

Directed Technical Change: Work from Home Patents During Covid-19 and Beyond

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Abstract: We examine the text content of U.S. patent applications, identifying those that advance technologies in support of video conferencing, telecommuting, remote interactivity, and working from home (collectively, WFH). We find that the share of new patent applications that advance WFH technologies steadily increases after the onset of COVID-19. The share of WFH applications is up around 50% in the first year after January 2020 compared to the last pre-pandemic year, 75% in the second year, and more than double in the last 3 months of 2022. The absolute number of WFH applications similarly reached multiple new time highs greatly surpassing any pre-pandemic peaks. This evidence suggests that (re-)directed technical change in reaction to COVID-19 will raise the quality and efficiency of remote work, thereby reinforcing a shift to working from home.

JEL Nos.: O14, O32, O33

Keywords: directed technical change, patents, COVID-19, coronavirus, working from home, remote interactivity, text analysis

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COVID-19 triggered an unprecedented massive shift to working from home (WFH). In the spring of 2020, American workers supplied roughly half of paid labor services from home, compared less than 5% beforehand (Barreo, Bloom and Davis, 2022)⁵. The prevalence of WFH continued even after the end of pandemic-related restrictions. According to survey evidence in Barrero, Bloom and Davis (2022), the percent of all full work days are supplied from home stabilized at just below 30 percent at the end of 2022, which represents a sixfold increase on the 2017-18 numbers. Stock prices also reflect the shift to working from home. For example, Papanikolaou and Schmidt (2022) report daily equity returns in 2020 for firms sorted by share of employees able to work remotely. From 14 February 2020 to 15 June, the cumulative return differential between the top and bottom quartiles is 19.4 percentage points, with most of the differential emerging by mid-March. Similarly, Pagano et al. (2020) find much higher returns in the wake of COVID-19 at “resilient” firms, as measured by the ability of their employees to perform jobs at home and without interactions in physical proximity.

These observations prompt us to ask whether COVID-19 has also shifted the direction of innovation toward technologies that support video conferencing, telecommuting, remote interactivity, and working from home (collectively, WFH). The economic reasoning is simple: When remote work becomes a bigger share of all work, the incentives to advance technologies that support WFH become stronger. Likewise, Acemoglu (1998) stresses that a high proportion of skilled workers in the labor force implies a large market size for skill-complementary technologies, creating incentives for skill-biased technical change. Motivated by this type of reasoning, we

⁵ For more information see Barrero et al. (2021), Bick et al. (2020), Brynjolfsson et al. (2020), and Ozimek, 2020.

assess how forcefully the direction of technical change responds to a large, sudden, surprise shift in working arrangements.

Specifically, we use human-guided automated readings of U.S. patent applications, identifying the ones that advance WFH technologies. We start with the raw XML files of new patent applications, which are published by the United States Patent and Trademark Office (USPTO) every Thursday. These files include the patent application date (filing date), publication date, application ID, inventor name, assignee (entity that owns the patent), patent class, title, and full text of the invention description. We examine the content of the invention descriptions to identify patent applications that advance WFH technologies. Our analysis sample contains all patent applications published from 7 January 2010 through 27 December 2022, which covers filings from 1 January 2010 to 12 September 2022.. There are about 4.4 million patent applications in our dataset, 26,901 of which pertain to WFH technologies according to our classification algorithm described below.

As a first step, we construct a dictionary of terms that pertain to WFH technologies. To do so, we manually reviewed thirty articles about “working from home” “working from home technologies,” “remote work tools” and the like drawn from online encyclopedias, newspapers, tech-oriented media, and popular blog posts. Based on our review, we created our dictionary of WFH terms: *telecommuting, telework, teleworking, working from home, mobile work, remote work, flexible workplace, work from home, mobile working, remote working, work remotely, working remotely, remote workplace, telecommuter, teleworker, home-sourced worker, home-sourced employee, work-at-home, work at home, telecommuting specialist, nomadic worker, nomadic employee, work-from-home, work-from-anywhere, video conference, video conferencing, virtual office, distance work, flexible work, virtual work, virtual worker, virtual-*

office, virtual employee, home office, home-based office, home-based work, home-based worker, work from anywhere, working from anywhere, work-from-anywhere, digital workplace, video chat, video call, teleconference, teleconferencing, working from a remote location, work from a remote location, work away, hybrid work, smartworking, smart work.

