

WestminsterResearch

<http://www.westminster.ac.uk/westminsterresearch>

Do responses to the COVID-19 pandemic anticipate a long-lasting shift towards peer-to-peer production or degrowth?

Dartnell, L. and Kish, K.

NOTICE: this is the authors' version of a work that was accepted for publication in Sustainable Production and Consumption. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in Sustainable Production and Consumption, 27, pp. 2165-2177, 2021.

The final definitive version in Sustainable Production and Consumption is available online at:

<https://doi.org/10.1016/j.spc.2021.05.018>

© 2021. This manuscript version is made available under the CC-BY-NC-ND 4.0 license <https://creativecommons.org/licenses/by-nc-nd/4.0/>

The WestminsterResearch online digital archive at the University of Westminster aims to make the research output of the University available to a wider audience. Copyright and Moral Rights remain with the authors and/or copyright owners.

Journal Pre-proof

Do responses to the COVID-19 pandemic anticipate a long-lasting shift towards peer-to-peer production or degrowth?

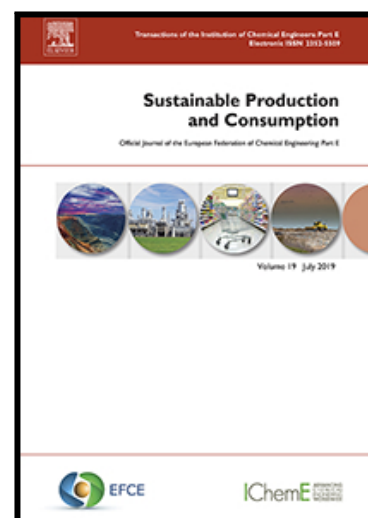
Dartnell Lewis R , Kish Kaitlin

PII: S2352-5509(21)00165-2
DOI: <https://doi.org/10.1016/j.spc.2021.05.018>
Reference: SPC 666

To appear in: *Sustainable Production and Consumption*

Received date: 12 December 2020
Revised date: 8 May 2021
Accepted date: 20 May 2021

Please cite this article as: Dartnell Lewis R , Kish Kaitlin , Do responses to the COVID-19 pandemic anticipate a long-lasting shift towards peer-to-peer production or degrowth?, *Sustainable Production and Consumption* (2021), doi: <https://doi.org/10.1016/j.spc.2021.05.018>



This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2021 Published by Elsevier B.V. on behalf of Institution of Chemical Engineers.

Do responses to the COVID-19 pandemic anticipate a long-lasting shift towards peer-to-peer production or degrowth?

Dartnell, Lewis R.^{1,*} and Kish, Kaitlin²

¹ Department of Life Sciences, University of Westminster, 115 New Cavendish Street, London W1W 6UW, UK. lewis@lewisdartnell.com

² Natural Resource Sciences, McGill University, 21111 Lakeshore, Ste-Anne-de-Bellevue, Sainte-Anne-de-Bellevue, Quebec H9X 3V9, Canada

* Corresponding author

Abstract:

The COVID-19 pandemic simultaneously triggered a sudden, substantial increase in demand for items such as personal protection equipment and hospital ventilators whilst also disrupting the means of mass-production and international transport in established supply chains. Furthermore, under stay-at-home orders and with bricks-and-mortar retailers closed, consumers were also forced to adapt. Thus the pandemic offers a unique opportunity to study shifts in behaviour during disruption to industrialised manufacturing and economic contraction, in order to understand the role peer-to-peer production may play in a transition to long-term sustainability of production and consumption, or degrowth. Here, we analyse publicly-available datasets on internet search traffic and corporation financial returns to track the shifts in public interest and consumer behaviour over 2019 – 2020. We find a jump in interest in home-making and small-scale production at the beginning of the pandemic, as well as a substantial and sustained shift in consumer preference for peer-to-peer e-commerce platforms relative to more-established online vendors. In particular we present two case studies – the home-made facemasks supplied through Etsy, and the decentralised efforts of the 3D printer community – to assess the effectiveness of their responses to the pandemic. These patterns of behaviour are related to new modes of production in line with ecological economics and as such add capacity to a broader prefiguration of degrowth. We suggest an adoption of a new “fourth wave” of DIY culture defined by enhanced resilience and degrowth to continue to add capacity to a prefigurative politics of degrowth.

Keywords: degrowth; peer-to-peer; prefigurative politics; micro-production; 3D printing

Funding: This research is partially funded by the Economics for the Anthropocene and Leadership for the Ecozoic programs at McGill University.

1. Introduction

Neoclassical welfare economics controls global political and economic decisions despite grounding in outdated theories of growth, human behaviour, and commodity production (Gowdy and Erickson 2005; Farley 2017). The COVID-19 lockdowns and restrictions of 2020 exposed cracks in global economies predicated on growth. This further confirmed assumptions put forward by economic sustainability scholars and experts of planetary health that neoclassical and neoliberal capitalism deepens crises faced by global communities

(Horton et al. 2014). The unprecedented health crisis has induced global economic disruption and social unrest. As millennials witness their second 'one-in-a-generation' stock market crash, the certainty of a stable future is challenged with escalating unemployment and serious backtracking on the emancipation of women (Guterres, 2020; Topping, 2020; United Nations, 2020). Neoclassical capitalism continues to create barriers to effective response to the COVID-19 crisis and human wellbeing in general. This is most evident in countries where concern over falling gross domestic product and unstable stock markets, rather than public health, lead governance strategies (Steinberger 2020).

While many governments resisted economic governance changes, consumer behaviour changed drastically. The inability to consume through traditional methods and the partial breakdown of large-scale production chains continue to drive new consumption patterns. In a recent report, Arora et al. (2000) outline five lasting effects the COVID-19 pandemic has created on consumer behaviour, including: 1) mindfulness of spending habits, particularly regarding the sustainability values of the brand and quality of products; 2) flight to digital and omnichannel; 3) shock to brand loyalty with new prioritization of value; 4) desire to support companies that support the caring economy and; 5) a 'homebody' economy where people purchase from home and primarily goods that are used within the home. Many of these trends are likely to be long-term, especially regarding decreased disposable income and value-oriented shopping. In China, where most are back to work, there is still a reported 55% decrease in income (Arora et al. 2020). Historically, economic disruptions of this nature unleash new technological innovation waves as the 'new economy' is driven by investment into technologies that show potential (Newman AO 2020). 3D printing and peer-to-peer production have emerged as a worthy investment stream particularly in the infrastructural ability to respond to global and local need (Newman AO 2020).

Additionally, while people now purchase more items through multinational online platforms such as Amazon, many also turned to local producers for some of their needs (Cambefort 2020). Not only are local producers considered a safer way to consume (choose online and pick up on the curb), but there is a drive to support members of one's community. Here, we explore the extent to which consumers turned their attention to peer-to-peer selling platforms, such as Etsy, to meet their needs during the pandemic. Some of these patterns that we explore in this paper point to changes called for within degrowth economics. We suggest that these trends amplify a prefigurative politics of degrowth by shifting DIY (Do It Yourself) and P2P (peer-to-peer) production and consumption into a new "fourth wave" of DIY. This new wave of DIY is characterized by enhanced resilience through polycentric governance, distributed diversity, and improved socio-ecological wellbeing.

To make this argument, we first consider several specific aspects of the response to the disruption of the established supply chains during the pandemic: a surge in interest in homemade produce; the rapid growth of P2P online marketplaces; and the mobilisation of the decentralised manufacturing capability of the 3D printer community. The data sets we use to investigate shifts in public interest include both the records of worldwide internet search terms provided by Google Trends (trends.google.com) and the financial reports returned by major online retailers and emerging customer-to-customer (C2C) and peer-to-peer (P2P) e-commerce platforms.

We will first situate the novelty of our study within the existing literature, before presenting these data analyses and case examples on the effectiveness of the shift into more value-oriented and peer-to-peer based production precipitated by the pandemic, We will then apply these trends to ideas for a new fourth wave of DIY that situates P2P production more firmly within the low/de-economic literature. Shifts in consumer behaviour and disturbances in neoclassical capitalism create room for more support and integration of these alternative, more sustainable, paths for production and consumption.

2. Literature Review

Heterodox economic disciplines, such as ecological economics and degrowth economics, have long challenged the underlying theories of the neoclassical capitalist system as guiding economic policy principles (Daly 1992; Costanza 1989; Georgescu-Roegen 1975; 1971). Instead, ecological economists argue that economic decision-making needs to begin with the re-embedding of society within constraints of the biosphere (Steffen et al. 2015) to sustain high quality of life across generations (Polanyi 1944; Raworth 2017; Daly and Cobb 1994). High-quality life also necessitates just distribution of resources and efficient allocation (Farley 2010). This is more succinctly defined as “a socially sustainable and equitable reduction (and eventually stabilisation) of society’s throughput” (Kallis 2011, 874). Throughput is the physical and social energy and materials extracted for use from the environment and returned as waste (Daly 1997). This shift is achieved by major contraction of the economy through reorganisations of social life.

Given that no other unplanned environmental or economic disruption has so greatly impacted humanity’s social organization or collective environmental footprint (McGrath 2020), the COVID-19 pandemic offers a unique opportunity to examine the role of peer-to-peer (P2P) production and consumption within a period of global economic contraction. Understanding the implications of the crisis with respect to production adaptation strategies is critical for facilitating more prolonged, significant, and intentional transitions (Boons et al. 2020). With the pandemic highlighting pre-existing fragilities in global value chains (GVCs), trade systems are likely to undergo strategic reconfigurations (Kano and Oh 2020), suggesting an opportunity for new ideas to influence systems in distress. Thus far, the shortages and weaknesses of GVCs have promoted some trade protectionism (Movsisyan 2020) as governments begin to favour and protect their internal sectors. While this may be measured as an increase in local production and consumption, it is also indicative of early out-group antagonism through policy. Thus, explorations of alternative production systems consistent with socially just economic contraction are important. Without pre-planned transition and attention to these networks, economies may be more likely to slip toward protectionism and nationalism.

Capitalist production tendencies are characterized by long supply chains, economies of scale, and centralization, which leads to significant waste, mainly through overproduction of goods and shipping costs. Distributed micro-production, including peer-to-peer (P2P) production, is characterized by on-demand production with short supply chains (Rauch, Dallasega, and Matt 2016), diversification over specialization (Gale 2000), improved

resilience to disturbances (Freeman, McMahon, and Godfrey 2017), commons knowledge and ownership (Bauwens 2005; Kostakis et al. 2018) and is generally more sustainable than traditional manufacturing (Rauch et al. 2015). In these ways, P2P production is strengthening emerging sustainable alternatives to mass production systems by providing technological infrastructure that allows for a greater scale and wider reach of localized production. The implications of enhanced P2P production include reduced material flow, challenges to alienation and social ailments associated with overconsumption (Arndt et al. 2004), and democratic and polycentric governance strategies. However, there is a gap in ecological economics and degrowth economic literature regarding how to reconceptualize different logics of production, particularly regarding how production systems have, and may in the future, change in low-growth contexts, and how to pave the way for such transitions (Mair, Druckman, and Jackson 2020; Kish and Quilley 2020).

