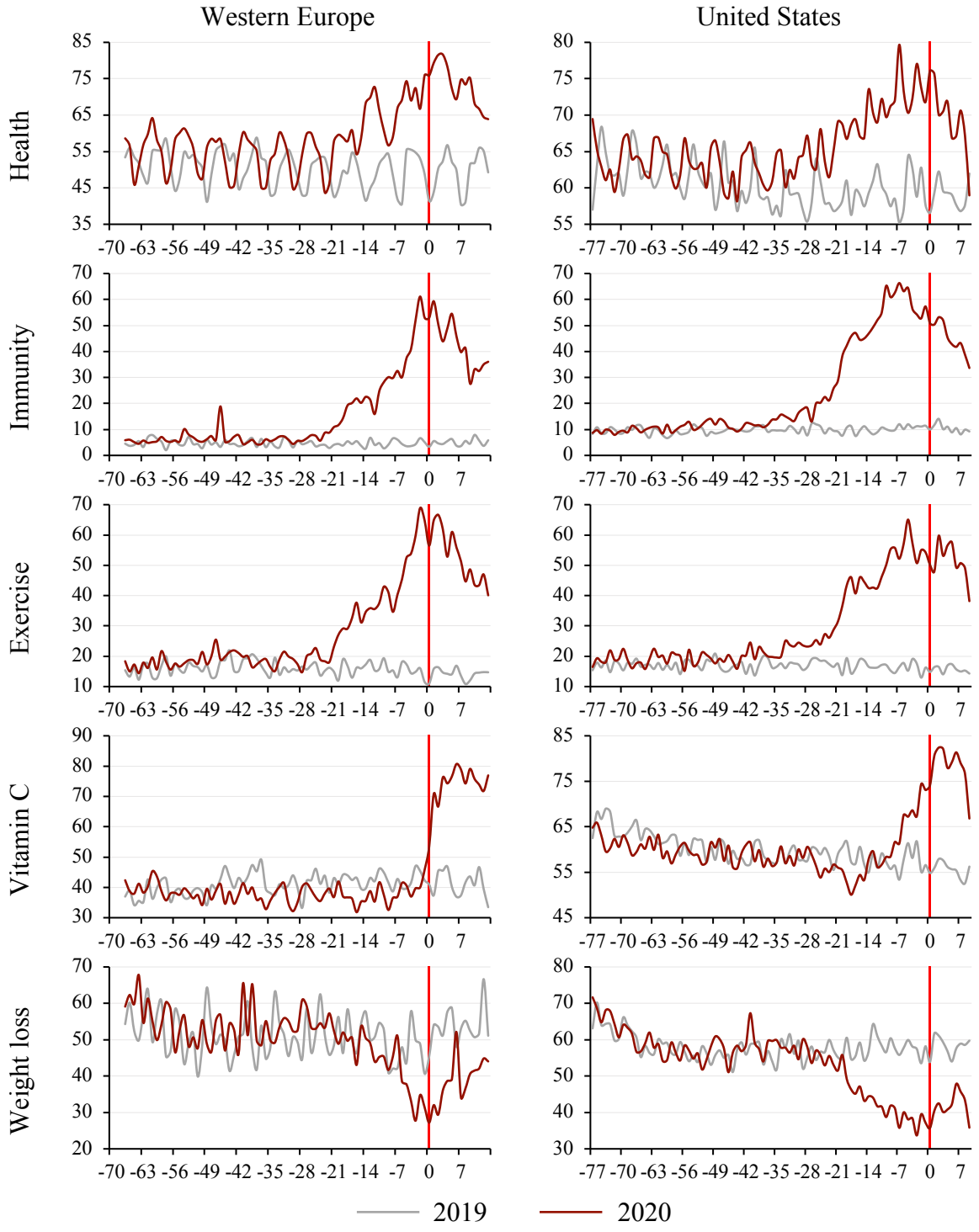
5. Results

Figure 1 presents re-scaled search volumes pre- and post-lockdown in 2020 and for the corresponding period in 2019 for Western Europe and the United States for all five search topics: *health*, *immunity*, *vitamin C*, *exercise* and *weight loss*. Interest in most topics increases noticeably around the lockdown announcement date in 2020 but not in 2019, the exception being *weight loss*, which experienced decreased interest. While the increase in interest in *vitamin C* in Western Europe is sudden and coincides with lockdown announcement, most topics experience increased volume beginning approximately three to four weeks prior to lockdown announcement, consistent with Goolsbee and Syverson's (2021) findings that consumers voluntarily reduced activity prior to the implementation of lockdowns, driven by the reported number of local COVID-19 deaths. It could also be attributed to other aspects of the pandemic including number of cases, media coverage or government responses other than lockdowns.

