Centre for Economic Performance

Discussion Paper ISSN 2042-2695

No. 1929
June 2023

The impact of COVID-19 on productivity

Nicholas Bloom
Philip Bunn
Paul Mizen
Pawel Smietanka
Gregory Thwaites

LSE The London School of Economics and Political Science

UKRI Economic and Social Research Council

Abstract
We analyse the impact of Covid-19 on productivity using data from an innovative monthly firm survey panel that asks for quantitative impacts of Covid on inputs and outputs. We find total factor productivity (TFP) fell by up to 5% during 2020-21. The overall impact combined large reductions in 'within-firm' productivity, with an offsetting positive 'between-firm' effects as less productive sectors, and less productive firms within them, contracted. Despite these large pandemic effects, firms' post-Covid forecasts imply surprisingly little lasting impact on aggregate TFP. We also see significant heterogeneity over firms and sectors, with the greatest impacts in those requiring extensive in-person activity. We also ask about unmeasured inflation in the form of deteriorating product quality, finding an additional 1.4% negative impact on TFP.

JEL Classification: C83; D24; D84; E24; E32; O47

This paper was produced as part of the Centre's Growth Programme. The Centre for Economic Performance is financed by the Economic and Social Research Council.

The authors would like to thank the Economic and Social Research Council, Nottingham and Stanford universities for financial support. We would like to thank Jonathan Haskel, Richard Heys, Stuart Newman, John Van Reenen, and seminar participants at CompNet, Dartmouth, Edinburgh, ESCoE, the Federal Reserve Bank of St Louis, KLEMS, Stanford and the Nottingham Macro Working Group, Oliver Coibon and two referees for comments. The views do not necessarily represent those of the Bank of England, the Deutsche Bundesbank, or their Committees.

Nicholas Bloom, Stanford University NBER and Centre for Economic Performance at LSE, Philip Bunn, Bank of England, Paul Mizen, University of Nottingham, Pawel Smietanka, Deutsche Bundesbank and Gregory Thwaites, University of Nottingham.

Published by
Centre for Economic Performance
London School of Economics and Political Science
Houghton Street
London WC2A 2AE

Introduction

The global spread of Covid-19 has led to a widespread economic contraction and reorganization, with significant effects on standards of living and the public finances. The impacts on productivity, however, are more complex but equally important. Before the pandemic productivity growth rates in the United Kingdom, United States and European Union had been declining, registering average growth rates of less than 1% in the decade *pre-pandemic*.[1] Given this low starting rate of growth, the pandemic could potentially drive productivity growth into zero or negative territory, lowering living standards, and placing a huge strain on the public finances and interest rates.

This paper decomposes the drivers of both labor and total factor productivity in the United Kingdom during the Covid-19 pandemic using a unique firm-level survey. We show that the acceleration in labor productivity over the first year of the pandemic was due to hours worked contracting most sharply in low-productivity sectors and firms, a positive effect which more than offset a contraction in within-firm labor productivity.[2] Total factor productivity performed less well and fell because capital inputs did not decline as fast as labor inputs. Almost all of the variation in productivity is accounted for by surviving firms; the effects from firm entry and exit are estimated to have been small.

Looking further ahead, we find that firms' forecasts of the medium-run impact of Covid-19 – a unique feature of our data – imply only a small negative effect on productivity. This is a striking

[1] On the continuing decline in productivity growth see for example Jones (2009), Cowen (2011), Gordon (2016), and Bloom et al. (2020).

result given the depth of the recession that Covid-19 caused and has important implications for fiscal and monetary policy makers.

As with the broad pattern of economic restrictions and mortality, we show that the relative performance of labor and total-factor productivity in the United Kingdom qualitatively match those in the United States. This suggests it is possible to generalize our results to other industrialized countries that have been heavily affected by the pandemic and that have a broadly similar industrial structure to the UK. Many of the drivers of our results are likely to be common across countries. For example, the pandemic disproportionally affected firms in consumer-facing industries that have lower than average productivity. This is a key reason why we find that reallocation between firms made a positive contribution to productivity. And the pandemic will have increased intermediate costs and therefore lowered productivity within firms across countries, with the adverse effects on within firm productivity likely to have been largest in industries where it is harder for jobs to be done from home.

This paper employs unique firm-level survey data from the Decision Maker Panel (DMP), a large representative monthly panel survey of UK firms, which has been running since 2016, and which we combine with company accounts data where available. Over 5,000 firm panel members were asked about the impact of Covid-19 on the main components of productivity, covering labor and capital inputs, outputs and prices.[3] This enables us to measure directly the impact of Covid on

[3] We did not provide any specific guidance to the survey respondents as to whether their estimates of the impact of Covid-19 pandemic on their businesses should be inclusive of government support, or not. We assume that firms responded including the impact of government response. It would be complex for firms to exclude the impact of

these quantities, rather than infer it through some measure of exposure. Our survey data shows that these reported impacts account for much of the realized changes in the early firm-level data on productivity during the pandemic that have since become available, highlighting the value of this survey methodology for assessing the impact of major shocks and policy interventions on firms.

For both labor productivity and total factor productivity (TFP), we decompose the aggregate impacts into 'within-firm' and 'between-firms' effects (hereafter within and between effects) using the accounting framework of Baily et al. (1992). We do this on a quarterly basis for the period during the Covid pandemic and we assess the possible medium-term impacts using firms' forecasts.

Whilst a similar decomposition of productivity during the pandemic will eventually be possible using accounts or administrative data, our survey-based approach has a number of advantages. The first is timeliness, the survey data are available in close to real time, whilst administrative data typically lag by one to two years. Second, our survey-based estimates are quarterly, whereas administrative data are typically only annual. Given the speed of the onset of the pandemic and fact that government restrictions varied significantly across quarters, being able to analyse the data on a quarterly basis can help better understand the dynamics. Third, the survey data are also forward looking, allowing the potential medium-term effects to be studied many years before that will be possible with backward-looking administrative data. Fourth, the DMP asked firms

government responses to the pandemic in their survey responses and the fact that our aggregate estimates approximately match up to the official data is consistent with firms taking into account government support when responding.

specifically about the marginal impact of Covid, so our data abstract from the effects of other firm specific shocks and the need to produce a counterfactual of what would have otherwise happened. Our contribution is to present an approach that could be used to help study the effects of future large economic events as well as to help understand what happened to productivity during the pandemic.

Our estimates suggest that Covid-19 lowered *total factor productivity* in the UK private sector by up to 5% during the pandemic, consistent with the fall in TFP in official data (Figure 1).[4] The main driver was businesses reporting a large reduction in TFP within firms. The within effects in turn were driven by firms, on average, reporting higher unit costs corresponding to a combination of higher intermediate input costs and lower and less fully utilized capacity.

The negative within effects on TFP were partially offset by positive between effects – low-productivity sectors shrank more than high-productivity sectors, and the least productive firms within these sectors suffered most. The *sector* result arises because the lowest productivity sectors tend to involve more face-to-face activity – travel, leisure, retail etc. – and so contracted as a share

[4] Figure 1 shows the close correspondence between DMP estimates of the impact of Covid-19 on productivity and changes in official aggregate labor productivity and TFP data for the UK. The aggregate productivity data shown in Figure 1 are adjusted for an experimental hours worked series that more closely matches administrative data on the percentage of employees being put on furlough and not working any hours under the Government Coronavirus Job Retention Scheme (Figure A1 in the Appendix shows this). In the UK, a government 'furlough' policy allowed firms to keep employees not required to work any hours on their payroll rather than lay them off, with the government paying 80 percent of their wages. See ONS (2021) for more details on the experimental hours series. Figure A1 also shows official UK labor productivity data with and without this adjustment.

of value-added. The *firm* result arises because the pandemic appears to have more severely affected lower-productivity firms within sectors, in part because they struggled to deal with the need for rapid pandemic re-organization. These positive between effects on productivity, however, are not the usual Schumpeterian process of *creative destruction*, whereby lower productivity firms are replaced by higher productivity firms. Instead, much of this was simply a lockdown of low-productivity sectors (destruction without creation). So, while this helped to push up productivity, it reduced total economic output.

In contrast, the overall effects of Covid-19 on hourly *labor productivity* are estimated to have been positive during the acute phase of the crisis, again consistent with official data (see Figure 1).[5] DMP data imply that hours worked – the only input controlled for when estimating labor productivity – dropped by over 40% in 2020 Q2, with only a partial recovery after that. This drop was similar in magnitude to the fall in real sales, although increased intermediate costs meant that there was a negative within-firm impact. But that was more than offset by the positive between effects, such that we find a positive overall impact on labor productivity. The effects on TFP had the opposite sign because capital inputs fell by much less than labor inputs - the pandemic-period fall in investment flows only had a relatively small impact on the capital stock.

[5] The effects on labor productivity *per job* are estimated to be negative throughout, particularly in 2020 Q2 and Q3, as the number of jobs fell by much less than hours worked due to workers being put on full-time furlough (still employed but not required to work any hours). We focus on the more economically meaningful measures in this context of hourly labor productivity and TFP.

To gauge the effects over the medium term, we asked panel members about the expected impacts of Covid-19 on factor inputs and outputs in 2023+. The effects are estimated to be relatively small in aggregate. Firms' forecasts imply that the pandemic will reduce labor productivity by around 1% over the medium term compared to a reduction of around 0.5% in TFP. However, we show that unmeasured inflation, in the form of a deterioration in product quality at a given price, presents a downside risk to the measurement of real GDP and hence TFP, of the order of 1.5%. This could also be important as a potential driver of longer-run inflation if firms return to their pre-pandemic levels of product quality, and raise prices accordingly.

Alongside our aggregate estimates, we also show how there has been substantial heterogeneity in the impact of Covid-19 on productivity across firms. That dispersion was particularly wide during the early part of the pandemic, but even over the longer term, where the average effects of Covid on productivity are expected to be small, there are some firms who expect productivity to be higher and others who expect it to be lower. Covid is more likely to have had positive effects on productivity in firms where more of the work can be done from home, in firms where sales involve less face-to-face contact with customers and in firms with more skilled employees.[6] Productivity is more likely to have fallen in firms where it is harder for work to be done from home, where there is more face-to-face contact with customers and where increases in costs have been larger.

This paper draws together four strands of literature: the decomposition of productivity growth, productivity over the business cycle, business surveys, and the economic impact of Covid-19.

[6] It is perhaps odd to think of the pandemic as increasing firms' productivity, but in the case of working from home there is evidence firms sub-optimally adopted this pre-pandemic (Barrero et al. 2021).

First, on decomposing productivity growth Baily et al. (1992) developed the original within and between formula we employ in this study. Their decomposition has been extensively used in the productivity literature (see, e.g. Foster et al. (2001) or Syverson (2011)). Bartelsman et al. (2013) show that differences in the covariance between size and productivity drive productivity differences across countries, while Hsieh and Klenow (2009) highlight the importance of misallocation for productivity.

Second, on the link between productivity growth and business cycles, Fernald and Wang (2016) show that TFP has been roughly acyclical in the US since the mid-1980s. In contrast, Ball (2014) shows that the recession of 2008-9 had persistent negative effects on output among a sample of 23 OECD countries, and Cerra and Saxena (2008) show that output does not return to trend following recessions in a broader sample of countries and time periods.

Third, on using business surveys to evaluate the impact of major shocks we build on a recent growth literature, for example Altig et al. (2020b) and Bhandari et al. (2020). More generally the survey literature has focused on a range of topics around expectations and prices, for example, Coibion and Gorodnichenko (2012) and Coibion et al. (2018)). The use of these large, high-frequency forward-looking firm surveys in this paper to measure the productivity impact of shocks – both the within and between elements – is novel and highlights the value of large-scale, representative firm surveys for analysing the impact of major economic shocks. The timely nature of our survey data, and the forward-looking aspect are particularly valuable for policymakers, given other sources of productivity microdata are only available with a lag.

Lastly, our paper is one of many in a rapidly growing literature on the economic impact of Covid-19, which are already too numerous to cite and many of which are surveyed in Brodeur et al. (2020)

and Criscuolo (2021). Some examples include, Bartik et al. (2020a and 2020b), Brynjolfsson et al. (2020), Gourinchas et al. (2020), and Papanikolaou and Schmidt (2020) who show pervasive impacts on firms. Baqaee and Farhi (2020) show that negative sectoral supply shocks can be stagflationary and can be amplified by complementarities in production, Chetty et al. (2020), Forsythe et al. (2020) and Cajner et al. (2020) show large and heterogeneous labor market impacts of Covid-19, Adams-Prassl et al. (2020), Alon et al. (2020) and Mongey et al. (2020) and show the gender impact of the pandemic, Guerrieri et al. (2020) show that supply shocks can cause demand shortages, and Jorda et al. (2020) examine the longer-run consequences of past pandemics. Most recently, Andrews et al. (2021) have found evidence of a positive reallocation effect from Covid among small businesses in Australia, New Zealand and the UK.

Section 2: The Decision Maker Panel (DMP) during Covid-19

Survey methodology

The DMP is a large and representative online survey of Chief Financial Officers in UK businesses.[7] It is similar in style to the Survey of Business Uncertainty run in the United States by the Federal Reserve Bank of Atlanta (Altig et al. (2020a)). The survey asks about recent developments and expectations for the year ahead in sales, prices, employment and investment. An important advantage of the DMP survey relative to many other business surveys is the quantitative nature of the data that it collects.

[7] See Bloom et al. (2019) for analysis of the impact of Brexit on UK businesses using data from the DMP.