Upticks in P2P manufacturing (Bednar and Modrak 2014; Hu 2013) can partly be attributed to a shift from market demand of impersonal mass production to an increased overall demand for individualized products. Motivations and outcomes of this shift are comparable to the call for artisanal goods during the Arts and Crafts movement, as resistance to the growing production culture of factories, efficiency, and mass production (Morris 1880; Ruskin 1854). The primary difference between P2P production of the Arts and Crafts movement in the 1880s and modern-day P2P is the enhanced technological capabilities to connect producers and consumers across distributed P2P nodes. As a result, a new P2P Arts and Crafts movement now sees a revival through local and artisanal production empowered and connected by technological platforms such as Etsy. Through these P2P systems, production is based on real community and market demand, while their capacity is enhanced through online connection. This blurring of lines between physical and digital production and consumption boundaries is sometimes referred to as the 4th Industrial Revolution (4IR), which is expected to drive a manufacturing reset in terms of a) improved customer-centricity across supply chains, b) supply-chain resilience through connected and reconfigurable networks of producers, c) increased speed of production for on-demand production, and d) overarching eco-efficiency (Betti, de Boer, and Giraud 2020).

Limits to growth meets 4IR among these intersections and outcomes. While the dominant vision of 4IR rests on an assumption of continued ephemeralization (Heylighen 2007) and increased smart-technologies, it also embodies the seeds of new technics centred on Internet-connected, open-source, and P2P collaboration. These new technics promote localized micro-manufacturing that make possible a re-emergence of highly networked artisans through 3D printers, home production spaces, playful fab-labs, makerspaces, and other shared manufacturing spaces (Lipson and Kurman 2013; Gershenfeld 2013). These developments have fuelled a growing counter-culture of P2P makers (Billio and Varotto 2020; Lou and Peek 2016). By eliminating costly storage, long-range transportation, infrastructural overhead, undercutting monopolies, and disincentivising mass advertising, P2P production is part of a more prominent solution for sustainable production schemes. Questions do still remain regarding scalability and how to design and implement larger networks that support such a system on a global scale (Mourtzis and Doukas 2014; Mourtzis, Doukas, and Psarommatidis 2012). Furthermore, existing structures of P2P production may be revolutionary as a reorientation of traditional manufacturing within embedded economies, but the literature does not sufficiently explore this, nor are there explorations of the extent to which people rely on P2P production for their everyday

consumption, or in different contexts the numerous socio-ecological benefits associated with broader P2P culture.

This paper explores these gaps, first through an overview of changes in P2P consumption within the economic contraction of the COVID-19, followed by an analysis of how P2P production evolves alongside degrowth.

The data sets we use to investigate shifts in public interest during the pandemic include the records of worldwide internet search terms provided by Google Trends (trends.google.com). Several studies have already been published that use these rich data sets of internet searches as tools to explore the immediate and persistent responses to the COVID-19 pandemic.

Effenberger et al. (2020) investigated the relationship between public interest in coronavirus and the contemporaneous number of infected cases for selected countries around the world. They found that across Europe and the US the internet search intensity for the disease peaked around 11.5 days before the first peak of newly infected cases. Similarly, Lu and Reis (2021) used Google Trends data to investigate the temporal correlation between a range of search terms specific to symptoms of COVID-19 and clinically reported cases and deaths from the virus in 32 countries. They revealed a clear pattern of disease progression, strongly correlated to the clinical data, and so demonstrated this approach as a useful tool for real-time whole-population surveillance of the clinical progression of pandemics before widespread laboratory testing is available. Calculating a related metric to Effenberger et al. (2020), Lu and Reis (2021) found that the increase in COVID-19 symptom related searches preceded the rise in reported cases by an average of 18.5 days. Pan et al. (2020) use machine learning techniques to analyse search data provided by Google Trends and forecast confirmed cases of COVID-19.

Other studies have used Google Trends data to elucidate how the unfolding pandemic has impacted people's behaviour and mental health, as well as other effects on society. Hoerger et al. (2020) found pandemic-associated spikes in searches for symptoms and self-treatment of anxiety; Zitting et al. (2021) reported a sharp increase in Google searches about insomnia during the pandemic; and Onchonga (2020) used Google Trends to investigate the worldwide public interest in self-medication during the onset of the pandemic. Caperna et al. (2020) used a combination of internet search term data from Google Trends and machine learning methods to calculate an unemployment index, which they found rose significantly and persistently after the imposition of national lockdowns.

Of greatest significance to this present study, Schmidt et al. (2020) explore trends in public concerns in the US on food sourcing during the pandemic and report three distinct phases in food-related searches. First, from mid-Feb to mid-April 2020, search terms revealed interest in methods of food storage and concerns over food shortages. Second, starting at the beginning of March, a growing interest in sourcing food locally and directly from farmers. Third, from mid-late-March an increasing interest in take-out food and home delivery, coupled with more searches for food banks (food aid) and a sharply increasing unemployment rate.

Here, we employ similar techniques of selected queries of the Google Trends database, coupled with company financial reports, to investigate the public response to the pandemic in terms of shifts of attitude to more local, distributed or sustainable modes of consumption and production.

3. Methods

The literature demonstrates the potential of P2P production to shift to more sustainable production. Research is now required to ascertain the degree to which consumers may actually shift their behaviour toward P2P consumption within a context of economic contraction. Here we analyse data acquired on both the internet search volume of different keywords and the growth in revenue reported by various e-commerce platforms.

For many people now, keyword searches of the internet serve as the primary source of information. The Google search engine (google.com) accounts for 87% of English-language internet searches (Clement 2020 accessed November 2020). Google Trends (trends.google.com) provides data on the popularity of search queries run through this dominant search engine as a time series with weekly data points, and thus can offer insight on the changing concerns and interests of (English-speaking) internet users worldwide.

A first set of Google Trends database queries was selected to provide worldwide search volume datasets on terms related to the unfolding health crisis and home- or small-scale production. The search terms we used here were: "coronavirus", "covid", "pandemic", "3D printing", "do it yourself", "how to", and "sourdough" (see Figure 1). Each search term was entered into a separate query of the Google Trends database using their website portal (trends.google.com). For each query, we selected the region of interest as 'Worldwide', over the 'Custom date range' of 01/01/1999 to 15/11/2020 (the time of data capture for this study), including 'All categories', and for complete 'Web Search' (rather than, for example, limiting to searches for an image or news). The data returned by each Google Trends query was downloaded as a plain-text .csv file. Data from individual queries were then plotted using commercial analysis software (Wolfram Mathematica 12.2).

A second set of Google Trends database queries focussed on selected online shopping websites and e-commerce platforms. The search terms used were: "walmart", "ikea", "ebay", and "amazon", selected as the largest e-commerce sites ("Top 10 E-Commerce Sites in the US 2020" 2020 ; accessed December 2020), as well as "etsy" and "shopify", included as rapidly growing customer-to-customer (C2C) competitors offering marketplaces for homemade or peer-to-peer (P2P) production wares (see Figure 2). As before, each search term was entered as a separate query of the Google Trends database, selected over a 'Worldwide' region over the data range 01/01/1999 to 15/11/2020 to include 'All categories' of a complete 'Web Search', and the data returned saved as .csv files. This weekly search volume data for each online store was normalised to its mean value over the second and third quarters (Q2-Q3) of 2019 (i.e. 31st March – 29th September; covering a period without

significant deviations from holiday sales or promotions, for example) before being plotted so that the relative change in web traffic can be compared (see Figure 2).

Financial information was also acquired for these same e-commerce platforms, where publicly available. Financial returns were obtained from the US Securities and Exchange Commission (www.sec.gov) through their EDGAR (Electronic Data Gathering, Analysis, and Retrieval) online company lookup portal (www.sec.gov/edgar/searchedgar/companysearch.html). We performed searches for the following online-trading companies (with NYSE or Nasdaq stock code): "Walmart Inc. (WMT)", "Ebay Inc. (EBAY, EBAYL)", and "AMAZON COM INC (AMZN)", "ETSY INC (ETSY)" and "SHOPIFY INC. (SHOP)". For each company we accessed the 10-Q quarterly reports from Q1 2018 to Q3 2020 as 'Interactive Data', downloaded the corresponding spreadsheet and extracted the reported net revenue or sales figures. These data were then normalised to the mean for the first two quarters of 2018 so that the relative growth over time can be compared irrespective of the absolute size of these different businesses (see Figure 3).

4. Results and Discussion

4.1. What happened during the COVID-19 pandemic

We have interrogated publicly-accessible datasets to provide metrics on the changes in public concerns and interests in home- and small-scale production, as well as shifts in purchasing behaviour, during the COVID-19 pandemic.

4.1.1 Home and small-scale production

Internet search data acquired from Google Trends can provide invaluable insights into the changing prevalence of international public interest in different topics, as shown in Figure 1.

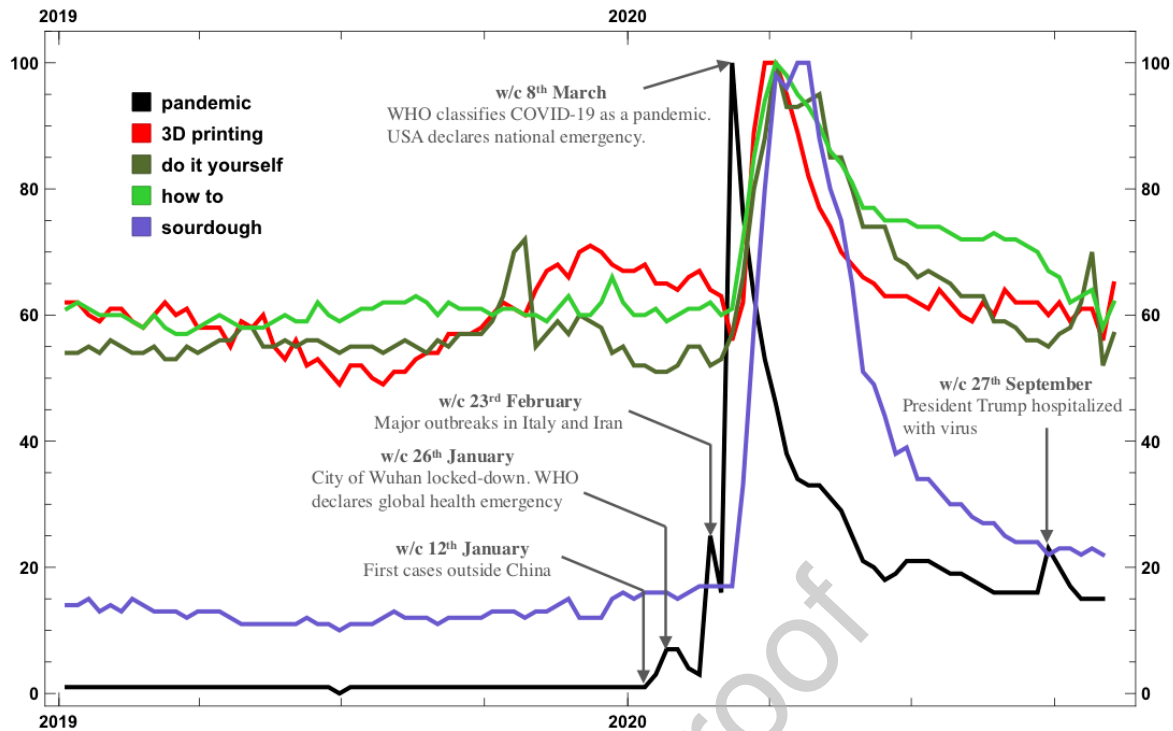


Figure 1. Time-series data (weekly datapoints) from Google Trends on relative internet search popularity of different terms since 2019, each normalised to their maximum over this period at 100. The “pandemic” search term plot is labelled with corresponding significant world events (with the week commencing date).