U.S. states announced lockdowns approximately one week later than their Western European counterparts (see Appendix, Table 4 and Table 5). If the increase in interest in the weeks prior to lockdown announcement is indeed driven by factors relating to the pandemic itself, interest in the United States could reasonably be expected to begin increasing approximately one week earlier relative to lockdown announcement, compared to Western Europe, which is indeed what is observed. Search interest in *health* exhibits clear cyclicality in Western Europe, consistent with the findings of Shimshoni, Efron and Matias (2009), who find that Google Search data are cyclical and predictable, especially for health-related topics.

In particular in Europe, lockdown announcement coincides with a peak in search interest (see *health*, *immunity* and *exercise*) and a minimum in the case of *weight loss*. This suggests that lockdowns are associated with a reversal in search interest trends. In the case of *health*, *immunity* and *exercise*, this is consistent with a crowding out effect, whereby lockdowns cause a reduction in voluntary measures. Furthermore, if the announcement of lockdowns in Western Europe fuelled expectations that the United States would follow suit, interest should peak

Figure 1: Daily Google Search volumes pre- and post-lockdown in 2020 and pre- and post- the corresponding date in 2019.



Notes: Population-weighted, re-scaled daily Google Search interest pre- and post-lockdown in 2020 (red) and pre- and post- the corresponding date in 2019 (grey) for Western Europe and the United States. The vertical and horizontal axes display search volume and days since lockdown announcement (represented by the vertical red line) respectively. Includes Western European countries that imposed a partial lockdown (see Appendix, Table 4). Population data for Europe obtained from Eurostat.

approximately one week prior to the announcement of lockdowns in the United States, which is precisely what is observed for *health*, *immunity* and *exercise*.

In contrast to the other search topics, *weight loss* experienced a decreased interest prior to lockdown announcement in Western Europe and the United States. As discussed in the data section, the basis for a topic's inclusion in this paper is that it might be of interest to a person who is interested in protecting themselves against COVID-19. Obesity's role as a risk factor for COVID-19 infection (Alberca et al., 2020) makes it a potential topic of interest to an obese or overweight individual seeking to reduce their risk of infection. However, there are a number of reasons this might not be the case. Reluctance among governments and media to highlight obesity as a contributing factor to COVID-19 infection for fear of perceived "fat-shaming" might result in a lack of public awareness of the risks of obesity in the context of COVID-19, as might a reluctance to accept the risks posed by obesity as a result of body positivity sentiments.

Figure 1 potentially provides some preliminary insight into the validity of the parallel trends assumption implicit in the DiD regression design employed in this paper, that in the absence of COVID-19-related lockdowns, search volumes would have evolved as they did in 2019. As discussed, the trends for the majority of the search topics deviate from the 2019 trends three to four weeks prior to lockdown announcement. This potentially raises concerns over the validity of the parallel trends assumption, although this preliminary analysis does not control for mortality rates.

5.1. Difference-in-differences estimation of lockdown effects

Table 1 and Table 2 present DiD estimates of the effect of lockdowns on search interest for Western Europe and the United States respectively. The effect of lockdowns is captured by the $After\ lockdown_{i,t} \times Year_t$ coefficient.

In Western Europe, lockdowns are associated with increases in search interest of 19.3, 26.0, 18.4 and 22.6 for *health*, *immunity*, *vitamin C* and *exercise* respectively and a decrease of 11.6 for *weight loss*. All results are statistically significant, with the effects on search volumes for *health*, *immunity*, *vitamin C* and *exercise* significant at the 0.1% level and the effect for *weight loss* significant at the 1% level. Remembering that search interest is indexed and normalised, the coefficient for *health* (19.3) can be interpreted as an increase in search interest of 19.3% of

Table 1: DiD estimates of the effects of lockdowns in Western Europe.