The sampling frame for the DMP is the population of UK businesses with 10 or more employees in the Bureau van Dijk FAME database.[8] It covers small, medium and large private sector businesses across all industries. Firms are selected randomly from this sampling frame and are invited by telephone to join the panel by a recruitment team based at the University of Nottingham. This approach helps to ensure that the survey provides a representative view of the UK economy. Once firms are part of the panel they receive monthly emails with links to a 5- to 10-minute online survey. Firms that do not respond to the survey for three consecutive months are re-contacted by telephone to check whether they received the emails or have other reasons for not completing the survey. When the DMP firm recruitment team first contact firms they ask to speak to the CFO, and failing that the CEO. As a result 85% of respondents are in these two positions (70% are CFOs and 15% are CEOs) with the remainder mostly senior finance managers. Given that the typical firm in the survey has about 100 employees these CFOs and CEOs have a very good sense of the overall direction and performance of the business.

The DMP grew quickly after its launch and has averaged just under 3,000 responses a month since 2019, covering around 5% of UK private sector employment. That makes it one of the largest monthly business surveys in Europe. The surveys have a rotating three-panel structure – each member is randomized at entry into one of the three panels (A, B or C). Each panel is given one third of the questions in any given month, so that within each quarter all firms rotate through all questions. This helps to keep the survey short for respondents whilst yielding a regular monthly flow of data. Covid-19 has not had a large impact on the DMP response rate. Figure A2 in the

[8] FAME is provided by Bureau Van Dijk (BVD) using data on the population of UK firms from the UK Companies House. FAME itself is part of the global AMADEUS database.

Appendix shows how the response rate has only fallen slightly relative to 2019 and has remained in the region of 50-55% for active respondents. The regressions in Table A1 show that changes in response rates during the pandemic have not been larger in sectors more affected by Covid and have not been correlated with firm-level productivity. DMP data also match up well with the corresponding audited information from company accounts for variables such as sales and employment in the pre-Covid period (see Figure A3).

An important advantage of the DMP survey relative to other business surveys is the quantitative nature of the data that it collects. Many other business surveys tend to focus on questions that ask businesses to indicate whether they expect the conditions that they face to get better or worse, rather than by how much they expect them to get better or worse. But the extent to which conditions are better or worse has been particularly important in the context of the Covid-19 pandemic where the size of such changes was much larger than in normal times. This quantitative information on how businesses have been affected by Covid-19 and expect to be affected in the future is a crucial input into the analysis in this paper on how Covid-19 has affected productivity. The reason that the DMP targets the CFOs (or CEOs) at these firms is because they are likely to be sufficiently numerate to respond to detailed quantitative questions.

The core survey data that we use in this paper were collected between July 2020 and April 2022. For each firm we use the most recently available data point for each question. Our estimates of the impact of Covid-19 on productivity between 2020 Q2 and 2022 Q1 are therefore largely realised impacts, as estimated by firms, whereas data from 2022 Q2 onwards are expectations. Around 2,900 firms in the DMP survey have answered all of the relevant questions at least once during

this period and have all the accounting data necessary to calculate pre-Covid-19 labor productivity and TFP.[9]

The Covid-19 pandemic in the United Kingdom

At the time of writing, the UK has experienced relatively high case and death rates during the Covid-19 pandemic in comparison to many other industrialized countries. Fluctuations in excess death rates and the stringency of anti-Covid non-pharmaceutical measures have been well synchronized between the UK and the US (Figure 2). This is consistent with various measures of the economic impact of Covid-19 being highly synchronized between the UK and the US (Altig et al. (2020b)), and suggests that results we obtain for the UK should be valid in the US and other industrialized countries with similar experiences of the pandemic and that have a broadly similar industrial structure.[10]

Section 3: Analytical framework

Our goal is to measure and decompose the aggregate impact of Covid-19 on both labor productivity and total factor productivity. To this end, we measure productivity at the firm level in the pre-Covid period using company accounts data, and then use the DMP to estimate the impact relative

[9] All firms must have answered all relevant questions relating to at least four different quarters to be included in the sample. Data for missing quarters are imputed using data for quarters where they did respond so that the panel we use is balanced.

[10] Figure A4 in the Appendix compares the industrial composition of the UK and US immediately prior to the pandemic. As shown in Panel A the industrial composition in both countries were similar. Firms providing consumer-facing services, such as retail trade, accommodation and food, or transport services, which were most affected by the pandemic, were as important part of the UK economy as they were of the US (see Panel B).

to this baseline, inferring this impact from the reported effects of Covid-19 on inputs and outputs among the DMP respondents.

Measuring the impact of Covid-19 on inputs and outputs using the DMP

Between April 2020 and April 2022, the DMP survey included questions about the expected impact of Covid-19 on respondents' sales, employment, and investment. The questions were of the form: '*Relative to what would have otherwise happened, what is your best estimate for the impact of the spread of coronavirus (Covid-19) on the sales/employment/investment of your business in the following quarters?*' These questions asked about the impact in the current quarter and about expectations for the following three quarters and the medium term (for example in April 2022 this was 2023+).[11] Respondents provided numerical responses to these questions. This direct and innovative approach to gauging the impact effects of a shock is different to other studies that estimate the productivity impact of shocks using before-after comparisons or some natural experiment with treatment-control comparison. Effectively our survey asks firms for a partial derivative of inputs and outputs with respect to the Covid-19 pandemic.

To estimate the impact of Covid-19 on total hours worked, we use data on the impact of Covid-19 on employment, the average hours worked of employees who remain active, and data on the

[11] Figure A5 in the Appendix shows a screenshot of how these questions were asked in the survey. In earlier survey waves, the questions asked about the medium term impact referred 2022+. Responses for 2022+ were used to impute data for 2023+ if data directly referring to 2023+ were not available.

percentage of employees on furlough.[12] The Appendix shows that our estimates of the aggregate percentage of employees on furlough closely match estimates based on official data sources.[13] Since June 2020, businesses were also asked about the impact of measures to contain Covid-19 on their unit costs.[14] To assess the impact of Covid-19 on the capital stock, we cumulate the reported effects of Covid-19 on investment at the firm level and assume an annual depreciation rate of 4% and no additional capital scrapping.[15] For prices, the DMP asks firms about changes in output prices over the past year and about expectations for the next year.[16] Here we assume that the change in output price inflation, relative to 2019, was the effect of Covid-19. We calculate price effects at the 1-digit industry level rather than firm level. Overall, we find that the effects of Covid-19 on both capital and prices are small, especially in the short run, so neither of these assumptions have

[12] Workers who were on furlough under the UK government's Coronavirus Job Retention Scheme (CJRS) were counted as employed, but were not working any hours (with the government paying 80 percent of their wages). This accounts for most of the initial fall in hours worked in 2020 Q2. By 2022 most of the reduction in hours worked was estimated to be due to lower employment. The CJRS closed at the end of September 2021.

[13] Figure A1 Panel A in the Appendix shows estimates of the percentage of employees in the private sector on a full-time furlough using DMP data and administrative data from HMRC. The two series match closely.

[14] The wording of this question is 'Relative to what would otherwise have happened, what is your best estimate for the impact of measures to contain coronavirus (social distancing, hand washing, masks and other measures) on the average unit costs of your business in each of the following periods?'

[15] Annual investment approximates to 6% of the capital stock in the UK. The depreciation assumption is consistent with aggregate UK data. The assumption of no additional capital scrapping poses some downside risk to our capital estimates.

[16] For detailed list of all DMP questions please see: https://decisionmakerpanel.co.uk/wp-content/uploads/2022/04/List-of-questions-up-until-April-2022.pdf

large impacts on our productivity calculations.[17] Figure 3 summarises all of the inputs into our calculations.

Firm-level productivity

We use 2017-2019 accounting data from Bureau van Dijk's FAME dataset to calculate each measure of productivity in the pre-Covid period for all firms in the survey.[18] Labor productivity is calculated as real value-added (operating profits plus total labor costs divided by the aggregate GDP deflator) per employee using accounting data. TFP is calculated as the residual from a production function, $ln(VA_{it}) = \beta ln(L_{it}) + \alpha ln(K_{it})$, where VA_{it} is real value-added of firm i in year t, L is labor input which we measure as total remuneration (wage bill) and K is capital, measured as total real fixed assets.[19] Nominal values from accounting data are deflated using the GDP deflator. The elasticities of output with respect to capital and labor are assumed to be 0.37 and 0.63 respectively, to align with their economy-wide factor shares.[20]

We measure the proportional impact of Covid-19 at the firm level on real final sales dy and infer the impact on value added dv in a manner analogous to the national accounts:

[17] We assume that the impact on prices does not persist over the medium term (2023+).

[18] Figure A6 in the Appendix shows that these measures of labor productivity constructed from accounting data correlate well with official data at the industry level.

[19] Usually TFP would be normalized at the industry level. We do not do this because we require differences in the level of productivity between industries to consider the effects of reallocation between industries on aggregate productivity.

[20] In section 6 we also show that our results are robust to using industry level factor shares.

$$dv = (dy - s_M dm)/(1 - s_M)$$

where *dm* is the impact on intermediates and s_M is the share of materials in final sales. We define the impact of Covid on value-added total factor productivity *da* as the impact on value-added less the impact on elasticity-weighted inputs:

$$da = dv - \alpha dk - \beta dl$$

where *dk* and *dl* are the proportional impacts on the firm-level capital stock and labor input respectively, measured in heads or hours, and α and β are the corresponding elasticities of value-added. Three important things to note about our definition of *da* are that (1) we are measuring differentials *dx* with respect to the impact of Covid-19, not time or any other variable, (2) we measure the capital stock rather than capital services, and (3) we do not quality-adjust the impact of Covid-19 on labor input within firms.

In order to map this into our survey questions, we define unit costs, M_u=M/Y, as the volume of intermediates per unit of real final sales, such that the change in intermediates dm is $dm_u + dy$. We then have:

$$da = dv - \alpha dk - \beta dl$$

$$= (dy - s_M dm)/(1 - s_M) - \alpha dk - \beta dl$$

$$= \big(dy - s_M(dm_u + dy)\big)/(1 - s_M) - \alpha dk - \beta dl$$

$$= dy - \frac{s_M dm_u}{(1 - s_M)} - \alpha dk - \beta dl$$

We measure firm-level changes in value-added TFP with this equation. In section 6, we examine the sensitivity of this approach to alternative interpretations from our respondents to the question on unit costs. Figure 1 shows that our aggregate measures of productivity based on survey and accounts data are closely linked to the official statistics calculated by the ONS. Figure A7 in the Appendix also shows how our estimates of the impact of Covid-19 on productivity from the DMP are well correlated at the firm level with realized changes in overall productivity from accounting data, where comparable data are available for the early part of the pandemic.[21]

Decomposing productivity into within and between effects

In order to produce an estimate of the impact of Covid-19 on aggregate productivity in the UK, we follow Baily et al. (1992):

$$\Delta\Pi_t = \sum_{\mathrm{i}\in\mathrm{Surv}} \bar{\varphi}_i \Delta\pi_{\mathrm{i,t}} \qquad \text{… within firms} \tag{1}$$

$$+ \sum_{i\in Surv} \Delta\varphi_{i,t}(\bar{\pi}_{\mathrm{i}} - \bar{\Pi}) \qquad \text{… reallocation between surviving firms} \tag{2}$$

$$+ \sum_{i\in\Delta Entry} \varphi_{i,t}(\bar{\pi}_{\mathrm{i}} - \bar{\Pi}) \qquad \text{…. reallocation to new firms} \tag{3}$$

$$- \sum_{i\in\Delta Exit} \Delta\varphi_{i,t-1}\left(\pi_{i,t-1} - \bar{\Pi}\right) \qquad \text{…. reallocation from exiting firms} \tag{4}$$

[21] At the time of writing accounting data covering the first year of the pandemic (financial year 2020) were available for about 80% of our sample. No more recent data were available and accounting data are only annual, not quarterly.

Here $\pi_{i,t}$ is productivity in firm *i* at time *t,* Π_t is aggregate productivity at time *t,* $\varphi_{i,t}$ is the employment/hours share of firm *i* at time *t* and a bar over a variable indicates the average of the variables across times *t*-1 and *t*. Δ is with respect to Covid-19, not time. Δ*Entry* and Δ*Exit* denote firms that entered or exited due to Covid-19.

The within effect (1) measures the contribution of changes in firm-level productivity for a given allocation of labor across firms. The between effect (2) is the impact on productivity of a reallocation of inputs towards firms with lower or higher levels of productivity. Productivity levels are measured as an average of periods *t* and *t*-1. There is an additional between effect arising from the birth (3) or death (4) of firms which depends on both the rate of entry and exit and whether firms that are born or die have productivity levels different to the average.

Section 4: Results

Here we first describe the within effects and then the between effects before combining them and summarising the overall impact of Covid-19 on productivity. Figure 4 shows our estimates of the within and between effects.[22]

[22] See Table A2 in the Appendix for the precise numbers. Figure A8 in the Appendix also shows the results in labor productivity per head space, although we focus on the more meaningful measure of labor productivity per hour in this section.