Second, we execute computer-automated readings of the patent application texts that summarize the invention and describe its potential applications. If the text contains one or more terms in the dictionary above, we regard the patent application as one that advances WFH technologies. Similar results obtain when requiring the text to contain two or dictionary terms, or when the word search is limited to the abstract of the applications.

Sample titles (assignee, filing date) of patent applications selected by our WFH classification include “Method and System for Elevating a Phone Call into a Video Conferencing Session” (Zoom Video Communications, Inc., 20 March 2020), “Optimizing Video Conferencing Using Contextual Information” (Facebook, Inc., 30 April 2020), “Video Conference System, Video Conference Apparatus, and Video Conference Method” (Optoma Corporation, 5 May 2020), “Speech Recognition and Summarization” (Google LLC, 18 May 2020), “Defining Content of Interest for Video Conference Endpoints with Multiple Pieces of Content” (Cisco Technology, Inc., 2 July 2020), and “Sales Management and Video Chat System and Method for a Salesperson Mobile Device and a Remote Visitor Web Browser” (Dealer Inside, Inc., 7 July 2020). A list of these, along with details from the patent application, as well as filing and publishing information can be found in the Appendix 1.

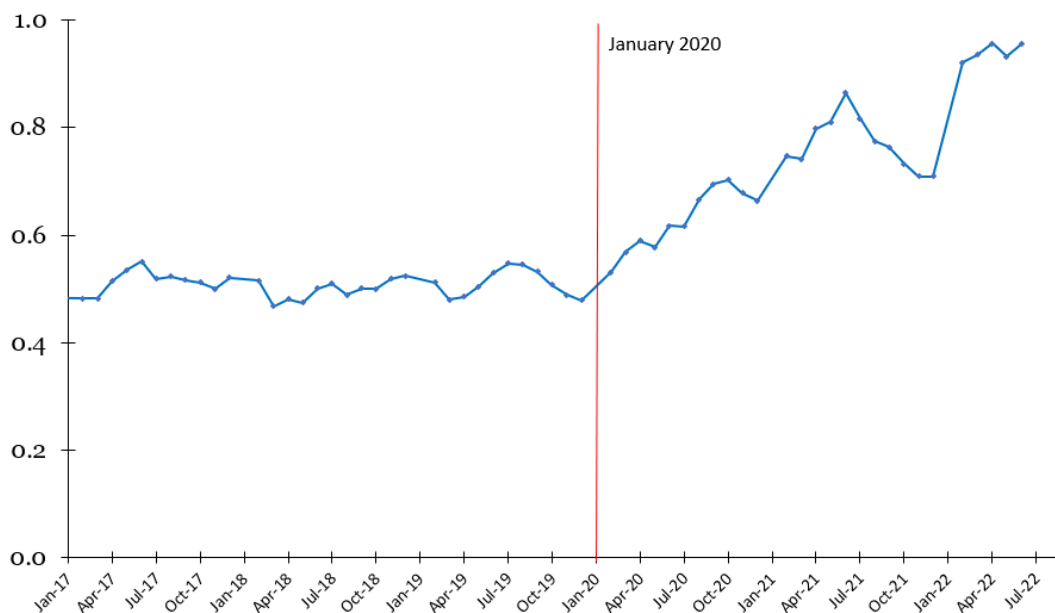
Before turning to our main results, we note there are generally long and variable lags from the filing of new patent applications until publication by the USPTO.⁶ That means our analysis sample misses a fraction of recent patent filings, and that fraction becomes larger near the end of our sample. In Appendix 2, Figure A2.1 we show the distribution of these lags for all published patent applications that were first filed from 1 January 2010 to 24 December 2018. The mean lag from filing to publication is 12.9 months for all patent applications and 11.5 months for those that support WFH technologies. The similarity of the lag structures suggests that the reported *percentage* of filings accounted for by patent applications that support WFH technologies is unlikely to be much distorted by publication lags, even near the end of our sample.⁷ Figure A2.2 shows that these gaps were not much different WFH-classified patents in 2021, and WFH-classified patents in 2019, and similar analysis shows that the same is true for non-WFH classified patents. Nonetheless, in Figure A2.3, we also show the robustness of our results using the updated adjustment mechanism first proposed in Bloom, Davis and Zhestkova (2021).