	Health	Immunity	Vitamin C	Exercise	Weight loss
After lockdown $_{i,t}$ ×*Year*	19.314***	25.970***	18.448***	22.634***	-11.643**
	(1.347)	(2.210)	(1.768)	(1.671)	(2.840)
Deaths	0.380**	0.348	0.091	1.655***	0.434**
	(0.084)	(0.145)	(0.130)	(0.117)	(0.094)
Country FE	Yes	Yes	Yes	Yes	Yes
Year, Week and Day FE	Yes	Yes	Yes	Yes	Yes
Observations	1 799	1 799	1 799	1 799	1 799

Notes: This table presents difference-in-differences estimates of the effects of lockdowns in Western European countries according to the model specified in equation (6). The model includes controls for a dummy variable that takes a value of one in the days following the date that lockdowns were announced, as well as country, year, week and weekday fixed effects, and the one-day lagged number of new COVID-19-related deaths per million. Robust standard errors are clustered at the day level and displayed in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2: DiD estimates of the effects of lockdowns in the United States.

	Health	Immunity	Vitamin C	Exercise	Weight loss
After lockdown $_{i,t}$ ×*Year*	8.422***	19.953***	24.525***	17.901***	-10.727**
	(1.349)	(1.523)	(1.553)	(1.239)	(1.962)
Deaths	0.11	0.788**	1.556***	1.880***	-0.644**
	(0.141)	(0.204)	(0.252)	(0.208)	(0.109)
State FE	Yes	Yes	Yes	Yes	Yes
Year, Week and Day FE	Yes	Yes	Yes	Yes	Yes
Observations	8 555	8 555	8 555	8 555	8 555

Notes: This table presents difference-in-differences estimates of the effects of lockdowns in the United States according to the model specified in equation (6). The model includes controls for a dummy variable that takes a value of one in the days following the date that lockdowns were announced, as well as state, year, week and weekday fixed effects, and the one-day lagged number of new COVID-19-related deaths per million. Robust standard errors are clustered at the day level and displayed in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

the maximum search interest for the period under consideration, which is indexed to 100. Given that indexing and normalising represent significant abstraction from absolute search volumes, it is useful to interpret these effects in terms of standard deviations. Search volume for *immunity* exhibited the largest increase of 1.6 standard deviations, followed by *exercise* (1.2 standard deviations), *vitamin C* (1.0 standard deviation) and *health* (0.9 standard deviations). The decrease in volume for *weight loss* was smaller in magnitude at 0.5 standard deviations.

Search interest is positively related to the lagged number of deaths for *health*, *exercise* and *weight loss* at the 1%, 0.1% and 1% levels respectively. While this is consistent with Goolsbee and Syverson's (2021) findings that voluntary measures are heavily influenced by the number of COVID-19 deaths, the effects are modest with an increase in the lagged death rate of one standard deviation corresponding to increases in search interest of 0.05, 0.26 and 0.06 standard deviations for *health*, *exercise* and *weight loss* respectively.

The effects of lockdowns on search interest in the United States are similar to those for Western Europe, with increases in interest in *health*, *immunity*, *vitamin C* and *exercise* of 8.4, 20.0, 24.5 and 17.9 respectively, and a decrease of 10.7 for *weight loss*. All results are statistically significant, with the effects on search volumes for *health*, *immunity*, *vitamin C* and *exercise*, significant at the 0.1% level and the effect for *weight loss* significant at the 1% level. Expressed in terms of standard deviations, in contrast with Western Europe, search volume for *vitamin C* experienced the largest increase (1.3 standard deviations), followed by *immunity* (1.1 standard deviations), *exercise* (1.0 standard deviation) and *health* (0.5 standard deviation), while interest in *weight loss* experienced a decline of 0.6 standard deviations.

Search interest is positively related to the death rate for *immunity*, *vitamin C* and *exercise* at the 1%, 0.1% and 0.1% levels respectively. The relationship is negative for *weight loss* at the 1% level. Again, the effects are modest with an increase in the lagged death rate of one standard deviation corresponding to changes in search interest of 0.04, 0.08, 0.10 and -0.03 standard deviations for *immunity*, *vitamin C*, *exercise* and *weight loss* respectively.

Increased interest in certain immune health-related topics is consistent with theories of public goods dilemmas, whereby forced cooperation (towards the goal of transmission suppression) via government-imposed lockdowns, increases expectations that others will cooperate, increasing individual willingness to cooperate and therefore overall cooperation, including voluntary measures to improve immune health.