Within-firm effects

Businesses, on average, estimated that Covid-19 led to a very sharp fall in sales of around 35% in 2020 Q2 (on an employment-weighted basis), relative to what otherwise would have happened (Figure 3).[23] This masks large dispersion between industries. For example, in the worst affected industries – accommodation and food and recreational services – sales were estimated to have been around 75% lower than they would have been in 2020 Q2, compared to 15-20% lower in the least affected industries such other production (which includes agriculture, mining and utilities), health and information and communication. Sales were still estimated to be around 5% lower than they would have been by 2022 Q1. Over the medium term (2023+), the effects on sales were expected to be close to zero. Total hours worked were estimated to have fallen by more than sales in 2020 Q2 and 2020 Q3, but with the effect converging on the impact on sales in later quarters.

The effects of Covid-19 on within-firm productivity are estimated to have been negative throughout the period from 2020 Q2 to 2022 Q1. For hourly labor productivity, the effects are estimated to have averaged -2.3%, with a peak negative within-firm effect in 2021 Q4 of -3.7% (see Figure 4 Panel A). Whilst the effects on real sales per hour are estimated to have been close to zero over most of the pandemic, higher intermediate costs lowered within-firm labor productivity (see Figure A9 in the appendix for the relative contributions).

The impact of Covid-19 on TFP, relative to hourly labor productivity, will depend on whether the impact on the capital stock was larger or smaller than on labor input. Figure 3 shows that

[23] Using sales weights the fall in sales in 2020 Q2 is estimated to have been smaller at 29%. This fall in sales is smaller because sales weights give less weight to lower productivity sectors than employment weights.

investment was reported to have been more negatively affected than sales in 2020, although the differences narrow in 2021. However, quarterly investment is equal to only about 1.5% of the capital stock on average, so that Covid-19 is likely to have only reduced the capital stock by around 2% by 2022 Q1. This means that elasticity-weighted inputs fell by less than labor inputs over the short run, such that within-firm TFP is estimated to have performed worse than labor productivity. Between 2020 Q2 and 2022 Q1, Covid-19 is expected to have lowered within-firm TFP by 5.5%, on average (see Panel B of Figure 4). The within-firm effects become less negative in later quarters as the additional cost pressures start to ease.

Despite the large effects during the pandemic, firms' forecasts imply that Covid will not have a large impact on within-firm productivity over the medium term. Within-firm labor productivity is expected to be 1.2% lower with the effect on TFP slightly smaller at -0.8%. In contrast to during the pandemic, TFP is estimated to perform slightly better than labor productivity over the medium term. That is because the capital stock is persistently smaller over the medium term (by around 2%) as lost investment during the pandemic is never recovered, whereas employment gets back to within 1% of where it would have otherwise been.

A small medium-run effect from the Covid pandemic on productivity is a striking result given the scale of the shock. It also contrasts to experience from the financial crisis where the effects on productivity were large and persistent. Cerra et al. (2022) review the evidence on hysteresis in business cycles. Fornaro and Wolf (2020) show, for instance, that a temporary reduction in the growth rate TFP growth due to a recession can result in a lower level of TFP relative to a counterfactual trend. One mechanism through which the pandemic could lower TFP is if fewer

ideas and innovations were generated. Data from the DMP indicates that their CEO's spent large amounts of time managing the effects of Covid-19 on their business over second half of 2020 – around 12 hours a week on average, which will have diverted them from other, potentially productivity-enhancing, activities (see Figure 5 Panel A). One risk to our estimates is that any effects from reduced innovations will only emerge beyond the end of our horizon and that firms are not fully aware of them when responding to the survey questions. But in the opposite direction, firms expect to invest more in IT and employee training over the medium term and less in land and buildings as a result of Covid (Figure 5 Panel B). This switch towards more intangible forms of investment, which are typically thought to be more productivity-enhancing, could help to support productivity, although again, any effects will take time to build (Adarov et al. 2022).

There has also been substantial heterogeneity in the impact of Covid-19 on productivity across firms. Figure 6 Panel A depicts kernel densities of the impact of Covid on TFP at the firm level realised during the first and second years of the pandemic and the expected impact over the medium term. The distribution of TFP across firms was wide and heavily left-skewed in the first year of the pandemic. The distribution narrowed a little in the second year but still remained wide. In the medium-term, the expected change in TFP is more symmetric across firms, but is still expected to remain notably dispersed. In the first two years of the pandemic Covid-19 is estimated to have reduced TFP for around 70% of firms, and increased it for 30%. Over the medium term, just over 50% of firms expect TFP to be lower than it would have been, with just under 50% expecting an increase.

Panel B of Figure 6 shows that the average expected medium-term impact of Covid on TFP also varies across industries, despite the aggregate effect being close to zero. Businesses in manufacturing, other production, transport and storage and recreational services – industries in which opportunities to work from home are limited – anticipate the most negative impacts, with real estate, information and communication and professional and scientific services – where working from home is easier – conversely anticipating the most positive effects.

The impact of Covid-19 on within-firm productivity is statistically significantly correlated with exposure to the shock. Columns 1, 2 and 3 of Table 1 show the results of some cross-sectional firm-level regressions of the impact of Covid-19 on within-firm productivity for different time periods on a range of firm-level characteristics. This can help provide some insights into the sources of lower TFP within firms. Firms in industries where a large fraction of the work can be done from home are estimated to have done better than firms in industries where it is harder to work from home. These differences are expected to persist over the medium-term. Related, firms with more sales that involved face-to-face contact with customers are more likely to have seen falls in productivity in the pandemic, although this is estimated to have less of an effect on productivity in the medium term. Lastly, conditional on these two effects, firms who paid higher wages before the pandemic – consistent with having more highly-skilled workers – expect more positive within-firm TFP effects. Taken together, these results suggest that the requirements to conduct sales face-to-face and the inability to switch to remote working were important drivers of lower within-firm reduction in productivity during the pandemic.

Between-firm effects for surviving firms

The impact of Covid-19 varied a great deal across sectors and across firms within those sectors. This sub-section describes the associated reallocation effects in more detail for surviving firms. The following subsection considers the effects of firm entry and exit.

Measures of pre-Covid productivity are highly correlated with firm-level changes in hours worked during the Covid-19 pandemic. This is shown by the regressions in Table 2.[24] As we input-weight productivity in our calculations it is this relationship that is a key determinant of the extent of the reallocation effects. Higher-productivity firms shrank less and therefore saw their overall weight increase, while low-productivity firms shrank more and saw their weight fall, leading to an increase in the average level of productivity and a positive between-firm effect.

Column 1 in Table 2 shows the strong positive relationship between pre-Covid labor productivity and the impact of Covid-19 on hours worked in the first year of the pandemic.[25] In column 2, we add 1-digit industry dummies. The coefficient on labor productivity almost halves but remains statistically significant. That indicates how reallocation between industries, or inter industry effects as we define them, played an important role in explain the overall reallocation effects, but there is still some effect from within industries, or intra-industry effects. The latter within-industry effect

[24] Also see Figure A10 in the Appendix for a chart version of these regressions.

[25] We do not have historic data on hours worked at the firm level but rather only on the number of employees. Consequently, we use labor productivity per job in this analysis as our measure of pre-Covid-19 productivity. This implicitly assumes that average hours worked per employee are the same across all firms.

could potentially reflect the fact that more productive firms are better managed and more able to cope with the dislocation of the pandemic, or possibly better capitalized so more able to deal with a period of tough business conditions. Columns 3 and 4 perform a similar exercise for the second year of the pandemic. The coefficients are smaller, but still significant, consistent with a smaller reallocation effect. Again, the size of coefficient drops once industry is controlled for in column in 4. Columns 5 to 8 replicate this analysis in TFP space. The results are similar to those for labor productivity.

Figure 4 shows the between-firm effects on a quarter-by-quarter basis. They are estimated to have been largest in 2020 Q2, at 11% for hourly labor productivity and 5% in TFP space. Since then, the between firm effects have gradually become smaller, aside from a spike in 2021 Q1 that was associated with the second wave of Covid in the UK and restrictions being reimposed. Figure 4 also splits out inter and intra industry effects: on average, the inter-industry component accounts for around two-thirds of the positive between-firm effect. Over the medium term, only a small between-firm effect of 0.1-0.2% is expected to persist as the substantial reallocation effects seen during the pandemic are expected to have been largely temporary.

Unsurprisingly, falls in hours worked were largest in firms that were most exposed to the Covid shock. Columns 4, 5 and 6 of Table 1 show how hours worked fell by more in firms where it is harder to work from home and where there is more face-to-face contact with customers. These are the same variables that were also associated with lower within-firm productivity (shown in columns 1 to 3). At the 1 digit industry level, the falls in hours worked in 2020 Q2 were reported to have been largest in recreational services and in accommodation and food, which are also the

two lowest productivity industries that we consider (see Figure A11 in the Appendix).[26] These are both industries where a large proportion of spending involves face-to-face contact and/or social activity and where it is particularly difficult for these services to be provided from home.

Importantly, it is worth highlighting that this positive between-industries impact of Covid on productivity is not entirely the usual Schumpeterian process of *creative destruction*. Instead much of this is simply a shutdown of low productivity industries without substantial creation in other industries. So, while this may have temporarily increased *average* productivity, it reduced total economic output and overall welfare.

Firm entry and exit

Our analysis focuses on reallocation effects between surviving firms, but firm entry and exit can contribute too. Firm entry typically falls and exit increases in recessions. However, changes in entry and exit during Covid have been modest in the UK, perhaps reflecting presence of Government support schemes.[27] The DMP survey only includes data for surviving firms, so instead we use other sources to supplement our analysis and provide an estimate of the impact of entry and entry on productivity. We estimate that entry and exit have only had a very small impact on current productivity relative to the effects accounted for by surviving firms.

[26] Figure A11 also shows the impact on capital by industry, although these differences are less important for understanding the TFP impact than changes in hours worked because the effects on capital are much smaller.

[27] Criscuolo (2021) shows that unlike the Global Financial Crisis the Covid-pandemic did not dramatically affect birth and death rates of firms. They also discuss possible reasons for that, e.g. changes to insolvency regulations and fiscal stimuli offered by governments in many developed countries.

The key determinants of how Covid-19 affected productivity during the pandemic through firm entry and exit will have been: (i) how Covid-19 affected the number of jobs lost/created, relative to what would have otherwise happened; and (ii) the average productivity of firms that died versus the average productivity of new firms that were born. Figure 7 uses aggregate ONS data to show that employment weighted firm births and deaths both fell during 2020 (Figure A12 in the appendix shows an alternative version of changes relative to 2019). They were both around 15% lower than in 2019, such that net entry and exit was little changed. In 2021, jobs lost from firms deaths rose to just above their 2019 values, whilst the number of jobs created from births remained a little below.

Firms that are newly born and those that die tend to be less productive than average, at least in the year of their birth or death. That implies lower births and higher deaths will raise average productivity in the short run, since there are fewer low-productivity firms in the economy than there would otherwise have been. Using labor productivity data derived from company accounts for the DMP sampling frame, we estimate that businesses incorporated since 2016 were around 30% less productive than average in their first year after incorporation and 10% less productive in years 2 and 3 (see Table A3). Firms who die are estimated to be 25% less productive than average in the last complete year before they exit. Although the sample is relatively small, this estimate is not significantly different for firms who died during the pandemic compared to those who died before it, and in fact the point estimate is slightly smaller.[28]

[28] The industry composition of births and deaths during the pandemic was broadly similar to before, with the exception of some increase in births in the retail sector. This is discussed in more detail by Bahaj et al. (2022).

Using deviations in the number of jobs created/lost by firm entry/exit from their 2019 averages and the above estimates of productivity differentials we calculate the effects of entry and exit on productivity in each quarter up to 2022 Q1. The effects are zero to one decimal place in most quarters, rising to +0.1% in 2022 Q1.[29] For the forward-looking aspect we assume that entry and exit rates remain at their 2022 Q1 values for the rest of 2022 before returning to 2019 rates in 2023. One risk to this assumption is that Covid does eventually lead to a large rise in firm failures, which have been postponed by the presence of Government support schemes. But this increase would have to be large and particularly concentrated amongst low-productivity firms to have a material impact on our estimates.

Overall impact

Bringing all of the different channels together, we estimate that Covid-19 has lowered TFP during the pandemic (see Figure 4). Although between effects have pushed up on TFP, our estimates suggest that between effects have been more than offset by lower within-firm TFP, partly associated with an increase in intermediate costs. Between 2020 Q2 and 2022 Q1, TFP is estimated to have been 3.6% lower, on average, because of Covid-19 than it otherwise would have been, with a peak impact of -5%. However, in the earlier part of the pandemic the magnitude of the offsetting positive between and negative within effects was much larger. The impacts are estimated to have become gradually less negative as the pandemic progressed with a small impact of around -0.5% expected to persist over the medium term (2023+).

[29] Figure A12 in the appendix shows the offsetting contributions from entry and exit.

The effects of Covid-19 on hourly labor productivity are estimated to have been more positive during the pandemic than those on TFP, because hours worked fell by more than elasticity-weighted capital and labor inputs (Figure 4). Labor productivity is estimated to have been around 1.5% higher, on average, between 2020 Q2 and 2022 Q1 with a peak impact of 10%. However, the estimated effect drops into negative territory from the middle of 2021, with a small negative impact of around 1% is expected to persist in the medium term.

Figure A13 in the Appendix shows 95% confidence intervals around our estimates which were generated by a bootstrapping exercise. Those confidence intervals are wider in the early part of the pandemic, but overall they show that that sampling error is unlikely to constitute a major source of uncertainty about our estimates.

Section 6: Sensitivity analysis

In this section of the paper we examine the sensitivity of our results to some of the key assumptions we make.