“Coronavirus”, “covid” and “pandemic” all show similar behaviour in the first three months of 2020 and so only “pandemic” is plotted here for clarity. The worldwide search volume for “pandemic” exhibits an early, small spike in the week of 26th January, with the emergence of news reports that the Chinese city of Wuhan had been put into complete lockdown, and the World Health Organisation declared a global health emergency (Reuters Staff 2020). Effenberger et al. (2020) also report that the worldwide public interest in coronavirus (as gauged through Google Trends) reached its first peak at the end of January 2020 when the number of new cases in China was growing exponentially. Interest waned again, until the major outbreaks erupted in Italy and Iran a month later and then the search traffic surged in the week commencing 8th March as the WHO classified COVID-19 as a pandemic and the USA declared a national emergency. After people had initially looked-up what the coronavirus pandemic is the volume of searches rapidly declined, approximately following an exponential decline with a half-life of 3-4 weeks. Three weeks after the peak in people searching the internet for information on the pandemic, Google Trends reveals a peak in the number of web searches for “3D printing” in the week of 29th March. We will return to this interest in 3D printing later. Google Trends also reveals that the following week (w/c 5th April), with widespread closure of shops, services and public spaces and many people confined to shelter at home, terms related to self-reliance such as “How to” and “Do It Yourself” peaked. A fortnight later, in the week beginning 19th April, Google tracked a specific example of homemade produce that became faddish during lockdown: people seeking how to make their own “sourdough” cultures for bread-baking. Whereas specific “sourdough” searches had significantly declined again by July 2020, more general searches for home-making guidance remained elevated. “How to” remained higher than “do it yourself” as this

former term has a broader usage and was still being used frequently by people seeking guidance on, for example, how to educate or entertain children confined at home during lockdown; whereas the latter is more associated with home-improvement projects (although the spike witnessed in the last week of October is attributed to searches relating to DIY Halloween costumes and decorations).

These internet search engine historical datasets thus describe a succession of public concerns and interests developing over the first weeks of the coronavirus outbreak: pandemic – 3D printing – How-to / DIY

4.1.2 Shifts in consumer behaviour

Concurrent with this lockdown-triggered swelling of interest in online instructions for how to make and do things for yourself at home was a surge in online shopping and e-commerce. Figure 2 plots the relative number of searches reported by Google Trends for online shopping platforms Walmart, Ikea, eBay, Amazon, Etsy and Shopify. These were selected as the largest e-commerce sites (“Top 10 E-Commerce Sites in the US 2020” 2020 ; accessed December 2020) or rapidly growing C2C competitors offering marketplaces for homemade or P2P production wares.

Walmart.com is the e-commerce site of the American chain of department stores and world’s largest company by revenue (“Global 500” 2020; accessed December 2020); Ikea is a Swedish multinational selling ready-to-assemble furniture and home fittings; eBay is an online marketplace for both B2C (business-to-consumer) and C2C auctions of new and used products; Amazon is primarily a B2C e-commerce store and the world’s largest online marketplace (“Global 500” 2020; accessed December 2020); Etsy is an online marketplace focussed on handmade produce and craft supplies; and Shopify is an e-commerce platform that supports independent producers and retailers with services including online sales and shipping.

We focussed here on English-language e-commerce websites (for which the Google Trends dataset is most applicable), and not, for example, large Chinese-language online shopping platforms like Alibaba and its C2C marketplace Taobao.com and B2C retail platform Tmall.com, or the B2W family of shopping websites in Latin America. Other English-language online C2C and B2C marketplaces for clothes, jewellery, home décor and other artisanal and handmade crafts, or e-commerce platforms for independent creatives, also exist. These include Zibbet, iCraft, Artfire, Hello Pretty and Bonanza, but Google Trends data cannot be used as a reliable proxy for traffic volumes because they currently receive too few searches, or their names are not unique search terms to allow confident assignment of the search volume stats to that specific website.

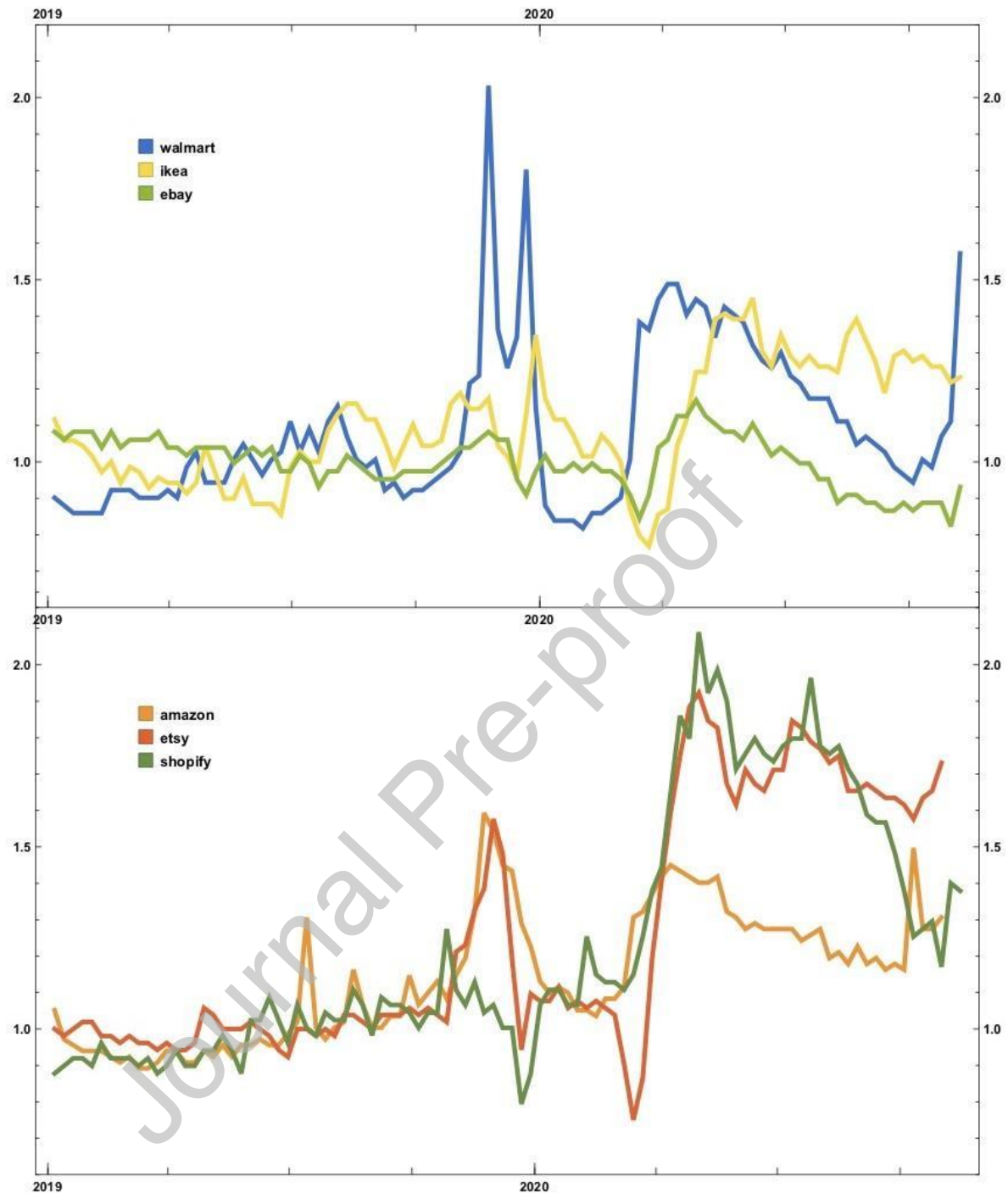


Figure 2. Time-series data (weekly data points) from Google Trends on relative internet search popularity of different e-commerce platforms since 2019, each normalised to its mean value over Q2-Q3 2019.

The weekly search volume data for each online store has been normalised here to its mean value over Q2-Q3 2019 (i.e. 31st March – 29th September; covering a period without significant deviations due to holiday sales or promotions, for example) so that the relative change in web traffic can be compared. These Google search frequencies are used here as a reliable proxy for actual visitor traffic volumes to these e-commerce sites. Even if an

internet user knows the exact URL they wish to navigate to (e.g., www.amazon.com) they are often lazy and simply type the keyword into their browser's navigation bar and thus perform a Google search for the relevant weblink (Newman 2010).

These time courses of internet searches for different online stores plotted in Figure 2 exhibit revealing trends in shifts in consumer preferences from the start of national lockdowns in mid-March through the duration of the pandemic across the remainder of 2020. Walmart exhibits two very sharp spikes in the last week of November (100% increase over Q2-Q3 2019 mean) and the last week of December (80% increase), taken to be due to the promotional efforts of 'Black Friday' and post-Christmas sales, respectively. Walmart also shows a steep 40-50% rise in searches at the beginning of the pandemic (week commencing 15th March 2020), but this increase is not sustained and the number of searches declines steadily over the following seven months to its pre-pandemic levels. Ikea shows a roughly 25% dip at the start of the lockdown, before exhibiting a slow climb to a 30-40% increase by mid-May, presumably as consumers confined at home begin thinking about furniture. eBay also experiences a dip in website searches at the start of the pandemic but then exhibits only a very weak pandemic increase in traffic (no more than 15% above the Q2-Q3 2019 mean) which readily declines back to pre-pandemic levels, if not even further suppressed. Indeed, viewing the longer history of Google search volume (plot not shown here), eBay has been steadily declining for the past five years.

Amazon and Etsy both show a ~60% spike in searches at the beginning of December, accounted for by the transient increase in present-buying for Christmas. Etsy initially exhibits a sharp 25% dip in searches mid-March, at the beginning of national pandemic lockdowns. Within a month, however, this is followed by a substantial jump in traffic which maintains at a plateau of between 60% and 90% increased searches during the pandemic. Shopify also experiences a substantial surge in searches from the onset of the pandemic, but this has declined again by Q3. Amazon shows no such dip in web traffic at the start of the pandemic but does not show as great an increase as Etsy; searches for Amazon remain around 15-45% elevated. While more detailed survey results are required to understand exactly why consumers behaved this way, we postulate that during the early days of the pandemic people's consumption was motivated by panic and subsistence, not by values. This would encourage consumption through channels that are reliable and inexpensive – such as Amazon. However, the shift toward value-oriented consumption would begin after people became more comfortable with the global situation. This would lead consumers toward places such as Etsy. The increase in Shopify signifies small-business adaptation to online purchasing trends. Other movements have self-organised to help customers buy locally or support smaller, independent vendors during the pandemic lockdowns rather than dominant online delivery platforms such as Amazon. For example, in the UK Bookshop.org started in November 2020 to connect customers with independent booksellers (Grant 2020) and in Canada the Not-Amazon.ca website is hoping to shift online shopping habits to local businesses (Fraser 2020).