Figure 1 reports the 3 month moving-average share of newly filed patent applications that support WFH technologies at a monthly frequency from January 2010 through July 2022, the last month that has a number of filings published already at least half of those from September-January 2020. We compute this percentage as 100 times the ratio of (a) patent application filings

⁶ Once the USPTO regards a patent application filing as complete, which can itself be a lengthy process, the application is assigned for examination. The examination process can also be lengthy. The publication of approved patent applications takes about fourteen weeks. The USPTO has various programs and initiatives to assist in the patent application process, some of which involve additional fees for an expedited process. For more information, see <https://www.uspto.gov/web/offices/pac/mpep/s1120.html>, <https://www.uspto.gov/patents-getting-started/patent-process-overview#step6>, and <https://www.uspto.gov/patent/initiatives/uspto-patent-application-initiatives-timeline>.

in the last 3-months that support WFH technologies to (b) all patent application filings in the last 3-months. We prefer this moving average specification to account for any month-to-month volatility in applications. Interestingly, the raw WFH share of new patent applications rises from 0.52 percent in January 2020 to 0.61 percent in February, before the World Health Organization declared the novel coronavirus outbreak a global pandemic (Muccari et al., 2020). China reported the first death from COVID-19 in early January and imposed a lockdown in Wuhan on 23 January. By the end of January, the virus had spread to many other countries, including the United States. Figure 1 suggests that these developments had already – by February – triggered the beginnings of a shift in new patent applications toward technologies that support WFH.

Figure 1. Three-Month Moving Average of Share of New Patent Applications that Support Work-from-Home Technologies, January 2017 to July 2022



Source: Authors’ analysis of XML files of patent applications published by the USPTO from 7 January 2010 through 27 December 2022, covering filings through 31 July 2022.

Note: The chart reports the percentage of patent application *filings* through 31 July 2022 that support WFH technologies. We calculate this percentage using our automated classification of invention descriptions in patent applications *published* through 27 December 2022.

By March, COVID-19 cases and deaths had exploded in many localities and countries around the world. Government-mandated lockdowns and voluntary social distancing responses led to an extraordinary collapse in economic activity. By April and May, half of paid work in the United States was performed by persons working from home. As Figure 1 shows, the WFH percentage of new patent applications continued to rise after February. In September 2020, the raw WFH share of new patent applications reaches 0.7 percent, and the moving average series 0.68, greatly surpassing any month before the pandemic struck. Thus, we find clear evidence that COVID-19 has shifted the direction of innovation toward technologies that support WFH on the short-term.

One possibility is that the initial mainly reflects a pipeline acceleration effect, whereby firms with nearly-completed WFH innovations rush to patent them in response to the pandemic-induced shift to remote work. In that case, the WFH share might return to its pre-pandemic baseline in 2021 – or even temporarily fall below its baseline. A second view is that the first part of Figure 1 shows the beginnings of a persistent rise in the flow of new patents that advance WFH technologies. The ongoing upward trajectory in the WFH share since the pandemic struck favors this second view.

When analyzing the longer-run trend, the data seems supportive of a true increase in WFH R&D activity. After the September 2020 local maximum, the share of patents continues to increase throughout 2021 and 2022. The share of WFH applications is up around 50% in the first year after January 2020 compared to the last pre-pandemic year, 75% in the second year, and more than double in the last analyzed months of 2022.