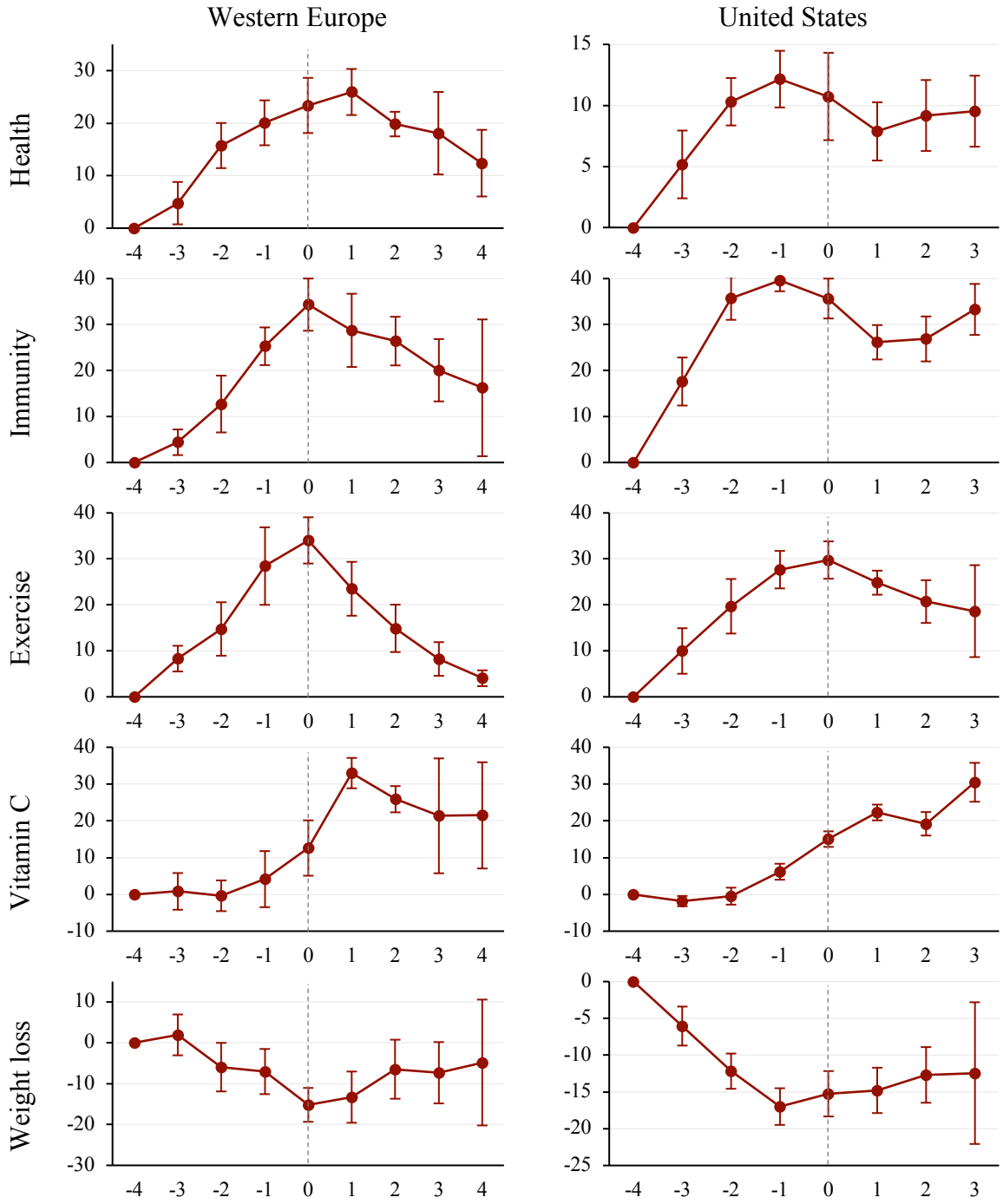
5.2. Event study

The DiD regression implicitly assumes that in the absence of COVID-19-related lockdowns, search interest would have evolved as it did in 2019. Figure 1 raised suspicions about the validity of this assumption, in general showing the effect on search volumes beginning in the weeks preceding lockdown announcement, although it was noted that this was prior to controlling for mortality rates, time fixed effects and country or state fixed effects. The results of the event study, presented in Figure 2, confirm that indeed, even after controlling for these variables, the effect on interest began in the weeks preceding lockdown announcement. This apparent failure of the parallel trends assumption undermines the results of the DiD estimation, the rectification of which, for example via propensity matching, is left to further research.