These Google Trends datasets of search-term volumes provide an invaluable insight into the changing patterns of consumer behaviour over the course of the developing pandemic. The data have a fine temporal resolution (weekly) for elucidating changing trends, but it is not necessarily the case that more internet searches translate to an increase in actual purchases or transactions on these e-commerce sites. It is therefore necessary to also

consider the quarterly sales figures reported by these companies – only available at a much lower temporal resolution (every three months) but a true reflection of the genuine purchasing behaviour during the pandemic. The Salesforce Shopping Index found that revenue generated by online shopping increased by 71% in Q2 2020, compared to the previous year; the greatest increase recorded since the Shopping Index began in 2013 (Garf 2020). Much of this rise is clearly explained by the pandemic closing bricks-and-mortar stores and consumers sheltering at home having no option other than online shopping, but has the pandemic also driven a shift in the pattern of e-commerce: have C2C / P2P marketplaces benefited disproportionately compared to the established B2C platforms?

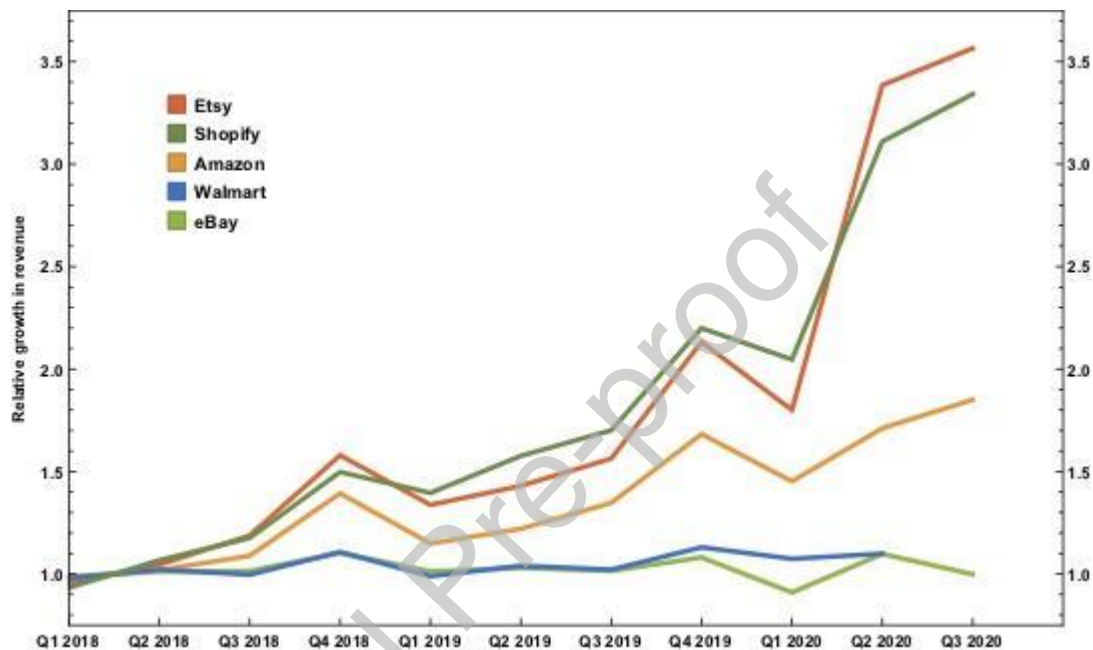


Figure 3. Net revenue or sales figures reported in quarterly returns filed in USA by selected e-commerce platforms, normalised to their mean over Q1-Q2 2018 so as to show relative growth over this time.

Figure 3 shows the net revenue or sales figures reported by Walmart, eBay, Amazon, Etsy and Shopify in their US quarterly returns. These financial income data have been normalised to the mean for the first two quarters of 2018 so that the relative growth over time can be compared irrespective of the absolute size of these different businesses.

All five companies shown here can be seen to exhibit a bump in sales in Q4 of each year with the Christmas commercialism. Neither eBay nor Walmart have undergone any significant growth in revenue since the beginning of 2018, whereas Amazon has experienced consistent growth of around 50% over the displayed two-year period leading up to the start of 2020. The biggest winners of 2020, however, have been Etsy and Shopify, with a substantial surge in revenue reported over the second and third quarters of 2020 during the coronavirus pandemic.

Shopify witnessed a 62% increase in new stores being opened on its platform between 13th March and 24th April, compared to the prior six weeks (“Shopify Announces First-Quarter 2020

Financial Results” 2020), and the overall Gross Merchandise Value (GMV) increased 119% in Q2 2020 compared to the previous year. Significantly, Shopify also recorded an increase in the number of customers shopping locally - choosing to purchase from a Shopify-hosted business located within 25 km, and the GMV from 'buy online, pickup in store' in English-speaking territories more than doubled in Q2 2020 compared to the previous quarter before pandemic lockdowns [<https://news.shopify.com/shopify-announces-second-quarter-2020-financial-results>].

Etsy reports that during the second quarter the marketplace saw an influx of 18.7 million new buyers and reactivated buyers (those who haven't purchased in a year or more) (“Etsy, Inc. Reports Second Quarter 2020 Financial Results” 2020). The major driver for this rapid expansion was that the P2P production model employed by Etsy was able to dynamically respond to the sudden increase in demand for non-medical-grade face masks triggered by the pandemic.

The US government announced guidelines on 3rd April 2020 that facemasks should be worn when out of the home, and later that same day Etsy sent a notification to all of its US-based craftspeople to prioritise manufacturing homemade masks (VanderMey 2020). Within a few weeks of this rallying-cry, 20,000 sellers on Etsy were offering homemade, non-medical grade masks, and by September 2020 the number had grown to 120,000. Over the second quarter of 2020 (April-June; during the first wave of the pandemic) 14% of Etsy's Gross Merchandise Sales (GMS; the dollar value of items sold in its online marketplaces) was from masks. Even excluding these mask sales, Etsy's second-quarter GMS had grown by 93% - an increase of \$1.0 billion - from the previous year (“Etsy, Inc. Reports Second Quarter 2020 Financial Results” 2020). Thus, once on the Etsy platform consumers browsed the full range of crafts available and bought items other than home-crafted masks - the pandemic had driven a surge in P2P in general.

The trend is clear. Many online shops have witnessed a boom in business during the pandemic, which is not surprising given that during the national lockdowns their bricks-and-mortar competitors on the high street or in shopping malls around the world experienced significant periods of closure. However, against this general backdrop favouring online shopping, P2P marketplaces like Etsy and Shopify that focus on artisanal or homemade wares experienced a proportionally much larger surge. As shown in Figure 2, e-commerce sites like Amazon, eBay and Walmart all experienced rises of up to 50%, but these declined again over the following months. Crucially, the increases experienced by Etsy and Shopify were not only of much greater magnitude – almost doubling the Q2-Q3 2019 mean – but have also been sustained throughout the 8 months of the pandemic in 2020. Thus, during the pandemic the general public were not only interested in finding out how to make things themselves, but they were also preferentially seeking-out homemade or artisanal products rather than mass-produced items.

Consumer research conducted by Accenture consultancy indicates that the shifts in habits formed during the coronavirus crisis will continue long afterwards. This includes a rise in home cooking and baking, as well as DIY activities, but also a shift in how we consume (as we have demonstrated in Figures 1 to 3). 56% of consumers said they are buying more locally sourced products, and 84% of those affirm they plan to continue to do so long-term.

In addition, 61% of consumers claim they are now making more environmentally friendly, sustainable, or ethical purchases, with 89% likely to continue after the pandemic (Standish 2020; Vujanic and Burns 2020). These results echo those of Schmidt et al. (2020), who found that from the early stages of the pandemic consumers in the US showed a growing interest in sourcing food locally and directly from farmers.

4.1.3 Response of the 3D printer community

The COVID-19 pandemic strained the capacity of vital hospital equipment for intensive care such as ventilators, and also highlighted the frailty of established supply chains for clinical PPE (personal protection equipment) including surgical masks, N95 respirator masks, transparent face shields, sterile gowns and gloves. There was much media attention in the early stages of the development of the pandemic on how non-traditional manufacturing processes, namely 3D printing, were being exploited to fill the supply gaps. Indeed, the surge of interest in 3D printing in the week of 29th March 2020 is conspicuous in the internet search data presented in Figure 1. 3D printing has the advantage of being very versatile and requires only minimum set-up time to begin manufacturing new products (compared to, for example, creating a suitable injection mould for traditional plastic production). Even despite severe disruptions to the traditional supply chains, items could be manufactured on-demand by this decentralised capacity.

This loose community, from individual hobbyists to medium-sized 3D printer factories, was able to swiftly mobilise to begin supplying items to their own local hospitals or others in need, and online communities of volunteers emerged to share opensource CAD (computer-aided design) files and 3D-printing file formats on online databanks, and worked collaboratively to re-iteratively improve designs. Overall, a broad diversity of 3D-printed equipment was designed and produced in response to the pandemic: PPE including face shields, respirators and mask adjusters; intensive care equipment such as ventilator valves; testing consumables like nasopharyngeal swabs; as well as personal tools such as door-opening and button-pushing devices (Choong et al. 2020; Singh, Prakash, and Ramakrishna 2020). 3D printing had started out as a novelty with some usage in healthcare sectors such as 3D printed limbs, trachea splints, and brain models for surgical simulation (Oladapo et al. 2021). But this community action during the COVID-19 pandemic, responding to deficiencies in PPE and other vital equipment that were not met by mainstream supply chains, represents one of the first widespread non-trivial usages of the technology and social infrastructures associated with it.

Despite these best intentions, however, it is unclear how great an impact these donated 3D-printed items actually had in providing viable substitutes for the needed clinical equipment and meaningfully supporting front-line health practitioners. Hospital supplies must satisfy stringent clinical specifications regarding safety and efficacy, and many of the donated 3D-printed items were poorly-designed or of inadequate quality (for example employing parts that weren't air-tight or were badly fitting), and hospitals had no way of verifying if they had been produced under the necessary sterile conditions. Other issues included well-meaning but misconceived efforts to manufacture individual components rather than the assembly of

complete products. For example, headbands for face shields were created, but the transparent visor and elastic still had to be sourced through conventional supply channels. Many hospitals were unable to actually use donated items and they were disposed of (Hilkene 2020). Published evaluations and cross-comparisons of 3D printed PPE have assessed the designs on protective safety and comfort, as well as practicality concerns such as print-time and scalability and found many to be clinically unsuitable or inefficient for production in higher numbers (including, for example, (Wesemann et al. 2020; Tarfaoui et al. 2020)).