In Figure A2.4, we plot the total number of patent applications, as well as patent applications classified as WFH. We show that these increases in the share of WFH patents are

not caused either by a decrease in other innovative activity or by a patent application selection effect, but rather the absolute number of WFH patent applications increasing. In fact, the highest number of classified WFH patents throughout the sample is found in September 2020, followed by July 2021, despite the lower number of patents applications published by the end of the data in this paper iteration (December 2022). The story therefore seems consistent to this second interpretation of the increase in WFH patent application, of a true increase in development of WFH technologies.

Under this second view, the directional shift in innovation will drive continuing improvements in WFH technologies and the tools and platforms that support WFH, unless the marginal utility of such improvements relative to the costs decreases. By improving the quality and productivity of remote work activity, a more rapid advance of WFH technologies will reinforce the shift to working from home.

Barrero, Bloom and Davis (2020) provide evidence of several other mechanisms that drive a persistent shift to working from home in the wake of the COVID-19 pandemic. These other mechanisms include better-than-expected experiences in working from home since the pandemic struck, investments in physical and human capital that enable and support working from home, a greatly diminished stigma associated with working from home, and an expressed desire by many people to avoid public transport and crowded facilities even after the pandemic ends due to lingering fears of infection risk.

Other evidence also points to strong commercial incentives to acquire existing WFH technologies in the wake of the COVID-19 pandemic. For example, Verizon announced on 16 April 2020 that it would acquire BlueJeans, a video conferencing firm, for about \$500 million (Krause, 2020). Zoom announced on 7 May that it would acquire Keybase, an identity

management firm (O’Flaherty, 2020). Adobe announced on 9 November that it would acquire Workfront, a leading work management platform for marketers, for \$1.5 billion (Bloomberg, 2020). And Salesforce announced on 1 December that it had agreed to acquire Slack, a workplace software company, for \$27.7 billion (Griffith and Hirsh, 2020).

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Pagano, Marco, Christian Wagner and Joseph Zechner, 2020. “Disaster Resilience and Asset Prices,” *COVID Economics: Vetted and Real-Time Papers*, Issue 21, 22 May.

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Appendix 1: Examples of patents classified as WFH

Application id: 16863524

Filing date: 30th Apr 2020

Publishing date: 13th Aug 2020

Assignee: Facebook Inc.

Title: Optimizing Video Conferencing Using Contextual Information

Abstract: The present disclosure is directed toward systems and methods for optimizing video conferences. For instance, systems and methods described herein optimize both the transmission and display of one or more video conference data streams. Systems and methods described herein optimize the transmission and display of one or more video conference data streams by identifying a context associated with the one or more video conference data streams and optimizing the one or more video conference data streams based on the identified context.

Application id: 16792798

Filing date: 17th Feb 2020

Publishing date: 11th Jun 2020

Assignee: VipVR LLC

Title: Systems and Methods for Scheduled Video Chat Sessions

Abstract: A computer-implemented method for facilitating a virtual meet-and-greet between a first client device, a second client device, and at least a third client device is provided. The method involves establishing a first private one-on-one video chat between the first client device and the second client device. The method also involves transmitting a request to the third client device to carry out one or more preloading operations to test the operation of one or more hardware and/or software elements of the third client device. The method further involves establishing a second private one-on-one video chat between the first client device and the third client device based at least in part on the third client device have successfully completed the preloading operations and being ready to establish a private one-on-one video chat.

Application id: 16827788

Filing date: 24th Mar 2020

Publishing date: 1st Oct 2020

Assignee: Hyperconnect Inc.

Title: Video Call Mediating Apparatus, Method and Computer Readable Recording Medium thereof

Abstract: A video call mediating method includes: connecting, by a first terminal and a second terminal, to a video call platform; extracting a first identifier (ID) of a user of the first terminal and a second ID of a user of the second terminal, that is not displayed on the first terminal and the second terminal, during a video call; creating a first identification code for the first terminal and a second identification code of the second terminal from the first ID and the second ID, respectively; establishing a first video call session between the first terminal and the second terminal; creating a first image and a second image corresponding to the first terminal and the second terminal, respectively, with reference to the first identification code and the second

identification code, respectively; and displaying the first image and the second image on a display of the first terminal and on a display of the second terminal, respectively.