Health, *immunity* and *exercise* exhibit increasing interest beginning in the weeks preceding lockdown, implying that the 2019 counterfactual underestimates the increase in searches prior to lockdown, resulting in overestimation of the effect of lockdowns. Consistent with preliminary observations based on Figure 1, this does not appear to be the case for *vitamin C* after controlling for the mortality rate and fixed effects. *Vitamin C* experienced only a statistically insignificant (at the 95% level) increase in search volume one week prior to lockdown announcement in Western Europe and a statistically significant (95%) but modest increase one week prior to announcement in the United States, providing support for the parallel trends assumption and the results of the DiD regression for *vitamin C*. As seen in Figure 1, *weight loss* experienced decreased interest in Western Europe and the United States prior to lockdown announcement. After controlling for the death rate and fixed effects, the effect is small in Western Europe, with a barely statistically significant (95%) decrease in volume one week prior to lockdown announcement, although the effect is significant (95%) in the United States. As noted in the discussion of Figure 1, the trends begin earlier relative to lockdown announcement in the United States, consistent with the fact that the U.S. states announced lockdowns, on average, approximately a week later than the countries in Western Europe (see Appendix, Table 4 and Table 5).

While these findings raise concerns over the results of the DiD regression and the positive effect of lockdowns on interest in health-related topics, they are nonetheless interesting, especially in the context of a crowding out effect. For most search topics in both regions, lockdown announcement represents a turning point in the positive trends in search volumes that began in the weeks preceding lockdown announcement. The week of lockdown announcement

Figure 2: Event study results.



Notes: This figure presents the effect of being in week *k* (horizontal axis) after lockdown announcement, on Google Search volume (vertical axis), estimated according to the event study model specified in equation (7). Effects are presented for each search topic for Western Europe (including only countries that imposed a full lockdown; see Appendix, Table 4) and the United States. The fourth week preceding lockdown announcement is the reference period. The model includes dummy variables for the three weeks preceding and four weeks following lockdown announcement, country or state as well as year, week and weekday fixed effects, and controls for the one-day lagged number of new COVID-19 deaths per million. Robust standard errors are clustered at the day level. Error bars represent 95% confidence interval.

represents the peak effect for *immunity* and *exercise* in Western Europe and *exercise* in the United States. The peak effect occurs within one week of the announcement week for *health* and *vitamin C* in Western Europe and for *health* and *immunity* in the United States. This is consistent with previous research that has found evidence of a crowding out effect, whereby government-imposed policies reduce voluntary motivation (Chernozhukov, Kasahara & Schrimpf, 2021; Yan, Malik, Bayham, Fenichel, Couzens & Omer, 2021; Schmelz, 2021). Another possible explanation is that a reduction in the risk of infection as a result of lockdowns might reduce the incentive to pursue voluntary measures, although controlling for mortality rates will alleviate this to the degree that mortality and infection rates are correlated. Similarly, search interest in *weight loss* is a minimum in the week of lockdown announcement in Western Europe and the week prior in the United States. This suggests that, despite the findings of the DiD regression, lockdowns led to increased interest in *weight loss*, potentially driven by an increase in free time due to lockdowns.

Given that U.S. states announced lockdowns approximately one week later than the countries of Western Europe, it is possible that reports of lockdowns in Europe may have fuelled expectations of similar measures being implemented in the United States. To the extent that a crowding out effect exists, this may result in people in the United States shifting away from voluntary measures such as using Google Search to collect health-related information prior to the formal announcement of lockdown measures. This is precisely what is observed for *health*, *immunity* and *weight loss* in the United States.

While most search topics conform to the general pattern whereby the week of lockdown announcement represents a turning point in the search volume trends, *vitamin C* provides an exception in the United States, which, aside from a small reversal in the second week after lockdown announcement, exhibits increasing search volumes until the third week after lockdown announcement, by which point it exceeds the previous peak in the week after lockdown announcement. While *health* and *immunity* in the United States conform to a pattern consistent with a crowding out effect, they too exhibit increase interest in the weeks following lockdown announcement, although unlike *vitamin C*, they fail to reach the peak of one week prior to announcement.