One specific limiting factor in healthcare capacity to treat the surge of hospitalised COVID-19 patients was the severe shortage of ventilator machines. For patients requiring sub-intensive care, continuous positive airways pressure (CPAP) machines were used instead but compatible breathing masks were also a limited resource. In response, an Italian engineering company, Isinnova, developed a 3D-printable part they called the 'Charlotte valve' (isinnova n.d.) that enables CPAP machines to be connected to an inexpensive leisure item, the 'Easybreath' full-face snorkelling mask sold by the multinational sporting goods retailer Decathlon (Choong et al. 2020). However, laboratory-based tests (using healthy volunteers) of this improvised solution found it to provide a viable emergency substitute in only limited contexts. The percentage of inspired oxygen was consistently lower, and the level of carbon dioxide accumulation was higher, with the adapted snorkel mask compared to a standard CPAP mask (Landry et al. 2020; Noto et al. 2020). Furthermore, the use of higher delivery pressures resulted in excessive leakage from the forehead seal, which would present a risk of spreading aerosolised virus from an infected patient (Landry et al. 2020).

In order to attempt to coordinate the response between the 3D-printer community and medical practitioners and help drive the improvement and of designs for consistent quality and safety ("COVID-19 Response | NIH 3D Print Exchange" n.d.) a broad US interagency collaboration was established on 25th March 2020 (FDA Commissioner 2020) between the National Institutes of Health (NIH), National Institute for Additive Manufacturing Innovation (NIAID), Food and Drug Administration (FDA), Veterans Healthcare Administration (VA), National Center for Defense Manufacturing and Machining (NCDMM) and America Makes (Hilkene 2020). This partnership clinically-reviewed and passed 31 community-submitted designs in the first three months, and by mid-November 2020 had matched more than 500,000 3D-printed face shields and 348,000 3D-printed face masks with health care providers and others in need (FDA Commissioner 2020).

While 3D printing is well-suited for reiterative prototyping or home production of one-off items, it is exceedingly slow (taking several hours to produce a single face mask, for example) and expensive for large-scale production. To what extent did this grassroots, altruistic effort from the 3D-printing community genuinely make a significant contribution to producing critical items during the lag-time of the traditional mass-manufacture and transport chains? This can only be fully assessed retrospectively, and the US Food and Drug Administration (FDA) and America Makes organisation have launched a study to assess the impact of non-traditional manufacturing such as 3D printing on the response of the public health system during the pandemic (FDA Commissioner 2020). Nonetheless, the COVID-19 pandemic brought a lot of public attention to 3D printing (as demonstrated, for example, by the plot in Figure 1).

Despite limitations, 3D printing as a response to the COVID-19 pandemic demonstrated that it is useful beyond trinkets and novelty. This was the first time that the general public, governments, and corporations saw a large-scale benefit of 3D printing as a tool for resilient communities through rapid response to crises. This additive manufacturing process is a highly versatile, distributed, fabrication technique and the upwelling of decentralised design and production in support of the beleaguered health services revealed admirable ingenuity, resourcefulness, and community spirit during the time of acute adversity. This example explored here therefore underscores the ability of such collaborative and open-source community action to respond rapidly but, as we have argued, the full effectiveness of such well-meaning grass-roots efforts can only be harnessed with a degree of top-down coordination, expert vetting of designs, and regulation. An interagency collaboration for such management did emerge in the US within the specific context of the COVID-19 pandemic, but if distributed 3D printing is to become a significant part of the future of sustainable production and peer-to-peer consumption such coordination infrastructure will need to become stably established.

We have so far explored the shifts in public interest and consumer behaviour during the pandemic, as well as discussed two specific case examples of the Etsy homemade facemasks and the response of the 3D printer community. We still need to ask what will happen after the coronavirus pandemic recedes? It is likely shoppers will continue to favour online platforms (Standish 2020), but will the pandemic also have affected a long-term shift towards preferring C2C, P2P and locally produced goods? In the following section we argue that even if these trends are not significant enough for widespread change, it is likely to have lasting impact through increased capacity to a prefigurative degrowth economy. We have demonstrated that there was indeed a small shock, and next we address how this small shock fits into to a larger, compelling, and more comprehensive long-term and large-scale transition toward degrowth economics.

4.2 How shocks help to prefigure long-term systemic change toward P2P and degrowth economies

The COVID-19 pandemic exposed further need to reorient economies from growth demands to human welfare and wellbeing, as argued by ecological and degrowth economic scholars. While visions of a degrowth society seem far off, more scholars are turning their attention to the role of prefigurative politics for strengthening the possibility of change (Jeffrey and Dyson 2020; Yates 2020; Kish 2019).

Prefigurative politics are living representations of ideological positions (Leach 2013). While groups of prefigurative actors may not immediately impact mainstream systems, they live within it according to their own ideals with hope of broader influence. This is a political lifestyle practice of social movements (Boggs 1977). These prefigurative groups then sit as pockets of opportunity for the future that may eventually find moments to become more mainstream as systems tend to follow certain pathways of change (Allen et al. 2014; Gunderson and Holling 2001). When opportunities through disruption, such as COVID-19, arise, there is a greater chance to influence the mainstream system (Westley, Zimmerman,

and Patton 2007). The stronger the prefigurative politic is, the more likely it will prevail. At the very least, it is likely to garner additional support.

This suggests two things: firstly, that local policy to enhance alternative systems that embody the values of socio-ecological transitions are a strong way to institute change and that secondly, such radical small-scale change communities should network together to strengthen response to opportunities. This allows for both incremental change and paradigmatic shifts. Incremental in the sense that capacity is built as cracks continue to emerge and at the same time capitalist systems continue to implement austerity measures etc. to maintain their systemic stronghold. With every disturbance, such as COVID-19, the movements improved their capacity and strengthen themselves as an alternative for the next crack (Gunderson and Holling 2001; Kingdon 1984). Eventually, the crack will be big enough that the system can have a larger scale flip – this is similar to theories put forward by Holloway in *Crack Capitalism* (Holloway 2010). From this view, prefigurative politics become extremely important. While system change is nonlinear and often associated with “black swan” events (Taleb 2007), prefiguration is design oriented. Thus, it is the role of ecological economists, degrowth economists, and sustainability activists to institute and live policy that helps support good prefigurative options – particularly ones that help link localized pockets of opportunity together, such as P2P production and consumption networks that seem to help bolster needs for consumers and producers in an event of economic contraction.

The roots of P2P DIY are in pre-industrial cultures when virtually all production was localized, what Fox describes as the first wave of DIY culture (2014). This first wave was agrarian, with limited alienation, and mainly conducted through homemade or simple tools. Transactions were limited to immediate community, with little to no surplus production as goods were made as needed, and the process was highly inefficient. The village blacksmith, thatcher, potters, etc all responded to the needs of the community, producing only what was required. This subsistence DIY was marked by people growing and making what they required to eat and use. This included geographically-limited trade as canals and railways were not yet invented and transport over land was prohibitively expensive – both in time and cost.

During the industrial revolution, production dramatically changed from man-made artisanal goods to machine produced goods. Innovations in machinery for more efficient and reliable production took over and those who may have previously worked to directly produce items became but one link in much longer production chains. This massive shift toward factory-produced goods and factory jobs fundamentally reoriented the way things are produced and how people consume. With more efficient and rapid production lines, people began to consume far more than they previously had. However, some criticised both the impact this had on the quality of products and the social changes associated with the division of labour and alienation from production (Giddens 1990; 1973; Durkheim 1893; Morris 1880; Ruskin 1854). These criticisms saw a revival of the DIY movement with shared workspaces, craftsman homes such as the Tudors of the Lake District, and eventual expansion into the United States where second wave DIY eventually caught on. Second wave DIY is characteristic of predetermined products and pre-cut goods accompanied by instructional booklets for self-assembly. Ikea (see Fig. 1) quite successfully latched onto this culture, combining the efficiency of the industrial production with the feel-good desire for DIY production.

Third wave, or informational DIY, characteristic of the 4IR, operationalizes the network capacity of the internet to distributed designs and empowers individuals to “invent, design, make, and/or sell goods that they think of themselves” (Fox 2014) rather than through prescribed designs. Fox argues that Informational DIY is revolutionary in its shift to presumption through enhanced individual innovation, and entrepreneurship. While knowledge is transferred through common pool knowledge banks, there is still a disconnection between most producers and distributed production nodes worldwide. Fox’s definition of the third wave continues to prioritize production efficiency, innovation for the sake of innovation, and is embedded in traditional neoclassical market economies. The wave he describes is highly reliant on technological systems while putting little effort into local nodes of independent production. Fox indicates the use of micro mobile factories within this wave, but this kind of production, disassociated from community and place, is antithetical to degrowth economics. It would make sense for highly specialized equipment to be mobile, but production embedded in place used and shared by a consistent community is vital for promoting democratic and just production systems. Fox’s third wave has many characteristics that are incompatible with degrowth economics, including increased efficiency, improved specialist knowledge, and production according to evaluation of opportunity cost and desire for recognition in production.

The trends observed during the COVID-19 pandemic, and the unpredictable nature of the future, suggest a need for production systems that combine socially resilient and technologically innovative production schemes. We suggest that these trends demonstrate initial movement toward a new kind of DIY, which we call the fourth wave of “resilient degrowth DIY” that continues to take advantage of technological innovations and P2P networks of the third wave while living within degrowth principles of sufficiency, sustainability, and necessity rather than efficiency and desire, characteristic of the first wave (see Table 1). Within such a wave, we would expect to see reduced efficiency in favour of artisanal products, heightened generalist knowledge as people try to add skills to their own repertoire, and production based on real community demands rather than market demands. We can also imagine that continued growth of online networking would help connect production nodes to locate recycled or locally sourced materials for production that do not rely on long supply chains. The pandemic provided a glimpse of the intersection of P2P production and low-growth economics – the network of producers were able to quickly adapt through diverse and decentralized networks – key characteristics of resilient systems (Stockholm Resilience Center 2015). Observable growth within this fourth wave DIY, as witnessed during the COVID-19 pandemic, may signal a shift towards producer and consumer behaviour that is more resilient and sustainable.