Application id: 16876597

Filing date: 18th May 2020

Publishing date: 3rd Sep 2020

Assignee: Google LLC

Title: Speech Recognition and Summarization

Abstract: The subject matter of this specification can be embodied in, among other things, a method that includes receiving two or more data sets each representing speech of a corresponding individual attending an internet-based social networking video conference session, decoding the received data sets to produce corresponding text for each individual attending the internet-based social networking video conference, and detecting characteristics of the session from a coalesced transcript produced from the decoded text of the attending individuals for providing context to the internet-based social networking video conference session.

Application id: 16919768

Filing date: 2nd Jul 2020

Publishing date: 22nd October 2020

Assignee: Cisco Technology Inc.

Title: Defining Content of Interest for Video Conference Endpoints with Multiple Pieces of Content

Abstract: A video conference system may include two or more video conference endpoints, each having a display configured to display content. The video conference system may detect a plurality of participants within a field of view of a camera of the system. The video conference system may determine an attention score for each endpoint based on the participants. The video conference system may determine whether the content of the first endpoint and/or the content of the second endpoint are active content based on whether the attention scores exceed a predetermined threshold value. The video conference system may send to secondary video conference systems an indication of the active content to enable the secondary video conference systems to display the active content.

Application id: 16825674

Filing date: 20th Mar 2020

Publication date: 24th Sep 2020

Assignee: Zoom Video Communications, Inc.

Title: Method and System for Elevating A Phone Call into A Video Conferencing Session

Abstract: An apparatus and/or method discloses an automatic call-to-conference elevation (ACE) capable of facilitating a transition from a phone call to a video conference. An ACE process, in one embodiment, is able to activate an ACE application to elevate user devices from participating in an audio call to a video conference based on a conference selection selected by a meeting initiator, host, or attendee. After identifying the capabilities, attributes, and/or functionalities associated with the user devices in accordance with activation of ACE, a

communication network coupling the user devices as meeting attendees is established for facilitating the video conference based on identified capabilities, attributes, and/or functionalities of the user devices. In one aspect, the process is capable of transitioning connections of the user devices from an audio call to a video conference.

Application id: 16866554

Filing date: 5th May 2020

Publishing date: 12th November 2020

Assignee: Optoma Corporation

Title: Video Conference System, Video Conference Apparatus, and Video Conference Method

Abstract: A video conference system, a video conference apparatus and a video conference method are provided. The video conference system includes a video conference apparatus and a display apparatus. The video conference apparatus includes an image detection device, a sound source detection device, and a processor. The image detection device obtains a conference image of a conference space. When the sound source detection device detects a sound generated by a sound source in the conference space, the sound source detection device outputs a positioning signal. The processor receives the positioning signal, and determines whether a real face image exists in a sub-image block of the conference image corresponding to the sound source according to the positioning signal to output the image signal. The display apparatus displays a close-up conference image including the real face image according to the image signal.

Application id: 16922832

Filing date: 7th July 2020

Publishing date: 22nd Oct 2020

Assignee: Dealer Inside Inc

Title: Sales Management and Video Chat System and Method for a Salesperson Mobile Device and a Remote Visitor Web Browser

Abstract: Sales management and video chat systems and methods use website listings that correspond to vehicles for sale at a place of business. A remote visitor clicks a live video; button beside a desired consumer good, and schedules a time for a video chat, using their web browser. A salesperson receives an alert, via a sales application running on the salesperson's mobile device. At the scheduled time, a video chat window opens in the visitor's web browser with live audio/video of the desired consumer good from the place of business in real-time. The website visitor uses their web browser for live communication, in real-time, to the salesperson on their sales application. After the video chat, the website visitor can use their browser to download and save a recording of the video chat session.

Application id: 16900738

Filing date: 12th Jun 2020

Publishing date: 17th Dec 2020

Assignee: Mersive Technologies Inc.