Interpretation of unit costs

Our baseline estimates of the within-firm impact of Covid-19 on productivity assume that, when DMP members respond to the question ‘what has been the impact of Covid-19 on unit costs’, they interpret unit costs to refer to intermediate input costs. Whilst this is a reasonable interpretation as a central case, an alternative interpretation is to assume that our respondents interpret `unit costs' to be the whole of the cost of production - variable labor, intermediates and perhaps overhead labor

and capital too. This could be in nominal or real terms, and - if the former - could have been deflated by what our respondents expect input or wage inflation to be.

To test the sensitivity of our results to this interpretation, we consider a case in which unit costs correspond to the full real costs of production in a Cobb-Douglas production function (such that cost shares are equal to elasticities). In this case we have:

$$dm_u = \alpha(1 - s_M)dk + \beta(1 - s_M)dl + s_M\, dm - \, dy$$

$$dv = \frac{dy - s_M dm_u}{(1 - s_M)}$$

$$= \, -\frac{dm_u - \alpha(1 - s_M)dk + \beta(1 - s_M)dl}{(1 - s_M)}$$

$$= \, \alpha dk + \beta dl - \frac{s_M dm_u}{(1 - s_M)}$$

From this it follows that

$$da = dv - \alpha dk - \beta dl$$

$$= -\frac{dm_u}{(1 - s_M)}$$

So in this very simple case, the change in value-added TFP at the firm level is just given by unit costs, scaled appropriately. Labor productivity is given by:

$$dv - dl = \alpha dk + \beta dl - \frac{dm_u}{(1 - s_M)} - dl$$

$$= \alpha(dk - dl) - \frac{dm_u}{(1 - s_M)}$$

where the last line assumes that the cost shares/elasticities of labor and capital in value added sum to unity.

Figure A14 shows how our central estimates of the impact of Covid-19 on productivity change under this interpretation of unit costs. The broad pattern of our estimates remains unchanged over the course of the pandemic, although the medium-term effects are more negative.[30]

Industry-level factor shares

When constructing our measure of TFP, the elasticities of output with respect to capital and labor are assumed to be 0.37 and 0.63 respectively, to align with their economy-wide factor shares. An alternative approach is to use industry-level factor shares. Panel B of Figure A14 in the Appendix shows that this makes little difference to our estimates of the aggregate impact of Covid-19 on TFP.

Quality adjustment

Our measures of firm-level value added and hence TFP are deflated by estimates of the impact of Covid on prices. However, it is possible that Covid has also had effects on the quality of goods and services sold – such as longer delivery times for goods or waits for services, for example –

[30] Panel A of Figure A14 shows how panel members estimate that around 20% of the rise in unit costs relates to capacity. That would be consistent with our central expectation that these costs primarily represent additional intermediate costs.

that are not reflected the price. In this case, measured output and hence productivity (be it labor productivity or total factor productivity) would be biased upward relative to true underlying productivity. So DMP respondents were asked to quantify, in terms of an equivalent change in the price, the extent to which the Covid pandemic had affected the quality of goods and services produces. 33% of firms said that Covid had reduced the quality of the services that they produce (where relevant) and 17% said that the quality of goods was lower (Figure 8 Panel A). Attaching some simple midpoints to the different response categories for this question and weighting goods and services appropriately implies that Covid may have lower the quality of output by around 1.3%.

Unmeasured inflation in the form of deteriorating product quality presents a downside risk to our estimates to the impact of Covid-19 on productivity. This is not a form of adjustment that will be easily picked up in official statistics. If the quality of output fell by 1.4%, that would translate into a 1.4% reduction in productivity in quality-adjusted space. Panel B of Figure 8 shows how that would lower our estimates of the impact of Covid on medium term TFP, if the effect were to persist. The effect of Covid on the quality of output, and therefore the implied effect on productivity also varies across industries. The effects are estimated to have been in largest in industries most affected by the pandemic such as accommodation and food and recreational services, whereas there is estimated to have been little effect in less affected industries such as finance and professional services.

Section 7: Conclusions

Covid is a global phenomenon that has reduced GDP and has important implications for productivity. Understanding these implications is imperative for public policymakers. Over the last decade US, UK and EU productivity growth rates have fallen below 1% a year, and the major impact from Covid-19 could push it into negative growth. We use an innovative approach to combine unique firm-level survey data on how Covid-19 has affected inputs and outputs with pre-Covid accounting data to estimate the impact of Covid-19 on productivity. While this paper presents a micro-data analysis of the impact of Covid-19 on productivity in the UK, it also gives an indication of the likely direction of the impact of Covid-19 in the US and other advanced European countries given the similar nature of the pandemic impact.

Our results suggest that Covid-19 has lowered *TFP* in the UK private sector by up to 5% during the pandemic. That reflects a large reduction in productivity within firms, partly because measures to contain Covid-19 increased intermediate costs, which is estimated to have been partially offset by a positive between-firm effect as low productivity sectors, and the least productive firms within them, were disproportionately affected and thus made a smaller contribution to the economy. In contrast, the overall effects of Covid-19 on hourly *labor productivity* are estimated to have been positive during the pandemic as capital inputs fell by less than labor inputs. The dynamics of the Covid-19 effect are also very notable. In earlier quarters these offsetting negative within and positive between firm effects are both estimated to have been larger.

Despite the large effects during the pandemic, firms' forecasts imply that Covid will not have a large lasting impact on aggregate TFP over the medium term. This is a striking result given the

size of the shock and the extent of the effects seen during the pandemic, and an important one for policymakers. However, unmeasured inflation in the form of deteriorating product quality presents downside risks to our estimates.

We also show how there has been substantial heterogeneity in the impact of Covid-19 on productivity across firms. That dispersion was most notable in the early part of the pandemic, but there are still expected to be winners and losers over the medium term. We show how firms where more of the work can be done from home and where sales involve less face-to-face contact with customers are most likely to have seen productivity increase, whereas more consumer facing firms, where increases in costs have been larger, are more likely to have seen productivity fall.

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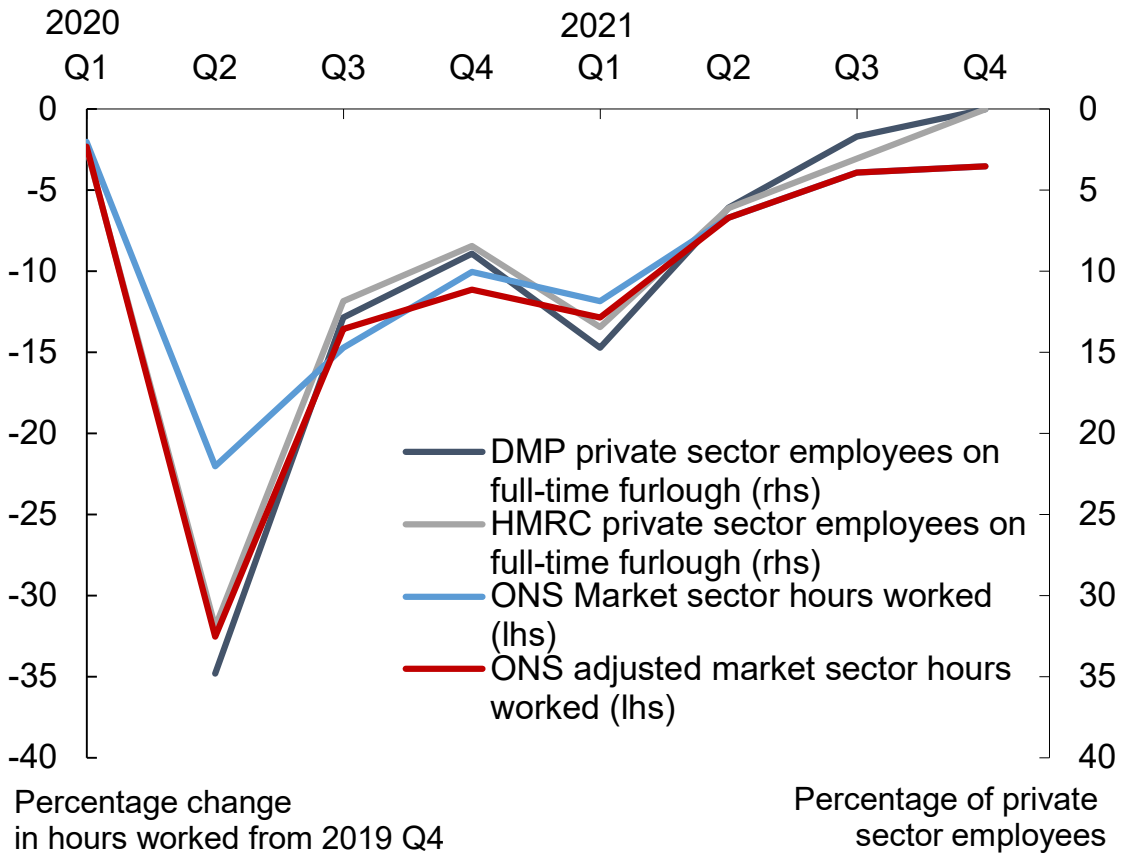
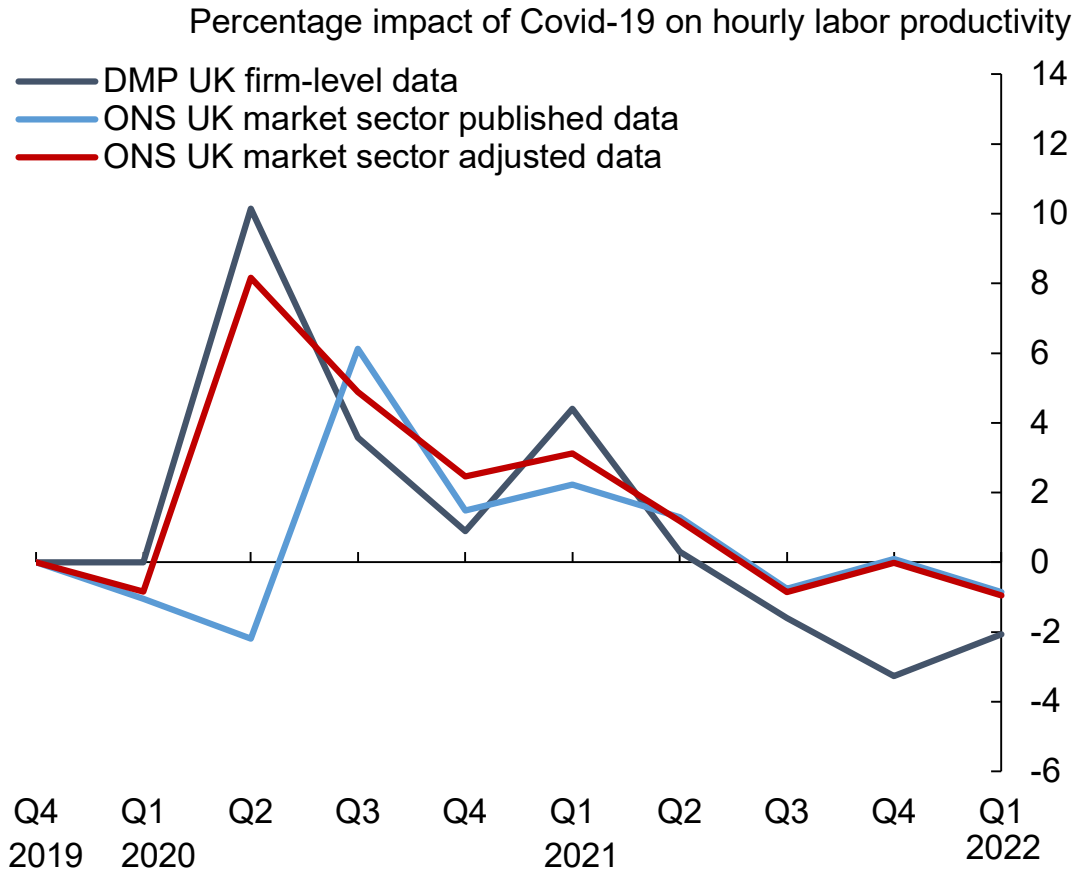
Appendix