In addition to providing insight into the validity of the parallel trends assumption, the event study facilitates investigation into the persistence of the effects on search volumes in the weeks following lockdown announcement and the degree to which people adapt to lockdowns. In

Western Europe, search volumes for *health* and *vitamin C* continue to increase in the week following lockdown announcement before reversing in the following week. In general, weekly effects on search volumes remain significantly different from zero (at the 95% level) for three weeks following lockdown announcement. However, search volume for *exercise* in Western Europe returns almost to the reference level within four weeks of announcement and the effect for *weight loss*, while negative, is statistically insignificant at the 95% level in only the second week following lockdown announcement.

The data section of this paper presented a discussion of the advantages and limitations of Google Search data relative to traditional survey data in a general setting, however its use in the context of COVID-19-related lockdowns presents a potentially important limitation. It is possible that changes in search interest are driven by compositional changes in the population of Google Search users resulting from lockdowns. To illustrate, consider that lockdowns were introduced to "flatten the curve" and alleviate the burden on health systems. The most effective way to achieve this is to protect those most likely to require medical care in the event that they contract COVID-19; that is, those who are most at-risk such as the sick and elderly. People who are more susceptible to COVID-19 are arguably more sensitive to health concerns and therefore more likely to seek health-related information. Lockdowns should affect these people disproportionately, resulting in a disproportionately large number of at-risk people confined to their homes with little else to do. It follows that this might affect the composition of the population of Google Search users similarly, resulting in a higher proportion of sick and elderly people. If the sick and elderly are more likely to use Google Search to collect information on health-related topics, this would drive an increase in interest purely via compositional changes in the population of Google Search users. Traditional survey data would avoid this issue by tracking the same group of individuals. Unfortunately, Google Trends does not provide demographic data, making it difficult to control for such compositional changes.

5.3. Robustness

Estimation of the DiD regression is repeated for Western Europe including all 12 countries whose governments had imposed either a full or partial lockdown by April 2020 (see Appendix, Table 4) with the results presented in Table 3. These results support the earlier findings with increases in search interest for *health*, *immunity*, *vitamin C* and *exercise* of 17.8, 28.1, 22.5 and 23.1 respectively, significant at the 0.1% level and a decrease in search volume for *weight loss* of 13.1, significant at the 1% level. These effects represent changes in search interest for *health*,

Table 3: DiD estimates of the effects of lockdowns in Western Europe, including countries that implemented only partial lockdowns.

	Health	Immunity	Vitamin C	Exercise	Weight loss
After lockdown $_{i,t}$ ×*Year*	17.846***	28.134***	22.508***	23.059***	-13.145**
	(0.995)	(1.950)	(1.588)	(1.604)	(2.896)
Deaths	0.453**	0.27	-0.016	1.766***	0.443**
	(0.099)	(0.133)	(0.128)	(0.101)	(0.095)
Country FE	Yes	Yes	Yes	Yes	Yes
Year, Week and Day FE	Yes	Yes	Yes	Yes	Yes
Observations	2 399	2 399	2 399	2 399	2 399

Notes: This table presents difference-in-differences estimates of the effects of lockdowns in Western European countries, including those with a partial lockdown, according to the model specified in equation (6). The model includes controls for a dummy variable that takes a value of one in the days following the date that lockdowns were announced, as well as country, year, week and weekday fixed effects, and the one-day lagged number of new COVID-19-related deaths per million. Robust standard errors are clustered at the day level and displayed in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

immunity, *vitamin C*, *exercise* and *weight loss* of 0.9, 1.7, 1.2, 1.3 and -0.6 standard deviations respectively. As is the case when only countries that implemented full lockdowns are included in the analysis, search interest is positively related to the lagged mortality rate for *health*, *exercise* and *weight loss* at the 1%, 0.1% and 1% levels respectively with an increase in the lagged mortality rate of one standard deviation corresponding to increases in search interest of 0.06, 0.26 and 0.05 standard deviations respectively.