Table 1: *Characterization of Waves of DIY derived from Fox 2014. We expand on this and include a new fourth wave of DIY production that is compatible with and advances degrowth economics*

	First Wave	Second Wave	Third Wave	Fourth Wave

Summary	Agrarian and pre-industrial	Factory industrial production	Informational and technological	Resilience and degrowth
Resources	Handmade tools and natural materials	Provided factory made materials with premade design	Digital equipment and tailored material to improve efficiency	More traditional methods paired with digital equipment and local materials
Specialization	Lack specialized tools and materials; highly diverse in abilities	Proprietary specialized knowledge & design	Common pool specialized knowledge collected online; still identify with one form	Shared knowledge with generalized abilities; sharing of work where abilities lack
Alienation	Limited alienation between others and work	Highly alienated	Less alienation in work; some alienation from others	Integrated production with life & community – limited alienation
Transactions	Very few, if any, market purchases	Firmly placed within neoliberal market transactions	Mostly placed within mainstream market transactions, some non and alternative market transactions	Many non-market transactions; alternative markets (local currencies)
Efficiency	Highly inefficient, with need to improve for quality of life	Highly efficient – all efforts to improve efficiency	Digitally enhanced efficiency; less efficient overall	As efficient as necessary for improved livelihood, but no more
Technological Reliance	None, except personally designed tools	Highly reliance on industrial technologies, factories	Highly reliant on technological equipment and networks	Highly reliant on shared local tools and less so on online networks
Innovation	Limited introduction of new goods or services; no need	Innovative for economic growth	Innovative for economic growth and personal curiosity	Democratic innovation through social provisioning
Surplus Production	None, all consumed	A lot of surplus production with significant waste	Less surplus production given smaller market reach	Production amount decided based on need

Collaboration	Small, isolated groups	Brand holders and consumers – no collaboration beyond market forces	Highly collaborative in localized areas	Highly collaborative in both local and global networks

Ecological and degrowth economics are not only concerned with a positive relationship between the economy and the environment. The wellbeing of individuals is also a central theme, particularly as it relates to measurements of success in society (J. C. J. M. van den Bergh 2009; V. D. Bergh and M 2007; Bleys 2012; Costanza et al. 2014). The fourth wave allows individuals to remain embedded in community while also providing significant mental health benefits, and thus higher quality of life. Modern mainstream production tendencies contributed to alienation, dissatisfaction, and narcissistic consumption associated with individualization (Brownhill, Turner, and Kaara 2012; Beck and Beck-Gernsheim 2002; Elias 2001; Ollman 1977). Artisanal production helps to combat these social ailments. Small scale and hands-on production is good for mental health across all age ranges (Lee and Worsley 2019; Dholakia 2018; Sun et al. 2015). Making products reassociates and de-alienates individuals with their work as the producer and others in their community as consumers. In contrast to embedded economies, modern market economies emerging from the industrial revolution are built on secondary forms of relationships. People buy and sell goods and products without any conception of who is on the other side. P2P production helps to reestablish a more personalized relationship of trade by promoting a more transparent relationship with the way goods are produced, where they are produced, and who is producing them. This new mode of production also disrupts innovation cycles meant to support consistent conspicuous consumption. Second and third wave innovation is based on market research, growth incentivization, and rapid competitive prototyping technologies. The fourth wave innovates based on the needs of the community and enhances opportunity for democratic innovation through social provisioning as groups decide as a community what is worth innovative capacity.

The P2P community also inherently values openness, collaboration, and co-production (Richterich 2020), key characteristics of a long-term sustainable institutions (Akbulut and Adaman 2020). While neoclassical capitalism thrives on intellectual property rights, fourth wave DIY requires open source knowledge and common spaces. Not only does this open everything up for broader creative innovation, but it also empowers cognitive justice for those in historically marginalized areas. Open source and P2P production is very similar to the popular paradigm of collaborative consumption which uses similar telematic infrastructures to facilitate a re-emergence of service systems, redistributed markets, and collaborative lifestyles (Botsman and Rogers 2010). This allows for broad and open access to services, knowledge, and networks that begin to deeply challenge conspicuous consumption and the value of personalized ownership toward collective ownership. This kind of movement thrives

on the expectation of community opportunities for reciprocity and gifting – which enhances human wellbeing and community orientation (Botsman and Rogers 2010). It also reduces the throughput of consumer goods, local material use, shorter supply chains, and promotes repairability and recycling (Kish, Hawreliak, and Quilley 2016). The P2P nature of open commons and collaborative consumption becomes reinforcing as the former facilitates access to knowledge through networked systems that empower and improve the latter – strengthening participation in the overall network.

We have argued that the consumption and production changes seen during the coronavirus pandemic have at least strengthened the prefigurative politics of P2P. Whether this growth is sustained is still to be seen. However, the prefigurative movement of fourth wave DIY was boosted through increased consumption of P2P products and further popularization of legitimate uses of 3D printers to respond to unknown crises. For such decentralised 3D-printing efforts to realise their full potential in the future, some degree of organisational infrastructure for top-down coordination and quality control is clearly still required. The theoretical contribution of framing a new fourth wave of DIY is significant for degrowth and ecological economic scholarship, particularly in green community development. De/low-growth scholars should attempt to bolster P2P and localized production strategies to establish a more sustainable pattern of production that is also more resilient for future challenges.

5. Conclusions

The COVID-19 pandemic simultaneously triggered a sudden, substantial increase in demand for items such as personal protection equipment and hospital ventilators whilst also disrupting the means of mass-production and international transport in established supply chains. We have surveyed the observed changes in behaviour in different communities of both consumers and peer-to-peer producers in response to the disruption during this crisis.

The data we present show a leap in public interest in home-making and small-scale independent production during the first wave of national lockdowns from mid-March 2020. Clear shifts were also seen in consumer behaviour, with a substantial and sustained relative increase in purchases made through C2C and P2P e-commerce platforms like Etsy and Shopify rather than established online vendors such as Amazon or Walmart. In particular, the P2P producers on Etsy were able to dynamically respond to meet the surge in demand for face masks triggered by the pandemic, and this drove a general increase in other homemade produce too. Thus, during the pandemic the general public were not only interested in finding out how to make things themselves, but they were also preferentially seeking-out homemade or artisanal products rather than mass-produced items. The 3D-printer community also responded rapidly to the severe disruptions to traditional supply chains and mobilised its decentralised manufacturing capability: collaborating on open-source designs for PPE including face shields and critical care equipment such as ventilator parts. Although it is as yet unclear how much of these 3D-printed items were clinically appropriate and so actually utilised, this exemplar has nonetheless been greatly significant in demonstrating to the general public and governments the great potential of 3D printing for creating community resilience and delivering a rapid response to crises. The formation of

the broad US interagency collaboration for providing expert-review and validation of open-source designs highlights the need of community coordination and guidance in order to maximise the efficacy of this distributed manufacturing capability.

Many of these behavioural patterns witnessed in both consumers and P2P producers during the pandemic are the kinds of prefigurative changes called for within degrowth economics. Historically, economic disruptions of the nature seen during the coronavirus global crisis allow novel technological innovation waves as the 'new economy' is driven by investment into undeveloped technologies that show potential. We have argued that these pandemic-driven shifts towards more value-oriented and peer-to-peer based production and consumption represent a new "fourth wave" of DIY. This fourth wave emerges out of the third wave of informational DIY that takes advantage of technological infrastructures to diversify and make DIY more efficient. The proposed new fourth wave continues to take advantage of advanced technological services and capabilities while focusing on the extended social and ecological benefits. Fourth wave DIY is more ecologically sound with shorter production chains, encompassing needs-based innovation, enhanced self-esteem, and limited production – production based on sales, rather than market expectations. The fourth wave is socially characterized by enhanced resilience through polycentric governance, distributed diversity, and improved social wellbeing of embedded livelihood. This kind of production is a piece of the larger degrowth transition puzzle. Thus far, no clear and coherent theory of degrowth production exists – what we present here represents a socio-ecological theory of production for transition into degrowth economies. This fourth wave presents a new means of production that values goods based on social value rather than cost efficiency.

The COVID-19 crisis was enough to, at least temporarily and perhaps permanently, shift some consumption behaviour to P2P and locally produced items. We can expect some of these observed shifts to last beyond the pandemic suggesting that while the COVID-19 pandemic itself has not pushed society across a threshold into a degrowth society, it has added capacity, experience, and public popularity to some elements of such a shift. The observable trends we explored suggest that the P2P networks associated with DIY, home manufacturing and 3D printing helped communities rapidly respond during a period of great uncertainty and provided alternative and value driven alternatives for consumers.

While a prefigurative politic of degrowth is difficult to empirically measure, these observations suggest that a form of production aligned with the ethics of degrowth received increased attention that contributes towards and grows a long-term prefigurative politic of a more social and ecologically driven mode of production. Thus, resources and practices that would help bolster P2P production and support a transition to greater sustainability would include: investment in shared makerspaces, tool libraries, 3D printers at libraries or other community spaces, repair cafes and legislation for 'right to repair', community currencies (such as the Brixton Pound) to encourage purchase of local goods, grants or funds to alleviate the precarious nature of artisan work, and decentralized renewable energy to power local production.

This study has provided a first analysis of the effects of the 2020 coronavirus pandemic on consumer behaviour and the response of the P2P manufacturing and 3D printing communities, within the context of potentially prefiguring a longer-term shift towards more

sustainable pathways of production and consumption. It would be most valuable to analyse the situation again from the perspective of a few years after the pandemic to assess how sustained these trends have been, in particular within the proposed fourth wave of DIY, and thus greatly improve our understanding of both producer and consumer behaviour during disruption to traditional production and distribution systems or economic contraction.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Works Cited

- Akbulut, Bengi, and Fikret Adaman. 2020. "The Ecological Economics of Economic Democracy." *Ecological Economics* 176 (October): 106750. <https://doi.org/10.1016/j.ecolecon.2020.106750>.
- Allen, Craig R., David G. Angeler, Ahjond S. Garmestani, Lance H. Gunderson, and C. S. Holling. 2014. "Panarchy: Theory and Application." *Ecosystems* 17 (4): 578–89. <https://doi.org/10.1007/s10021-013-9744-2>.
- Arndt, Jamie, Sheldon Solomon, Tim Kasser, and Kennon M. Sheldon. 2004. "The Urge to Splurge: A Terror Management Account of Materialism and Consumer Behavior." *Journal of Consumer Psychology* 14 (3): 198–212. https://doi.org/10.1207/s15327663jcp1403_2.
- Arora, Nidhi, Tamara Charm, Anne Grimmelt, Mianne Ortega, Kelsey Robinson, Christina Sexauer, Yvonne Staack, Scott Whitehead, and Naomi Yamakawa. 2020. "A Global View of How Consumer Behavior Is Changing amid COVID-19." McKinsey and Company. <https://www.mckinsey.de/~media/McKinsey/Business%20Functions/Marketing%20and%20Sales/Our%20Insights/A%20global%20view%20of%20how%20consumer%20behavior%20is%20changing%20amid%20COVID%2019/20200707/covid-19-global-consumer-sentiment-20200707.pdf>.
- Bauwens, Michel. 2005. "The Political Economy of Peer Production." ResearchGate. 2005. https://www.researchgate.net/publication/237720052_The_Political_Economy_of_Peer_Production.
- Beck, Ulrich, and Elisabeth Beck-Gernsheim. 2002. *Individualization: Institutionalized Individualism and Its Social and Political Consequences*. 1 edition. London ; Thousand Oaks, Calif: SAGE Publications Ltd.
- Bednar, S., and V. Modrak. 2014. "Mass Customization and Its Impact on Assembly Process' Complexity." *International Journal for Quality Research* 8 (3): 417–30.
- Bergh, Jeroen C. J. M. van den. 2009. "The GDP Paradox." *Journal of Economic Psychology* 30 (2): 117–35. <https://doi.org/10.1016/j.joep.2008.12.001>.
- Bergh, Van Den, and Jeroen C. J. M. 2007. "Abolishing GDP." SSRN Scholarly Paper ID 962343. Rochester, NY: Social Science Research Network. <https://doi.org/10.2139/ssrn.962343>.
- Betti, Francisco Betti, Enno de Boer, and Yves Giraud. 2020. "The Fourth Industrial Revolution and Manufacturing's Great Reset | McKinsey." McKinsey and Company. <https://www.mckinsey.com/business-functions/operations/our-insights/the-fourth-industrial-revolution-and-manufacturings-great-reset#>.
- Billio, Monica, and Simone Varotto. 2020. "A New World Post COVID-19: Lessons for Business, the Finance Industry and Policy Makers." SSRN Scholarly Paper ID 3665230. Rochester, NY: Social Science Research Network. <https://doi.org/10.2139/ssrn.3665230>.
- Bleys, Brent. 2012. "Beyond GDP: Classifying Alternative Measures for Progress." *Social Indicators Research* 109 (3): 355–76. <https://doi.org/10.1007/s11205-011-9906-6>.