Figure A1: Measures of hours worked and implications for productivity

Panel A: Hours worked and furlough

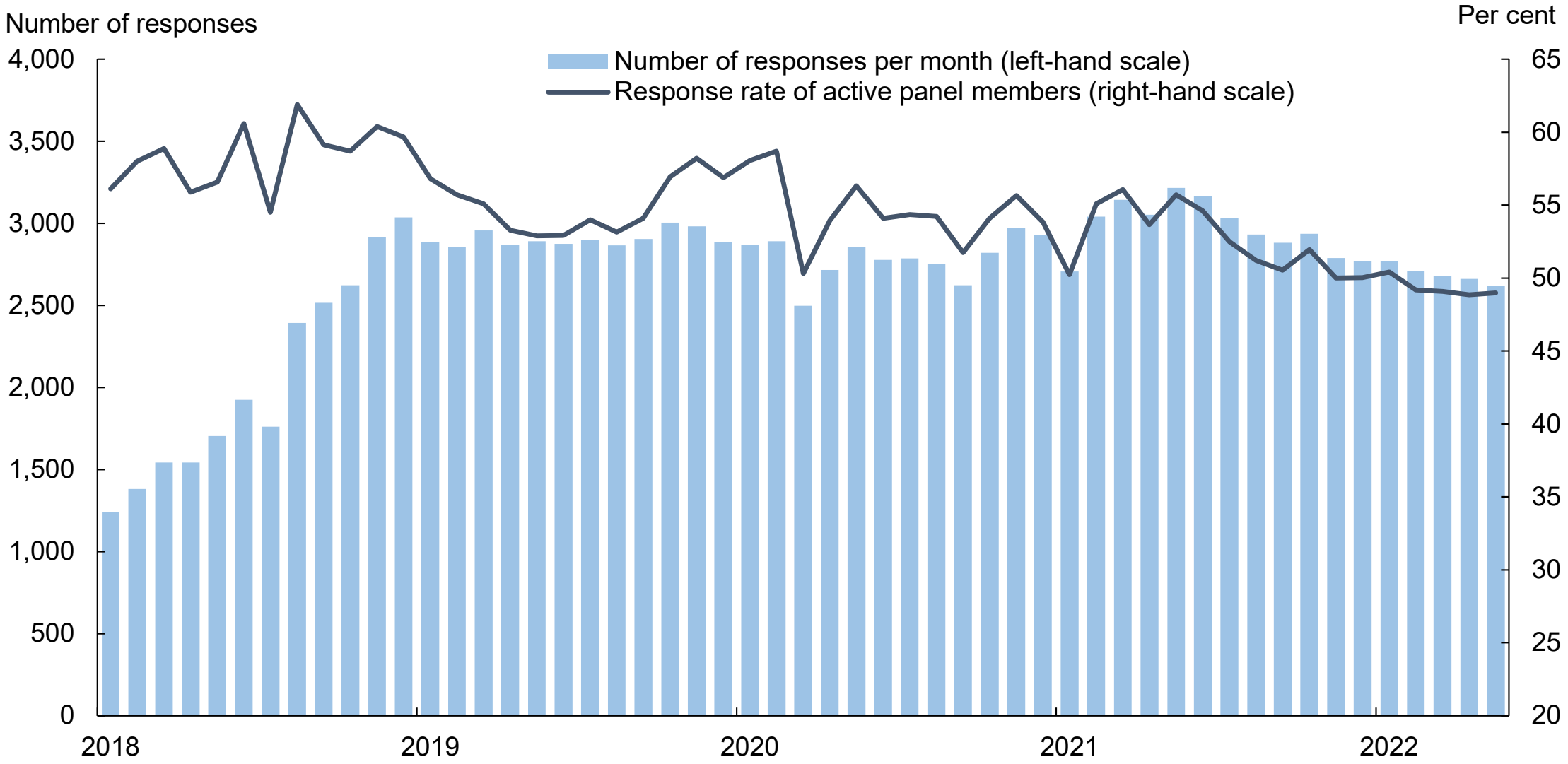


Panel B: UK labor productivity



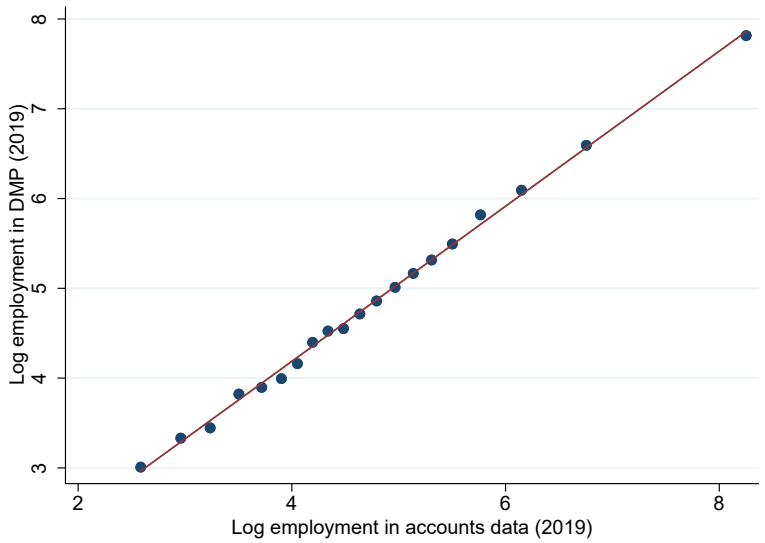
Notes: ONS adjusted hours worked are based on an experimental series that imputes missing values for hours worked during the Covid pandemic using people with similar characteristics rather than by carrying forward previous (often pre-Covid) responses for that person. See ONS (2021) for more details. The experimental hours series is only available for the whole economy. We assume the percentage difference between the published and adjusted series are the same for the market sector and the whole economy.

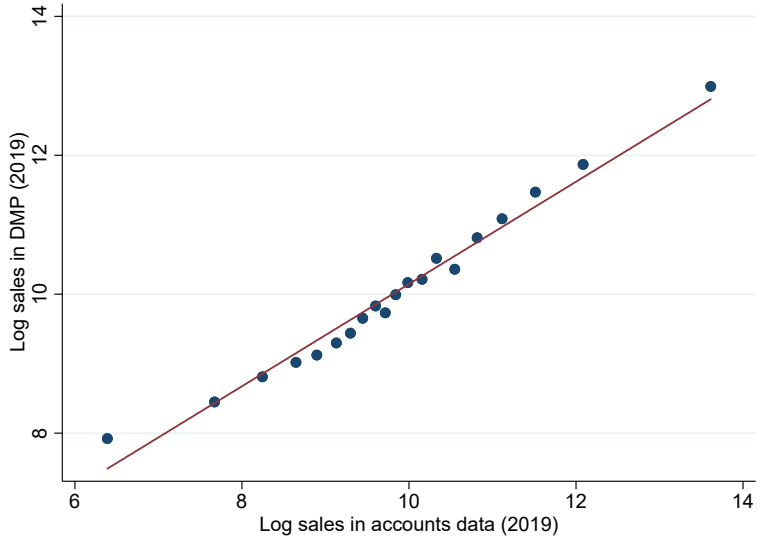
Figure A2: DMP response rate

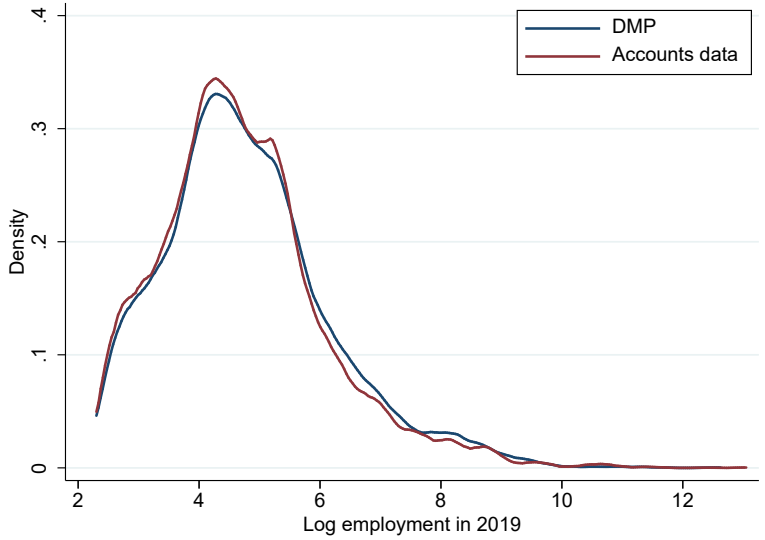


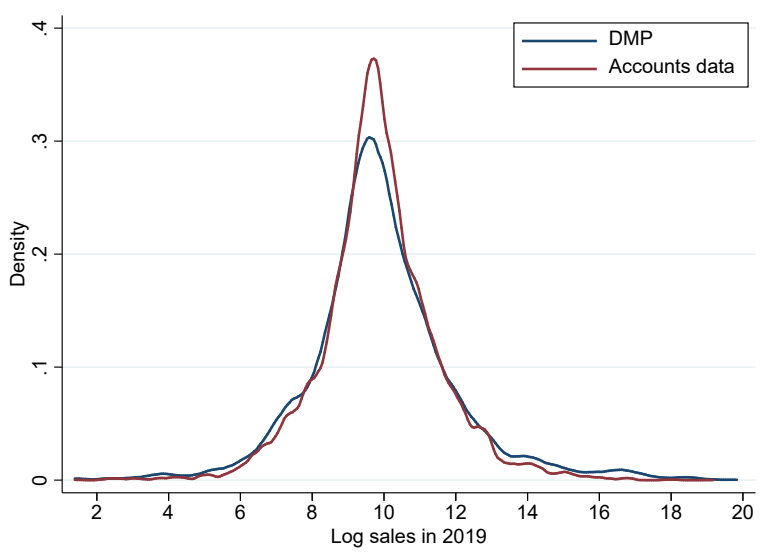
Notes: The response rate of active panel members is calculated as the percentage of panel members who had completed at least one survey over the last twelve months who responded to the survey in a given month.

Figure A3: DMP data versus company accounts data



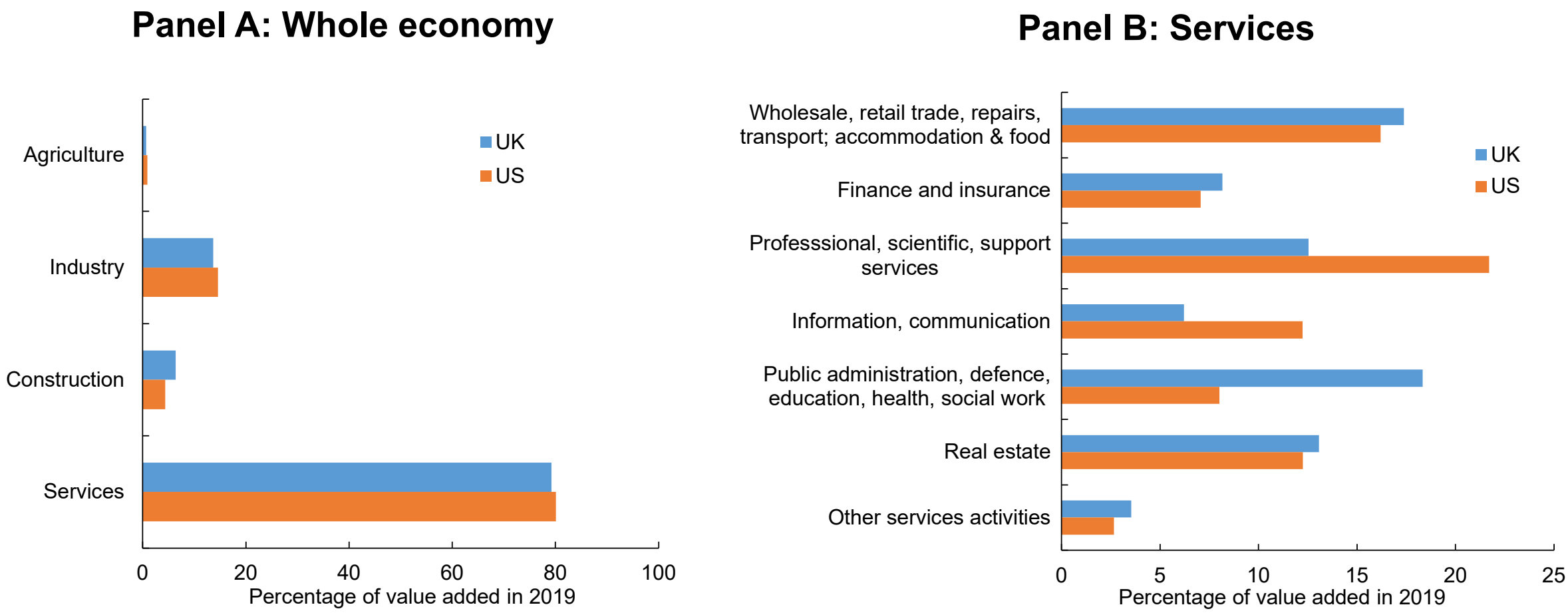






Notes: Sales values from the DMP survey are based on annualised quarterly sales reported by businesses plotted here against Bureau Van Dijk company accounts data. The dots on the top charts each represent 5% of observations, grouped by log employment/sales from accounts data in 2019.