Title: Bridging Video Conference Room System and Associated Methods

Abstract: A bridging video conference room system and method provides for using a client device to leverage the conference room infrastructure to hold a video conference with remote

users. A user may indicate an intent to host a video conference to a room-host device, which may then detect and parse a calendar invitation to cause the video conference software to launch on the user's client device as a host of the meeting. Other client devices may share content to the video conference by sharing to the bridging video conference room system without joining the video conference separately.

Application id: 16787723

Filing date: 11th Feb 2020

Publishing date: 4th June 2020

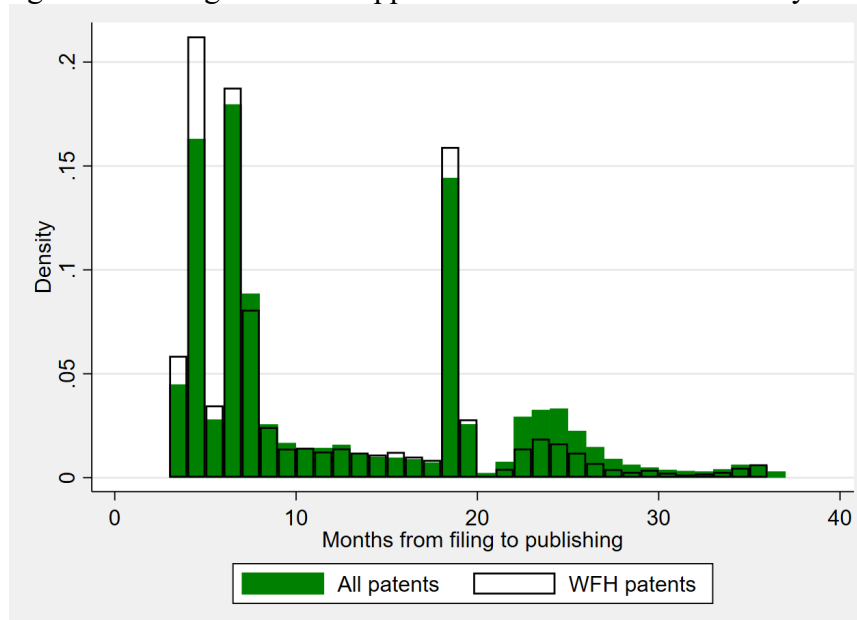
Assignee: Hyperconnect Inc.

Title: Video Call Method and Video Call Mediating Apparatus

Abstract: The video call method includes establishing, by a first terminal, a first video call session with a second terminal; establishing, by the first terminal, a second video call session with a third terminal; displaying, by the first terminal, a first video received from the second terminal through the first video call session and a second video received from the third terminal through the second video call session on a first display area and on a second display area, respectively; detecting, by the first terminal, a predetermined event; terminating, by the first terminal, one video call session among the plurality of video call sessions in response to the detecting the predetermined event; establishing, by the first terminal, a third video call session with a fourth terminal; displaying, by the first terminal, a third video received from the fourth terminal through the third video call session on a third display area.