- Boggs, C. 1977. "Radical America." *Radical America* 11 (6): 99–122.
- Boons, Frank, Alison Browne, Martin Burgess, and Ulrike Ehgartner. 2020. "Covid-19, Changing Social Practices and the Transition to Sustainable Consumption and Production." Technical Report 1.0. Food That Matters. University of Manchester. <https://doi.org/10.13140/RG.2.2.18506.59840>.
- Botsman, Rachel, and Roo Rogers. 2010. *What's Mine Is Yours: The Rise of Collaborative Consumption*. HarperBusiness.
- Brownhill, Leigh, Terisa E. Turner, and Wahu Kaara. 2012. "Degrowth? How About Some 'De-Alienation'?" *Capitalism Nature Socialism* 23 (1): 93–104. <https://doi.org/10.1080/10455752.2011.648844>.
- Cambefort, Marine. 2020. "How the COVID-19 Pandemic Is Challenging Consumption." *Markets, Globalization & Development Review* 5 (1). <https://doi.org/10.23860/MGDR-2020-05-01-02>.
- Caperna, Giulio, Marco Colagrossi, Andrea Geraci, and Gianluca Mazzarella. 2020. "A Babel of Web-Searches: Googling Unemployment During the Pandemic." SSRN Scholarly Paper ID 3627754. Rochester, NY: Social Science Research Network. <https://doi.org/10.2139/ssrn.3627754>.
- Choong, Yu Ying Clarrisa, Hong Wei Tan, Deven C. Patel, Wan Ting Natalie Choong, Chun-Hsien Chen, Hong Yee Low, Ming Jen Tan, Chandrakant D. Patel, and Chee Kai Chua. 2020. "The Global Rise of 3D Printing during the COVID-19 Pandemic." *Nature Reviews Materials* 5 (9): 637–39. <https://doi.org/10.1038/s41578-020-00234-3>.
- Commissioner, Office of the. 2020. "3D Printing in FDA's Rapid Response to COVID-19." *FDA*, November. <https://www.fda.gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/3d-printing-fdas-rapid-response-covid-19>.
- Costanza, Robert. 1989. "What Is Ecological Economics?" *Ecological Economics* 1 (1): 1–7.
- Costanza, Robert, Ida Kubiszewski, Enrico Giovannini, Hunter Lovins, Jacqueline McGlade, Kate E. Pickett, K. Vala Ragnarsdóttir, Debra Roberts, Roberto De Vogli, and Richard Wilkinson. 2014. "Time to Leave GDP Behind." *Nature* 505 (7483). <http://art.torvergata.it/handle/2108/91734>.
- "COVID-19 Response | NIH 3D Print Exchange." n.d. Accessed December 7, 2020. <https://3dprint.nih.gov/collections/covid-19-response>.
- Daly, Herman E. 1992. "Allocation, Distribution, and Scale: Towards an Economics That Is Efficient, Just, and Sustainable." *Ecological Economics* 6 (3): 185–93. [https://doi.org/10.1016/0921-8009\(92\)90024-M](https://doi.org/10.1016/0921-8009(92)90024-M).
- Daly, Herman E. 1997. *Beyond Growth The Economics of Sustainable Development*. Boston : Westminster : Beacon Press ; Random House, Incorporated Distributor.
- Daly, Herman E., John B. Cobb Jr, and John B. Cobb. 1994. *For the Common Good: Redirecting the Economy Toward Community, the Environment, and a Sustainable Future*. Beacon Press.
- Dholakia, Utpal. 2018. "The Powerful Benefits of Making Your Own Products." *Psychology Today*. 2018. <https://www.psychologytoday.com/blog/the-science-behind-behavior/201806/the-powerful-benefits-making-your-own-products>.
- Durkheim, Emile. 1893. *Division of Labour in Society*. Translated by W. D. Hall. New edition edition. Basingstoke: Macmillan.
- Effenberger, Maria, Andreas Kronbichler, Jae Il Shin, Gert Mayer, Herbert Tilg, and Paul Perco. 2020. "Association of the COVID-19 Pandemic with Internet Search Volumes: A Google Trends™ Analysis." *International Journal of Infectious Diseases* 95 (June): 192–97. <https://doi.org/10.1016/j.ijid.2020.04.033>.
- Elias, Norbert. 2001. *The Society of Individuals*. Reissue edition. New York: Continuum.
- "Etsy, Inc. Reports Second Quarter 2020 Financial Results." 2020. August 5, 2020. <https://investors.etsy.com/press-releases/press-release-details/2020/Etsy-Inc.-Reports-Second-Quarter-2020-Financial-Results/default.aspx>.

- Farley, Joshua. 2010. "Ecological Economics." In *The Post Carbon Reader: Managing the 21st Century's Sustainability Crises*. Post Carbon Institute : Watershed Media. <https://community-wealth.org/sites/clone.community-wealth.org/files/downloads/paper-farley.pdf>.
- . 2017. "Capitalism and the Steady State: Uneasy Bedfellows." In *Positive Steps toward a Steady State Economy*, 182–96. New South Wales: CASSE NSW.
- Fox, Stephen. 2014. "Third Wave Do-It-Yourself (DIY): Potential for Prosumption, Innovation, and Entrepreneurship by Local Populations in Regions without Industrial Manufacturing Infrastructure." *Technology in Society* 39 (November): 18–30. <https://doi.org/10.1016/j.techsoc.2014.07.001>.
- Fraser, Ashley. 2020. "'Not Amazon' Website Seeks to Boost Local Businesses across Canada | CBC News." *CBC*, December 11, 2020. <https://www.cbc.ca/news/canada/toronto/amazon-local-businesses-1.5836283>.
- Freeman, Rachel, Chris McMahon, and Patrick Godfrey. 2017. "An Exploration of the Potential for Re-Distributed Manufacturing to Contribute to a Sustainable, Resilient City." *International Journal of Sustainable Engineering* 10 (4–5): 260–71. <https://doi.org/10.1080/19397038.2017.1318969>.
- Gale, Fred P. 2000. "Economic Specialization versus Ecological Diversification: The Trade Policy Implications of Taking the Ecosystem Approach Seriously." *Ecological Economics* 34 (3): 285–92. [https://doi.org/10.1016/S0921-8009\(00\)00181-6](https://doi.org/10.1016/S0921-8009(00)00181-6).
- Garf, Rob. 2020. "Salesforce Q2 Shopping Index: Digital Sales Up 71 Percent." *Salesforce News*. July 15, 2020. <https://www.salesforce.com/news/stories/salesforce-q2-shopping-index-digital-sales-up-71-percent/>
- Georgescu-Roegen, Nicholas. 1971. *The Entropy Law and the Economic Process*. Harvard University Press.
- . 1975. "Energy and Economic Myths." *Southern Economic Journal* 41 (3): 347. <https://doi.org/10.2307/1056148>.
- Gershenfeld, Neil. 2013. *Fab: The Coming Revolution on Your Desktop - From Personal Computers to Personal Fabrication New Edition* by Gershenfeld, Neil Published by Basic Books. New edition edition. Basic Books.
- Giddens, Anthony. 1973. *Capitalism and Modern Social Theory: An Analysis of the Writings of Marx, Durkheim and Max Weber*. Cambridge U.K.: Cambridge University Press.
- . 1990. *The Consequences of Modernity*. Stanford, Calif.: Stanford University Press.
- Gowdy, John, and Jon D. Erickson. 2005. "The Approach of Ecological Economics." *Cambridge Journal of Economics* 29: 207–22.
- Grant, Katie. 2020. "Bookshop, the New Amazon Alternative, Sells £415,000 Worth of Books in Opening Week." *Inews.Co.Uk*. November 9, 2020. <https://inews.co.uk/news/consumer/bookshop-amazon-alternative-buy-books-independent-local-shop-sales-first-week-754265>.
- Gunderson, Lance H., and C. S. Holling, eds. 2001. *Panarchy: Understanding Transformations in Human and Natural Systems*. 2 edition. Washington, DC: Island Press.
- Heylighen, Francis. 2007. "Accelerating Socio-Technological Evolution: From Ephemeralization and Stigmergy to the Global Brain," April.
- Hilkene, Cullen. 2020. "COVID-19 Has Thrust 3-D Printing Into the Spotlight." *Supply Chain Brain*. November 13, 2020. <https://www.supplychainbrain.com/blogs/1-think-tank/post/32163--d-printing-and-the-covid-19-response-then-and-now>.
- Hoerger, Michael, Sarah Alonzi, Laura M. Perry, Hallie M. Voss, Sanjana Easwar, and James I. Gerhart. 2020. "Impact of the COVID-19 Pandemic on Mental Health: Real-Time Surveillance Using Google Trends." *Psychological Trauma: Theory, Research, Practice, and Policy* 12 (6): 567–68. <https://doi.org/10.1037/tra0000872>.
- Holloway, John. 2010. *Crack Capitalism*. Pluto Press.
- Horton, Richard, Robert Beaglehole, Ruth Bonita, John Raeburn, Martin McKee, and Stig Wall. 2014. "From Public to Planetary Health: A Manifesto." *The Lancet* 383 (9920): 847. [https://doi.org/10.1016/S0140-6736\(14\)60409-8](https://doi.org/10.1016/S0140-6736(14)60409-8).