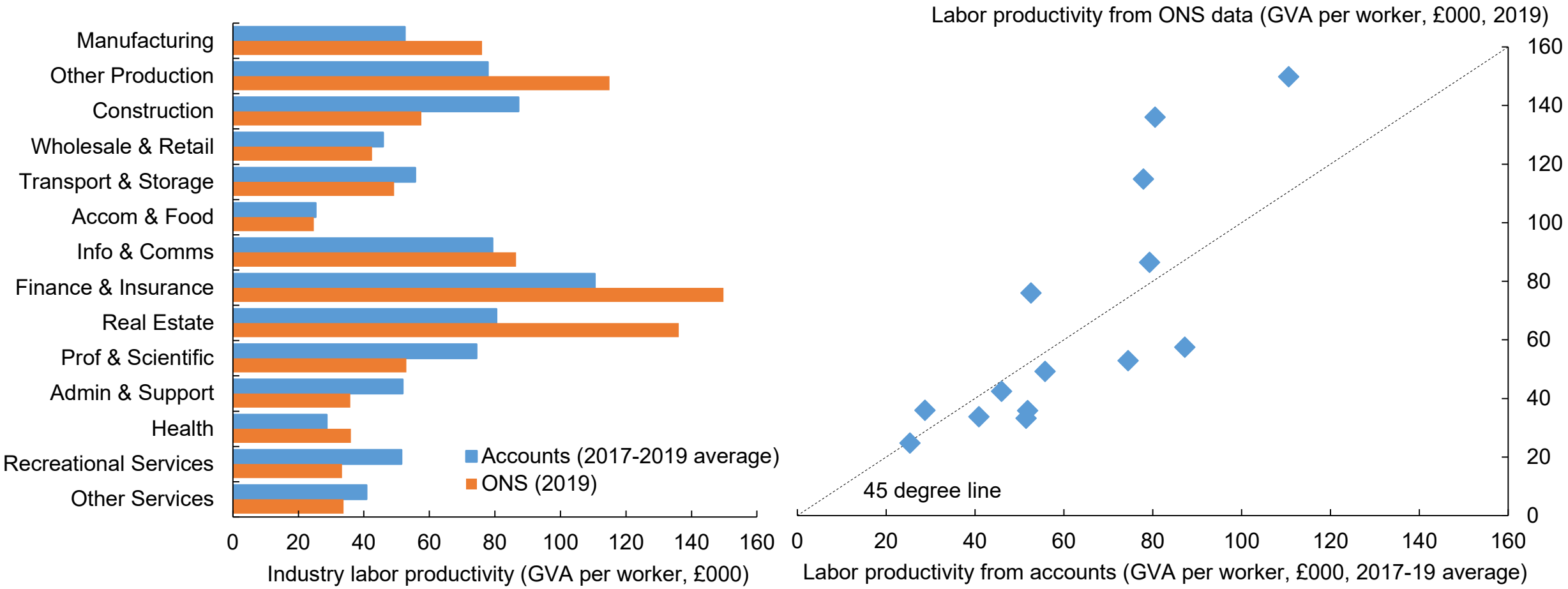
Figure A4: Industrial composition of the UK and US economies



Notes: Data are from OECD (2022), Value added by activity (indicator). doi: 10.1787/a8b2bd2b-en (Accessed on 21 June 2022)

Figure A5: Example survey question on impact of Covid-19

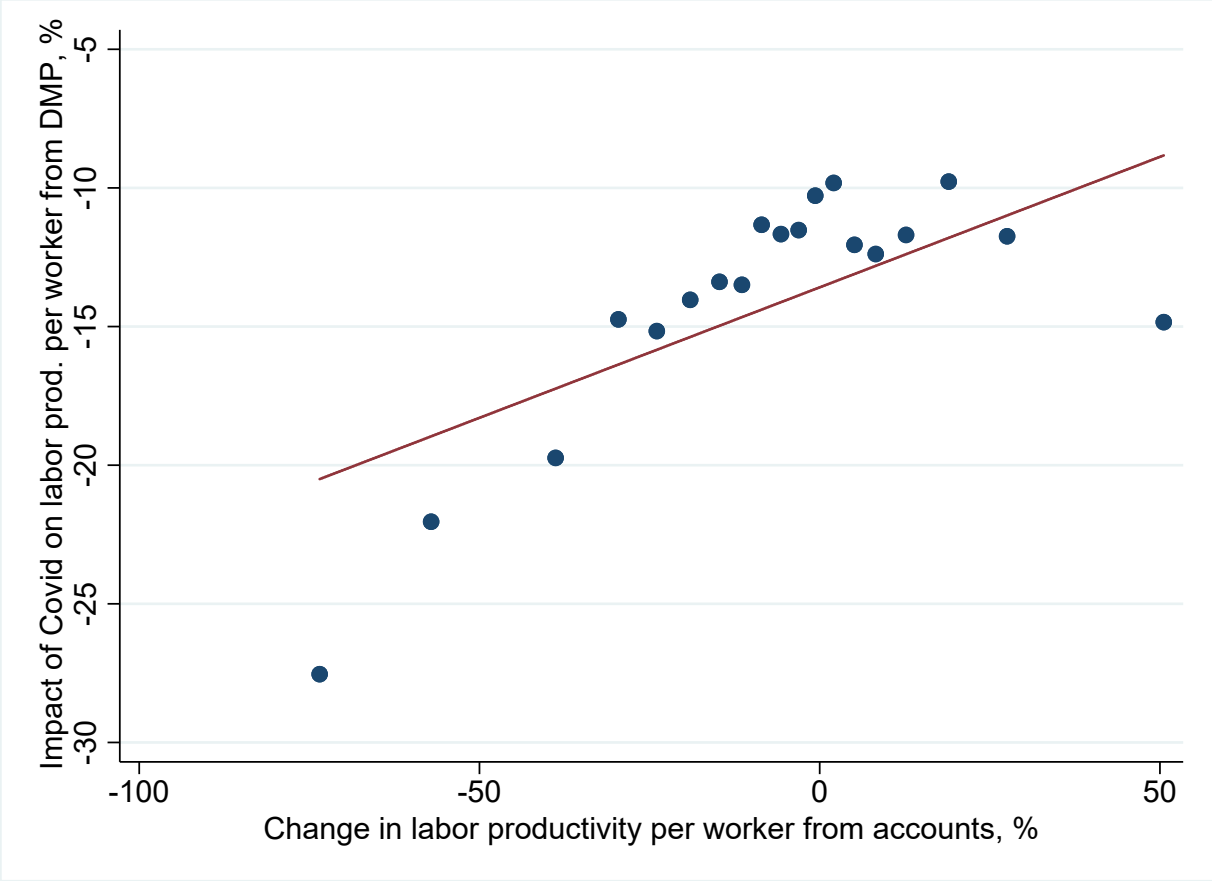
Figure A6: Different measures of industry-level labor productivity



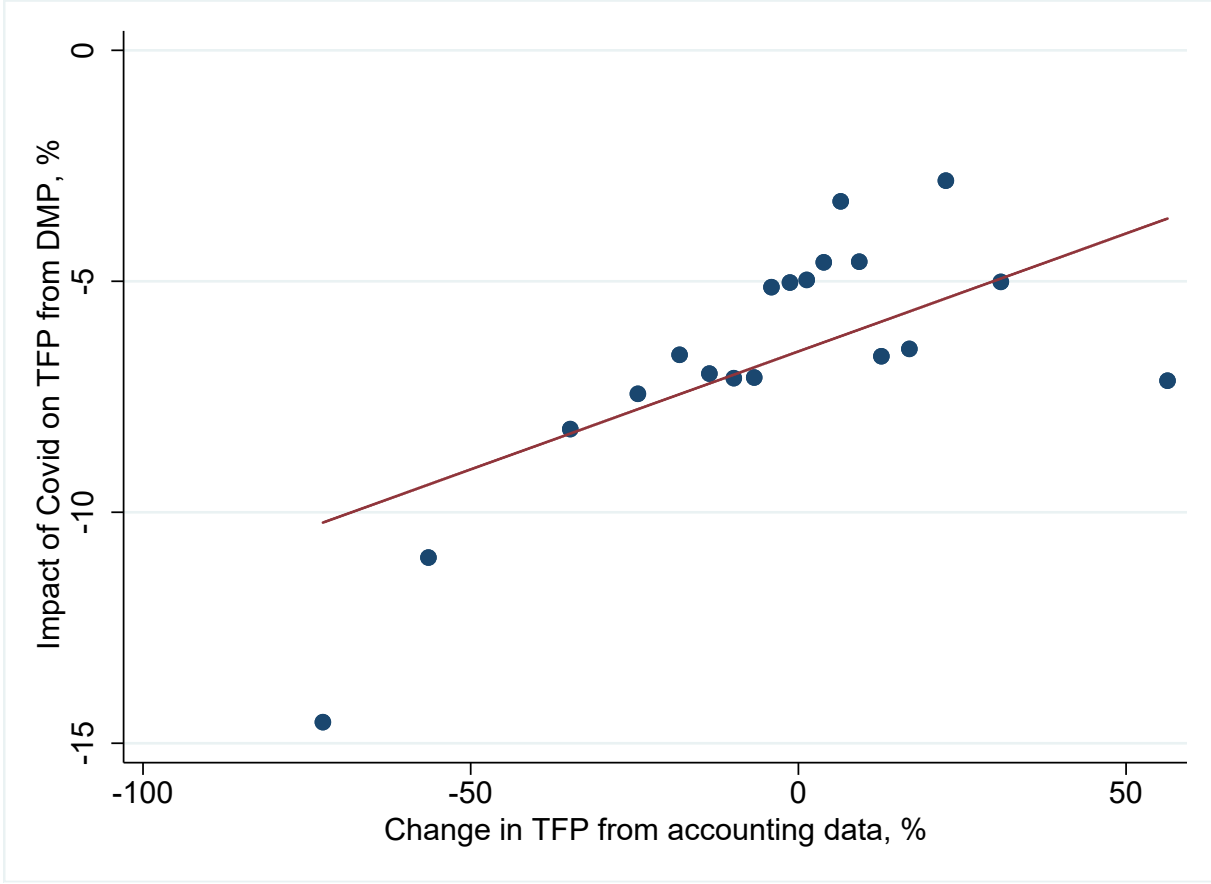
Notes: Labor productivity from company accounts is defined as real value-added (operating profits plus total labor costs divided by the aggregate GDP deflator, at 2019 prices) per employee using accounting data from Bureau Van Dijk FAME database.