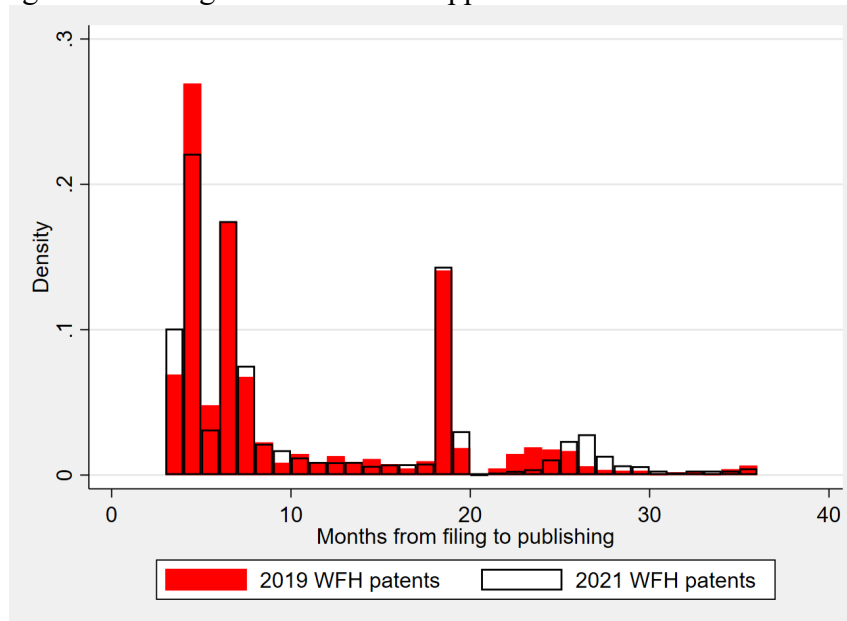
Appendix 2: Lag between applications and publishing for WFH and non-WFH patents

Figure A2.1. Lags in the Filing of Patent Applications to their Publication by the USPTO



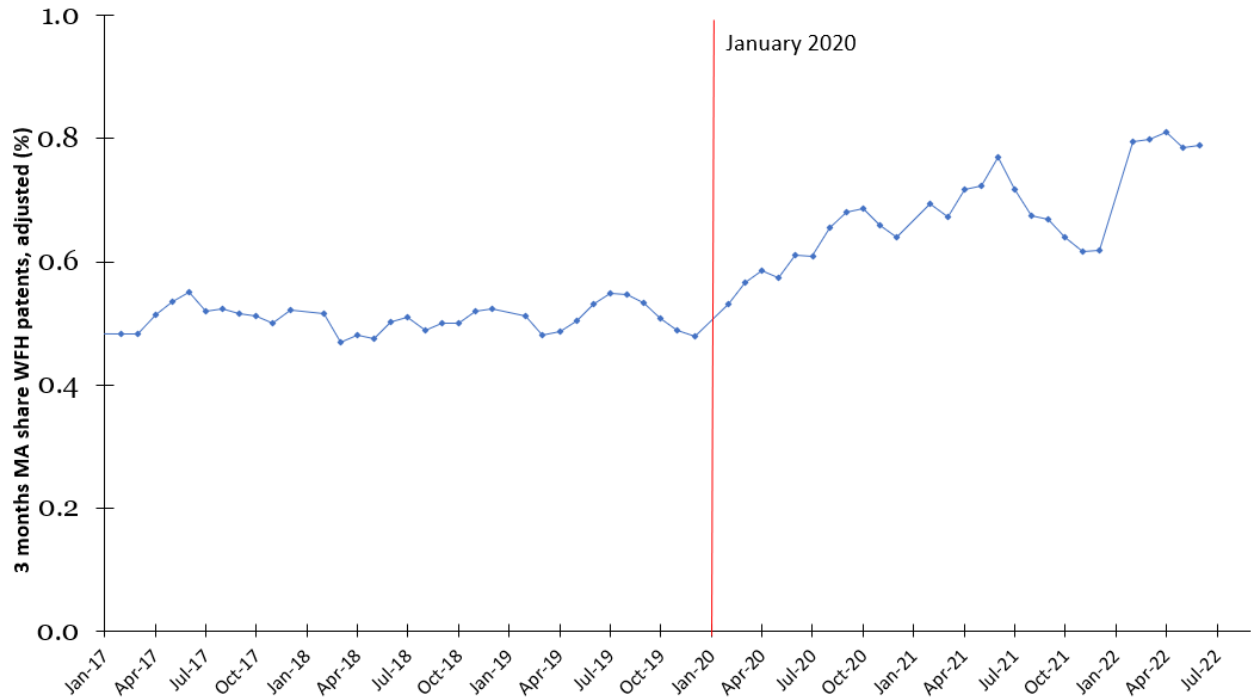
Source: Authors' analysis of XML files of published patent applications that were filed with the United States Patent and Trademark Office from 1 January 2010 through 24 December 2018.