Under a crowding out effect, people respond to stringent, government-imposed measures by reducing their reliance on voluntary measures such as improving health to protect against COVID-19. Less stringent measures associated with only a partial lockdown should precipitate a smaller decrease in interest in health-related topics. In other words, interest in health-related topics should be higher after lockdowns when countries that had only partial lockdowns are included. Indeed, this is exactly what is observed. The corresponding effects in the case considering only those Western European countries that imposed a full lockdown were 1.6, 1.2, 1.0, 0.9 and 0.5 standard deviations. With the exception of health, the effects on search interest in the case considering both full and partial lockdowns are larger in magnitude than the effects

in the case considering only full lockdowns, implying that search interest in these topics was, on average, higher when countries that experienced only a partial lockdown are included in the analysis.

6. Conclusion

Voluntary and government-enforced responses to the COVID-19 pandemic have had important health and economic consequences. This paper uses internet search data to ameliorate data availability issues associated with traditional survey data in the context of COVID-19 lockdowns. The DiD regression finds evidence that lockdowns resulted in increased interest in voluntarily improving health to protect against COVID-19, providing support for a public goods dilemma theory of lockdowns, whereby strictly enforced measures create the expectation that others will cooperate, driving individuals themselves to cooperate resulting in a higher overall level of cooperation. However, an event study reveals a potential violation of the parallel trends assumption implicit in the DiD regression design, suggesting that the effect of lockdowns might be overestimated. Indeed, an event study shows that lockdowns precipitated decreasing interest in health, consistent with government-imposed policies crowding out voluntary measures. Understanding the trade-off between voluntary and government-imposed measures has important implications for optimising public health policy in the context of the ongoing COVID-19 pandemic as well as future pandemics and other crises, suggesting that in addition to enforced measures, optimal policy should actively campaign to encourage voluntary, health-related measures.

Violation of the parallel trends assumption might be rectified via a number of avenues, including propensity matching or a synthetic control approach such as that employed by Cho (2020), however such adjustments are left to further research. To the extent that such research finds support for the existence of a crowding out effect, a potential research question concerns the implications of repealing lockdowns, in particular the symmetry of the crowding out effect and how government-imposed lockdowns affect private expectations concerning government and individual responsibility and a potential erosion of personal agency. This paper also considers the possibility that its findings might be driven by compositional change in the population of Google Search users associated with lockdowns. This is a problem that potentially affects other research that relies on internet search data to investigate the effects of COVID-19-related lockdowns and that traditional survey data could avoid by tracking the same group of

individuals. Techniques to control for compositional changes in the population of search users are also left to further research.

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Appendix

Table 4: Western Europe lockdown dates.

Country	Lockdown announced	Full lockdown effective	Partial lockdown effective
Austria	15 March	16 March	
Belgium	17 March	18 March	
France	16 March	17 March	
Germany	16 March		22 March
Ireland	28 March	28 March	
Italy	9 March	10 March	
Luxembourg	12 March	16 March	
Netherlands	16 March		16 March
Portugal	19 March	19 March	
Spain	14 March	14 March	
Switzerland	20 March		20 March
United Kingdom	23 March	24 March	

Table 5: United States lockdown dates.

State	Lockdown announced	Lockdown effective
Alabama	3 April	4 April
Alaska	27 March	28 March
Arizona	30 March	31 March
California	19 March	19 March
Colorado	25 March	26 March
Connecticut	20 March	23 March
Delaware	22 March	24 March
District of Columbia	30 March	1 April
Florida	1 April	3 April
Georgia	1 April	3 April
Hawaii	23 March	25 March
Idaho	25 March	25 March
Illinois	20 March	21 March
Indiana	23 March	24 March
Kansas	28 March	30 March
Kentucky	23 March	26 March
Louisiana	22 March	23 March
Maine	31 March	2 April
Maryland	30 March	30 March
Massachusetts	23 March	24 March
Michigan	23 March	24 March
Minnesota	26 March	27 March
Mississippi	1 April	3 April
Missouri	3 April	6 April
Montana	26 March	28 March
Nevada	1 April	1 April
New Hampshire	26 March	27 March
New Jersey	21 March	21 March
New Mexico	23 March	23 March
New York	20 March	22 March
North Carolina	27 March	30 March
Ohio	22 March	23 March
Oregon	23 March	23 March
Pennsylvania	23 March	1 April
Rhode Island	28 March	28 March
South Carolina	6 April	7 April
Tennessee	30 March	31 March
Texas	31 March	2 April
Vermont	24 March	25 March
Virginia	30 March	30 March
Washington	23 March	23 March
West Virginia	23 March	24 March
Wisconsin	24 March	25 March