Figure A7: Productivity from DMP and accounts during financial year 2020

Panel A: Labor productivity per worker



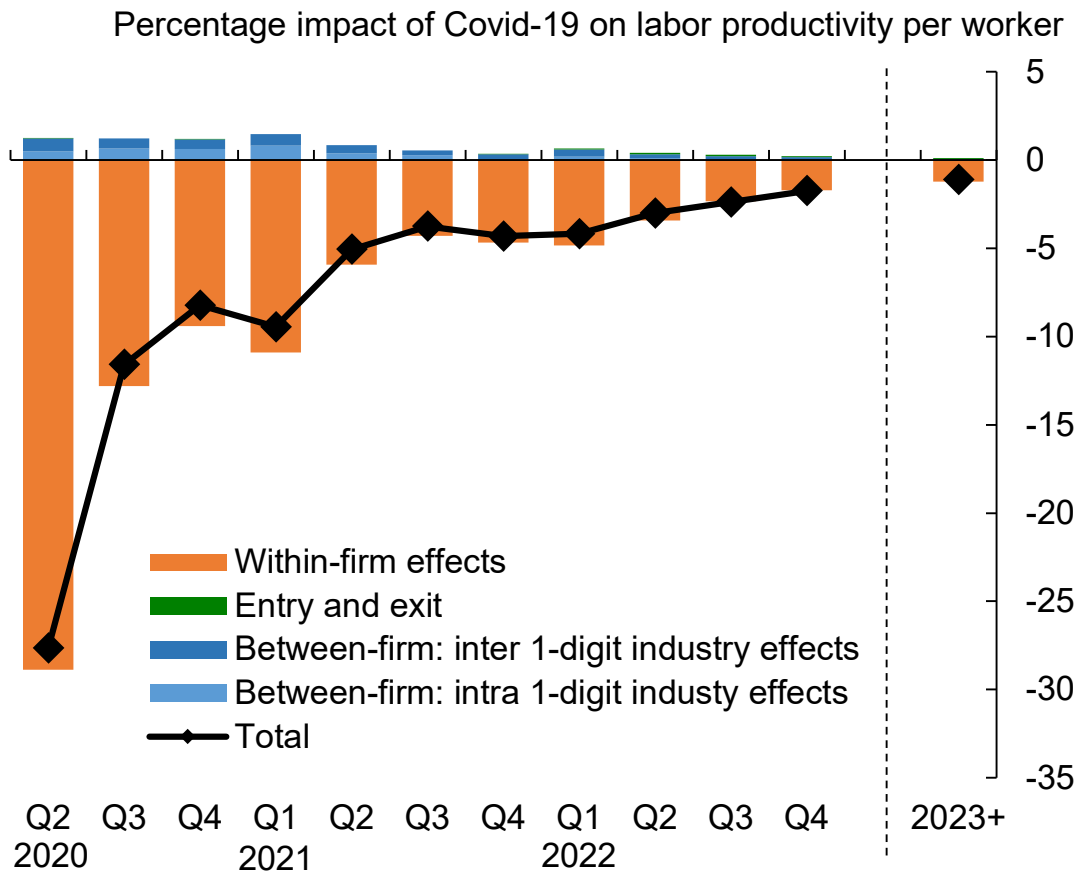
Panel B: TFP



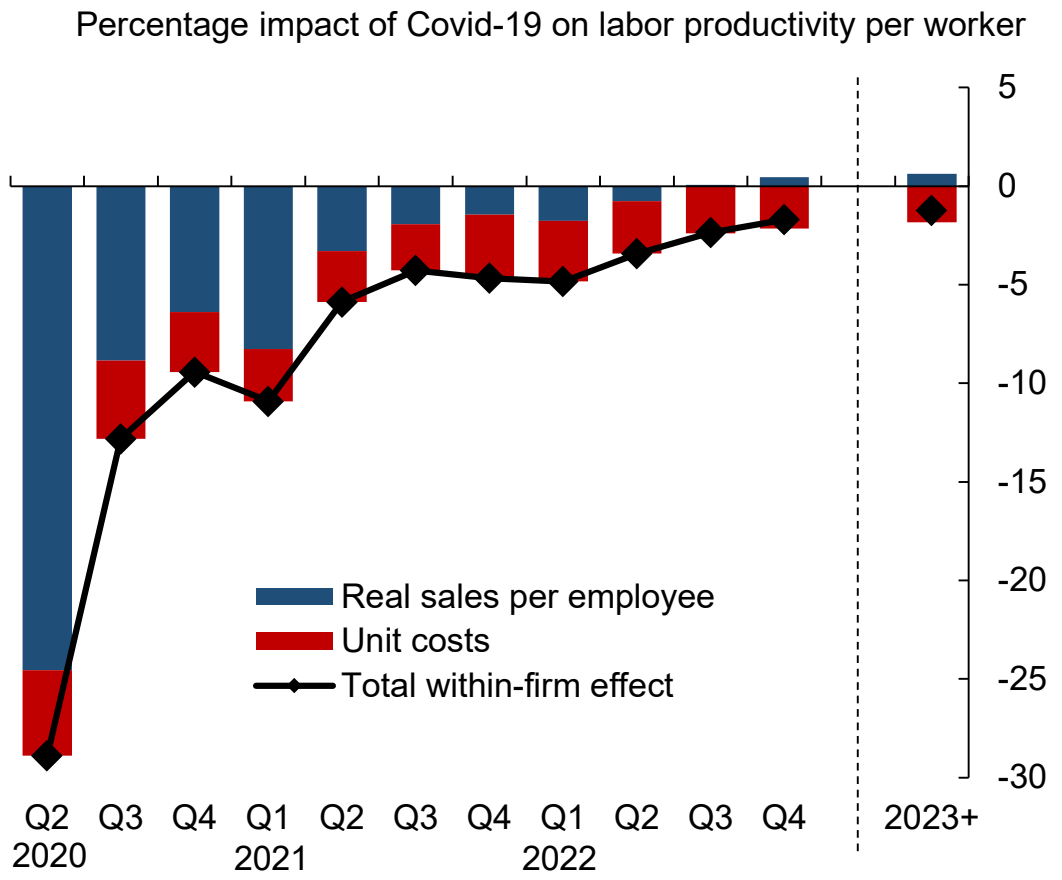
Notes: Accounting data used for the year ending between 1 April 2020 and 31 March 2021. DMP data are adjusted to correspond to the same four quarters as the accounting data for each firm. Accounting data were only available for around 80% of the sample at the time of writing. DMP data are a marginal impact of Covid-19 whereas the accounting data represent the overall percentage change from the previous financial year. The dots each represent 5% of observations, grouped by the change in productivity from accounts data.

Figure A8: Impact of Covid-19 on labor productivity per worker (including furloughed workers)

Panel A: Overall impact



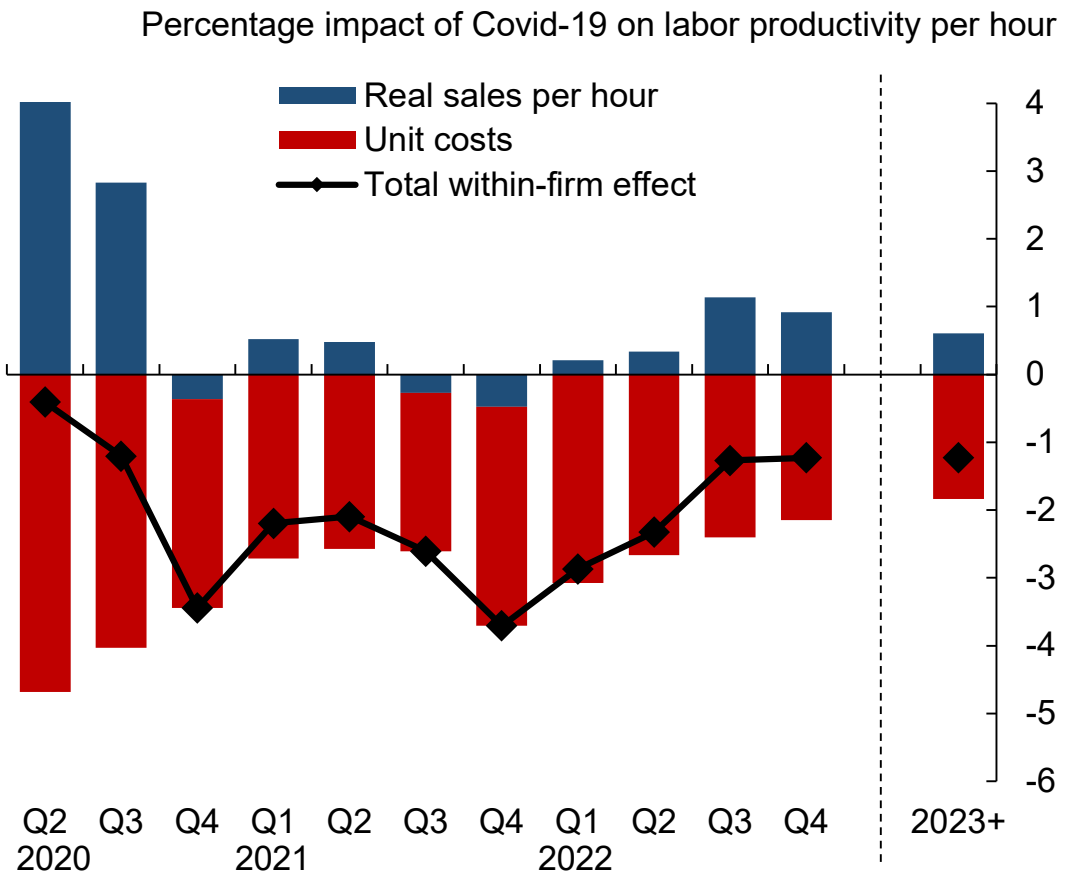
Panel B: Contributions to within-firm effect



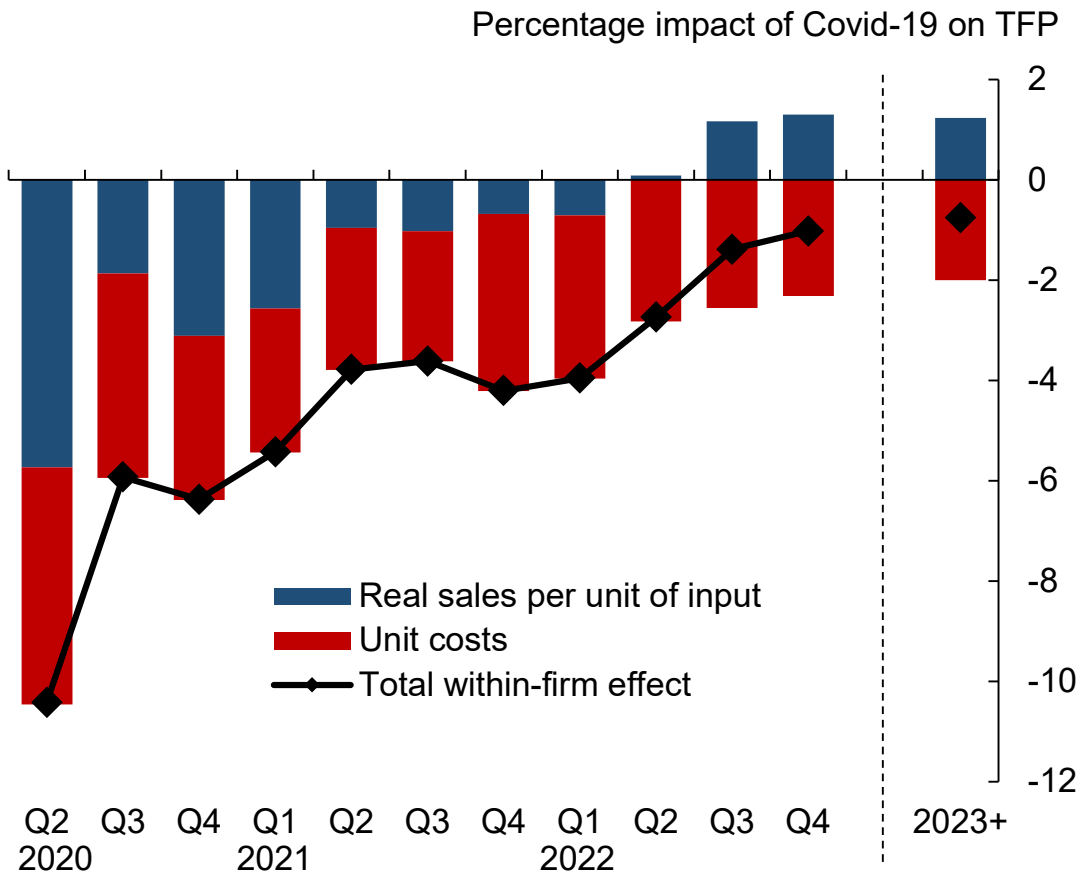
Notes: Impacts on productivity for surviving firms are estimated as $\Delta\Pi_t = \sum_{i\in Surv} \bar{\varphi}_i \Delta\pi_{i,t} + \sum_{i\in Surv} \Delta\varphi_{i,t}(\overline{\pi_t} - \overline{\Pi})$ where $\pi_{i,t}$ is productivity in firm i at time t, Π_t is productivity at time t, $\varphi_{i,t}$ is the labor input share of firm i at time t and a bar over a variable indicates the average of the variables across times t-1 and t. Changes between t and t-1 are changes due to Covid-19 only. The first term represents the within-firm effects. The second term represents between-firm effects. The impact of Covid-19 on labor productivity for each firm is calculated as $\frac{dLP}{LP} = \frac{dY}{Y} - \frac{dP}{P} - \frac{dL}{L} - \frac{dM}{M}$ $where \frac{dM}{M} = \frac{M}{Y-M}\frac{dM^U}{M^U}$. LP is labor productivity, Y is nominal sales, P is the price level, L is labor input, M are non-labor intermediate costs and M^U are intermediate unit costs.