Figure A2.2. Lags in the Filing of WFH Patent Applications to their Publication by the USPTO



Source: Authors' analysis of XML files of published patent applications that were filed with the United States Patent and Trademark Office from January-December in 2019 and 2021.

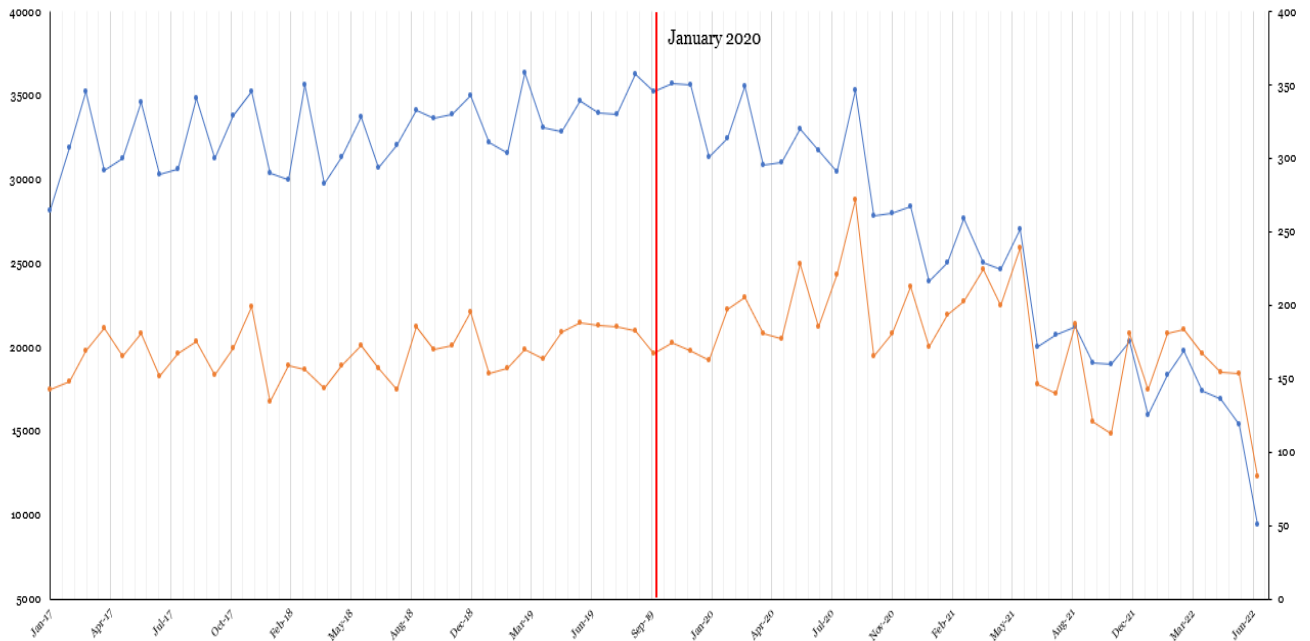
Figure A2.3. Three-Month Moving Average of Share of New Patent Applications that Support Work-from-Home Technologies, adjusted, January 2017 to July 2022



Source: Authors’ analysis of XML files of patent applications published by the USPTO from 7 January 2010 through 27 December 2022, covering filings through 31 July 2022.

Note: The chart reports the percentage of patent application *filings* through 31 July 2022 that support WFH technologies. We calculate this percentage using our automated classification of invention descriptions in patent applications *published* through 27 December 2022. The series was adjusted using the algorithm proposed in Bloom, Davis and Zhestkova (2021).

Figure A2.4. Total Number of Patent Applications Published by December 2022 by WFH Classification, January 2017 to July 2022



Source: Authors’ analysis of XML files of patent applications published by the USPTO from 7 January 2010 through 27 December 2022, covering filings through 31 July 2022.

Note: The chart reports the number of patent application *filings* through 31 July 2022, both total and that support WFH technologies. We group these applications using the automated classification of invention descriptions in patent applications *published* through December 2022.