- Hu, S. Jack. 2013. "Evolving Paradigms of Manufacturing: From Mass Production to Mass Customization and Personalization." *Procedia CIRP*, Forty Sixth CIRP Conference on Manufacturing Systems 2013, 7 (January): 3–8.
<https://doi.org/10.1016/j.procir.2013.05.002>.
- isinnova. n.d. "Easy – Covid19 ENG." *Isinnova* (blog). Accessed December 7, 2020.
<https://www.isinnova.it/easy-covid19-eng/>.
- Jeffrey, Craig, and Jane Dyson. 2020. "Geographies of the Future: Prefigurative Politics." *Progress in Human Geography*, May, 0309132520926569.
<https://doi.org/10.1177/0309132520926569>.
- Kallis, Giorgos. 2011. "In Defence of Degrowth." *Ecological Economics* 70 (5): 873–80.
<https://doi.org/10.1016/j.ecolecon.2010.12.007>.
- Kano, Liena, and Chang Hoon Oh. 2020. "Global Value Chains in the Post-COVID World: Governance for Reliability." *Journal of Management Studies* n/a (n/a).
<https://doi.org/10.1111/joms.12626>.
- Kingdon, John W. 1984. *Agendas, Alternatives, and Public Policies*. Little, Brown.
- Kish, Kaitlin. 2019. "Reclaiming Freedom Through Prefigurative Politics." In *Liberty and the Ecological Crisis*, 49–64. Routledge.
- Kish, Kaitlin, Jason Hawreliak, and Stephen Quilley. 2016. "Finding an Alternate Route: Towards Open, Eco-Cyclical, and Distributed Production." *Journal of Peer Production, Alternative Internets*, , no. 9 (September).
<http://peerproduction.net/issues/issue-9-alternative-internets/peer-reviewed-papers/finding-an-alternate-route-towards-open-eco-cyclical-and-distributed-production/>.
- Kish, Kaitlin, and Stephen Quilley. 2020. "Work, Labour, and Regenerative Production." In *Sustainable Wellbeing Futures*, 27–44. Edward Elgar.
- Kostakis, Vasilis, Kostas Latoufis, Minas Liarokapis, and Michel Bauwens. 2018. "The Convergence of Digital Commons with Local Manufacturing from a Degrowth Perspective: Two Illustrative Cases." *Journal of Cleaner Production, Technology and Degrowth*, 197 (October): 1684–93. <https://doi.org/10.1016/j.jclepro.2016.09.077>.
- Landry, Shane A., Dwayne L. Mann, Lee Djumas, Ludovico Messineo, Philip I. Terrill, Luke D.J. Thomson, Caroline J. Beatty, et al. 2020. "Laboratory Performance of Oronasal CPAP and Adapted Snorkel Masks to Entrain Oxygen and CPAP." *Respirology (Carlton, Vic.)*, August. <https://doi.org/10.1111/resp.13922>.
- Leach, Darcy K. 2013. "Prefigurative Politics." In *The Wiley-Blackwell Encyclopedia of Social and Political Movements*. American Cancer Society.
<https://doi.org/10.1002/9780470674871.wbespm167>.
- Lee, Sarah Priscilla, and Marcelo Bonilla Worsley. 2019. "Designing for and Facilitating Meaningful Making with Refugee Children." In *Proceedings of FabLearn 2019*, 89–95. FL2019. New York, NY, USA: Association for Computing Machinery.
<https://doi.org/10.1145/3311890.3311902>.
- Lipson, Hod, and Melba Kurman. 2013. *Fabricated: The New World of 3D Printing*. Indianapolis, Indiana: Wiley.
- Lou, Nicole, and Katie Peek. 2016. "By The Numbers: The Rise Of The Makerspace." *Popular Science*. 2016. <https://www.popsci.com/rise-makerspace-by-numbers/>.
- Lu, Tina, and Ben Y. Reis. 2021. "Internet Search Patterns Reveal Clinical Course of COVID-19 Disease Progression and Pandemic Spread across 32 Countries." *Npj Digital Medicine* 4 (1): 1–9. <https://doi.org/10.1038/s41746-021-00396-6>.
- Mair, Simon, Angela Druckman, and Tim Jackson. 2020. "A Tale of Two Utopias: Work in a Post-Growth World." *Ecological Economics* 173 (July): 106653.
<https://doi.org/10.1016/j.ecolecon.2020.106653>.
- McGrath, Matt. 2020. "Climate Change and Coronavirus: Five Charts about the Biggest Carbon Crash." *BBC News*, May 5, 2020, sec. Science & Environment.
<https://www.bbc.com/news/science-environment-52485712>.
- Morris, William. 1880. "The Beauty of Life." Presented at the Birmingham Society of Arts and School of Design, Birmingham, London.

- Mourtzis, Dimitris, and Michael Doukas. 2014. *The Evolution of Manufacturing Systems: From Craftsmanship to the Era of Customisation*. IGI Global. <https://doi.org/10.4018/978-1-4666-5039-8.ch001>.
- Mourtzis, Dimitris, Michalis Doukas, and Foivos Psarommatis. 2012. "A Multi-Criteria Evaluation of Centralized and Decentralized Production Networks in a Highly Customer-Driven Environment." *CIRP Annals* 61 (1): 427–30. <https://doi.org/10.1016/j.cirp.2012.03.035>.
- Movsisyan, Shushan. 2020. "COVID-19 PANDEMIC PROMOTES TRADE PROTECTIONISM." *Амбард*, no. 2 (3). <https://cyberleninka.ru/article/n/covid-19-pandemic-promotes-trade-protectionism>.
- Newman AO, Peter. 2020. "COVID, CITIES and CLIMATE: Historical Precedents and Potential Transitions for the New Economy." *Urban Science* 4 (3): 32. <https://doi.org/10.3390/urbansci4030032>.
- Noto, Alberto, Claudia Crimi, Andrea Cortegiani, Massimiliano Giardina, Filippo Benedetto, Pietro Princi, Annalisa Carlucci, Lorenzo Appendini, and Cesare Gregoretti. 2020. "Performance of EasyBreath® Decathlon Snorkeling Mask for Delivering Continuous Positive Airway Pressure." *MedRxiv*, November, 2020.10.28.20221317. <https://doi.org/10.1101/2020.10.28.20221317>.
- Oladapo, Bankole I., Sikiru O. Ismail, Temitope D. Afolalu, David B. Olawade, and Mohsen Zahedi. 2021. "Review on 3D Printing: Fight against COVID-19." *Materials Chemistry and Physics* 258 (January): 123943. <https://doi.org/10.1016/j.matchemphys.2020.123943>.
- Ollman, Bertell. 1977. *Alienation: Marx's Conception of Man in Capitalist Society*. 2nd edition. Cambridge; New York: Cambridge University Press.
- Onchonga, David. 2020. "A Google Trends Study on the Interest in Self-Medication during the 2019 Novel Coronavirus (COVID-19) Disease Pandemic." *Saudi Pharmaceutical Journal: SPJ* 28 (7): 903–4. <https://doi.org/10.1016/j.jsps.2020.06.007>.
- Pan, Z., H. L. Nguyen, H. Abu-gellban, and Y. Zhang. 2020. "Google Trends Analysis of COVID-19 Pandemic." In *2020 IEEE International Conference on Big Data (Big Data)*, 3438–46. <https://doi.org/10.1109/BigData50022.2020.9377852>.
- Polanyi, Karl. 1944. *The Great Transformation: The Political and Economic Origins of Our Time*. Beacon Press.
- Rauch, Erwin, Patrick Dallasega, and Dominik T. Matt. 2016. "Sustainable Production in Emerging Markets through Distributed Manufacturing Systems (DMS)." *Journal of Cleaner Production* 135 (November): 127–38. <https://doi.org/10.1016/j.jclepro.2016.06.106>.
- Rauch, Erwin, Matthias Dallinger, Patrick Dallasega, and Dominik T. Matt. 2015. "Sustainability in Manufacturing through Distributed Manufacturing Systems (DMS)." *Procedia CIRP*, The 22nd CIRP Conference on Life Cycle Engineering, 29 (January): 544–49. <https://doi.org/10.1016/j.procir.2015.01.069>.
- Raworth, Kate. 2017. *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. Chelsea Green Publishing.
- Richterich, Annika. 2020. "When Open Source Design Is Vital: Critical Making of DIY Healthcare Equipment during the COVID-19 Pandemic." *Health Sociology Review* 29 (2): 158–67. <https://doi.org/10.1080/14461242.2020.1784772>.
- Ruskin, John. 1854. *On the Nature of Gothic Architecture: And Herein of the True Functions of the Workman in Art ...* Smith, Elder, & Company.
- Schmidt, Claudia, Stephan Goetz, Sarah Rucker, and Zheng Tian. 2020. "Google Searches Reveal Changing Consumer Food Sourcing in the COVID-19 Pandemic." *Journal of Agriculture, Food Systems, and Community Development* 9 (3): 9–16. <https://doi.org/10.5304/jafscd.2020.093.032>.
- "Shopify Announces First-Quarter 2020 Financial Results." 2020. May 6, 2020. <https://news.shopify.com/shopify-announces-first-quarter-2020-financial-results>.

- Staff, Reuters. 2020. "WHO Declares China Virus Outbreak an International Emergency." *Reuters*, January 30, 2020. <https://www.reuters.com/article/us-china-health-who-idUSKBN1ZT2SP>.
- Steffen, Will, Katherine Richardson, Johan Rockström, Sarah E. Cornell, Ingo Fetzer, Elena M. Bennett, Reinette Biggs, et al. 2015. "Planetary Boundaries: Guiding Human Development on a Changing Planet." *Science* 347 (6223). <https://doi.org/10.1126/science.1259855>.
- Steinberger, Julia. 2020. "Pandemics: A Story of Life versus Growth." *OpenDemocracy* (blog). 2020. https://www.opendemocracy.net/en/oureconomy/pandemics-story-life-versus-growth/?fbclid=IwAR29bwfi0Y4BDFeMJ9-AsVNlg5QTvSrvl_CqBp3qrR60Q3yLf-mBhyPWfcE.
- Stockholm Resilience Center. 2015. "Applying Resilience Thinking." Text. February 19, 2015. <https://www.stockholmresilience.org/research/research-news/2015-02-19-applying-resilience-thinking.html>.
- Sun, Yuling, Silvia Lindtner, Xianghua Ding, Tun Lu, and Ning Gu. 2015. "Reliving the Past & Making a Harmonious Society Today: A Study of Elderly Electronic Hackers in China." In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, 44–55. CSCW '15. New York, NY, USA: Association for Computing Machinery. <https://doi.org/10.1145/2675133.2675195>.
- Taleb, Nassim Nicholas. 2007. *The Black Swan: The Impact of the Highly Improbable*. Random House Publishing Group.
- Tarfaoui, Mostapha, Mourad Nachtane, Ibrahim Goda, Yumna Qureshi, and Hamza Benyahia. 2020. "3D Printing to Support the Shortage in Personal Protective Equipment Caused by COVID-19 Pandemic." *Materials* 13 (15): 3339. <https://doi.org/10.3390/ma13153339>.
- "Top 10 E-Commerce Sites in the US 2020." 2020. *Disfold* (blog). March 10, 2020. <https://disfold.com/top-e-commerce-sites-us/>.
- VanderMey, Anne. 2020. "Etsy Rallies Its Artisanal Troops: 'Start Making Face Masks.'" *Bloomberg.Com*, April 7, 2020. <https://www.bloomberg.com/news/articles/2020-04-07/face-masks-on-etsy-are-a-top-seller>.
- Wesemann, Christian, Stefano Pieralli, Tobias Fretwurst, Julian Nold, Katja Nelson, Rainer Schmelzeisen, Elmar Hellwig, and Benedikt Christopher Spies. 2020. "3-D Printed Protective Equipment during COVID-19 Pandemic." *Materials* 13 (8): 1997. <https://doi.org/10.3390/ma13081997>.
- Westley, Frances, Brenda Zimmerman, and Michael Patton. 2007. *Getting to Maybe: How the World Is Changed*. Reprint edition. Toronto: Vintage Canada.
- Yates, Luke. 2020. "Prefigurative Politics and Social Movement Strategy: The Roles of Prefiguration in the Reproduction, Mobilisation and Coordination of Movements." *Political Studies*, July, 0032321720936046. <https://doi.org/10.1177/0032321720936046>.
- Zitting Kirsi-Marja, Lammers-van der Holst Heidi M., Yuan Robin K., Wang Wei, Quan Stuart F., and Duffy Jeanne F. 2021. "Google Trends Reveals Increases in Internet Searches for Insomnia during the 2019 Coronavirus Disease (COVID-19) Global Pandemic." *Journal of Clinical Sleep Medicine* 17 (2): 177–84. <https://doi.org/10.5664/jcsm.8810>.