Figure A9: Contributions to impact of Covid-19 on within-firm productivity

Panel A: Labor productivity per hour

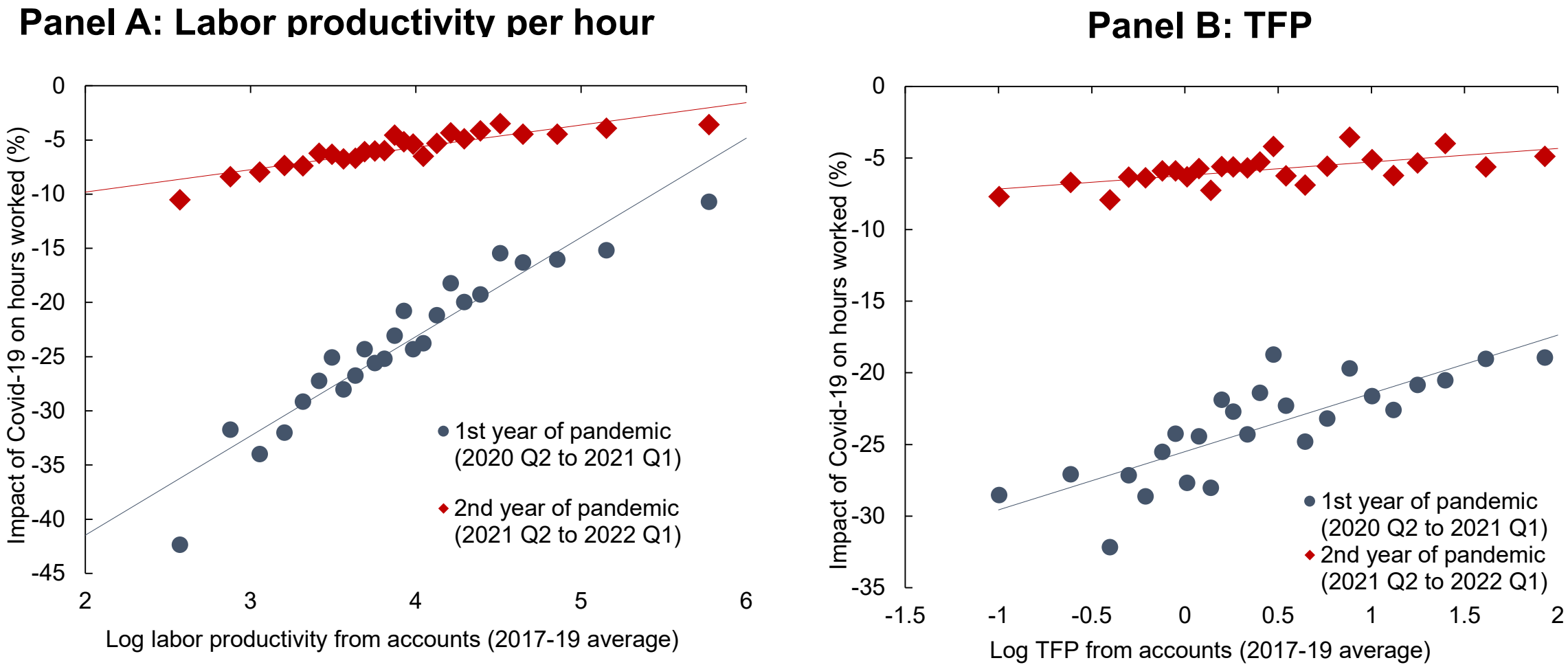


Panel B: TFP



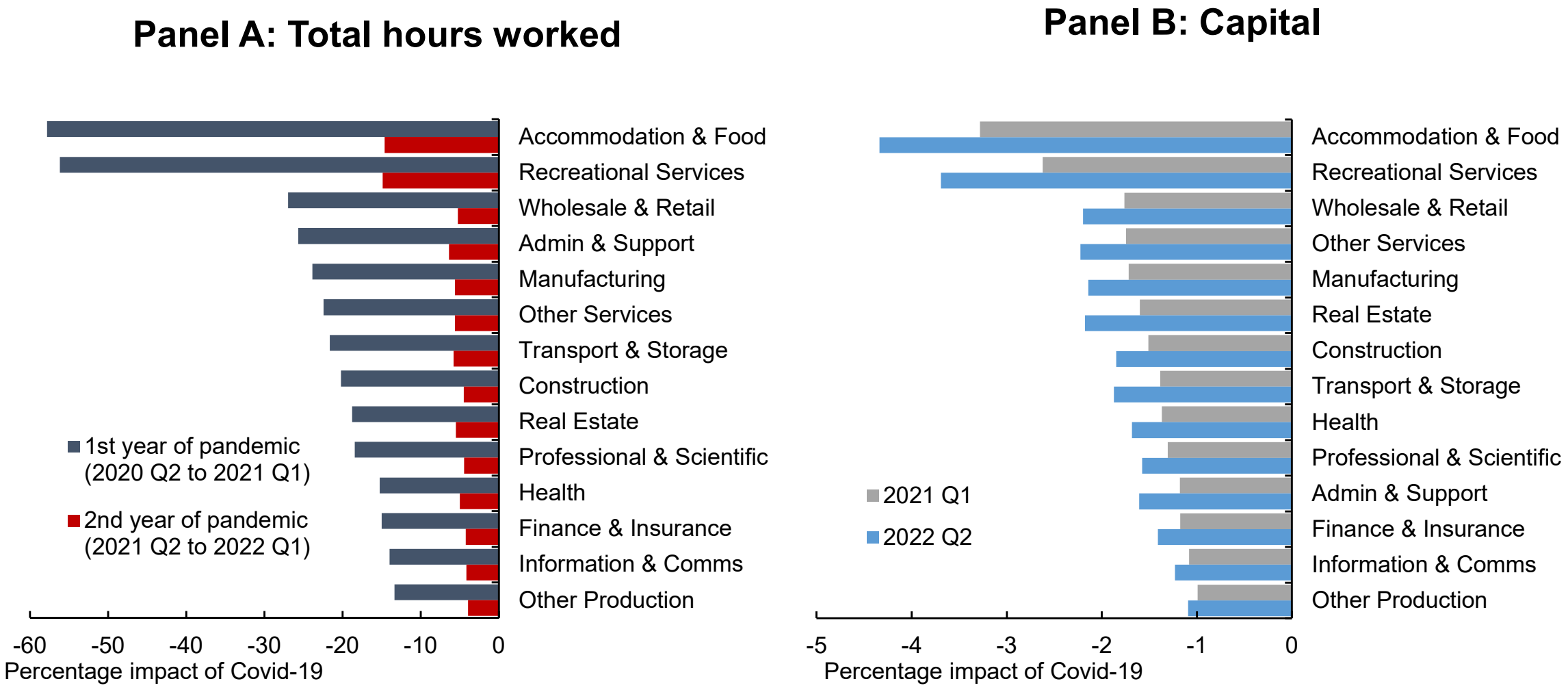
Notes: See notes to Figure 4 for details on how the impact of Covid-19 on within-firm productivity is calculated.

Figure A10: Impact of Covid-19 on hours worked and pre-Covid productivity



Notes: See notes to Figure 3 for details on how impact of Covid-19 on hours worked is calculated. Labor productivity is defined as real value-added (operating profits plus total labor costs divided by the aggregate GDP deflator) per employee. TFP is calculated as the residual from a production function $\ln(Y_{it}) = 0.63\ln(L_{it})+0.37\ln(K_{it})$ where Y_{it} is real value-added of firm i in year t, L is labor input (total real labor costs) and K is capital (total real fixed assets). Uses accounting data from Bureau Van Dijk FAME database. Nominal values from accounting data are deflated using the GDP deflator.

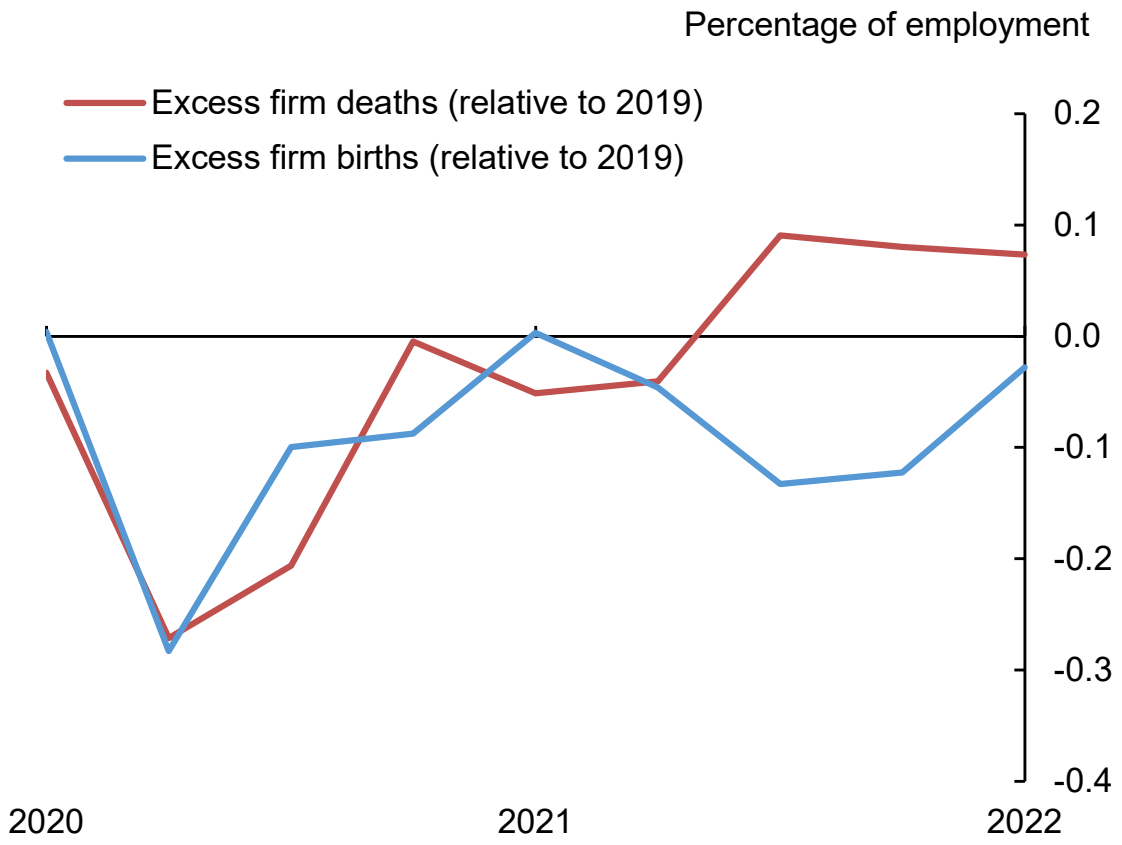
Figure A11: Impact of Covid-19 on hours worked and capital by industry



Notes: See notes to Figure 3 for details on how impact of Covid-19 on hours and capital worked is calculated.

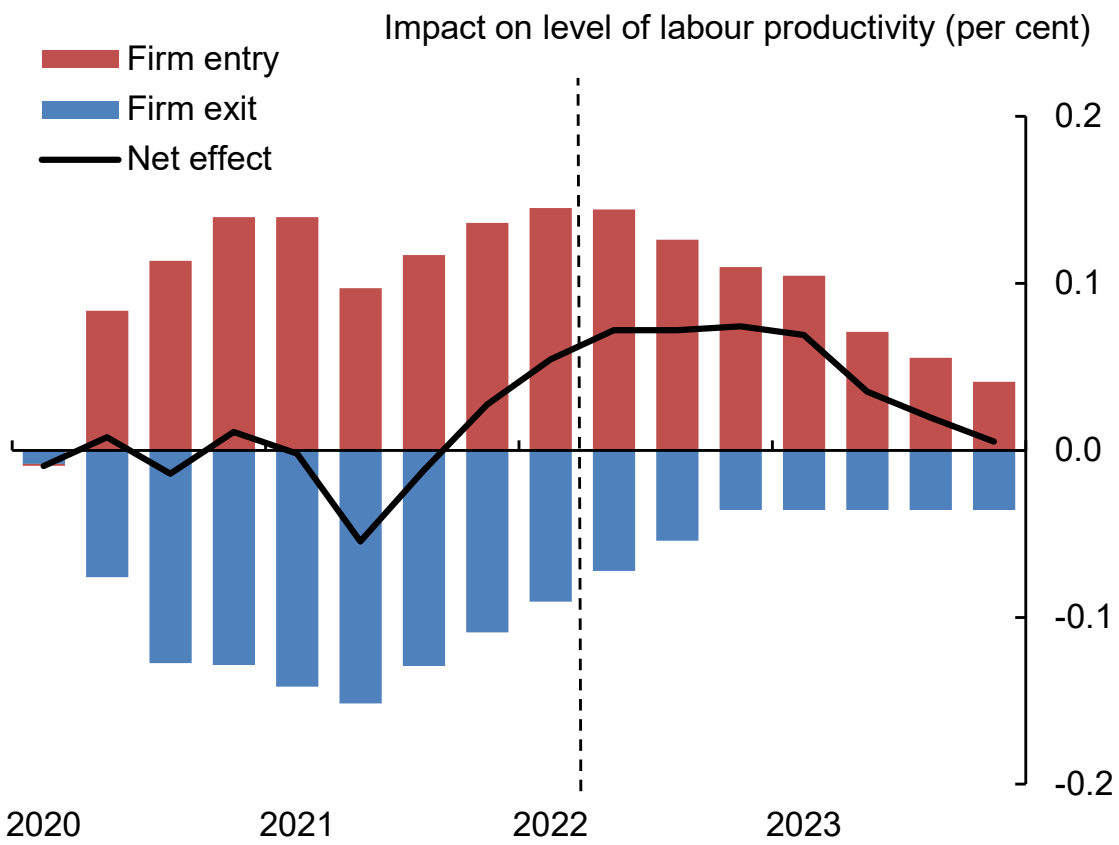
Figure A12: Firm entry/exit and impact on productivity

Panel A: Changes in firm entry/exit relative to 2019



Notes: Firm birth and death rate data are from the Office for National Statistics. These data have been seasonally adjusted by the authors.

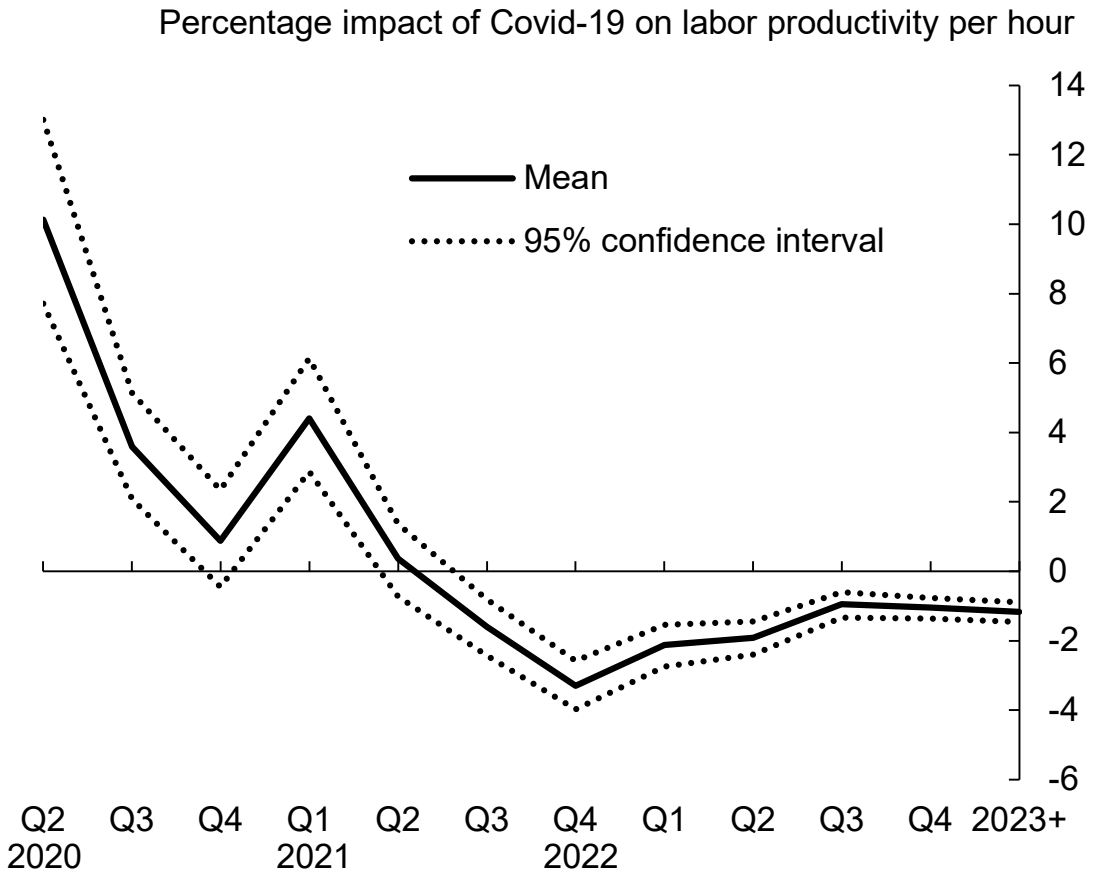
Panel B: Impact of changes in firm entry/exit (relative to 2019) on productivity



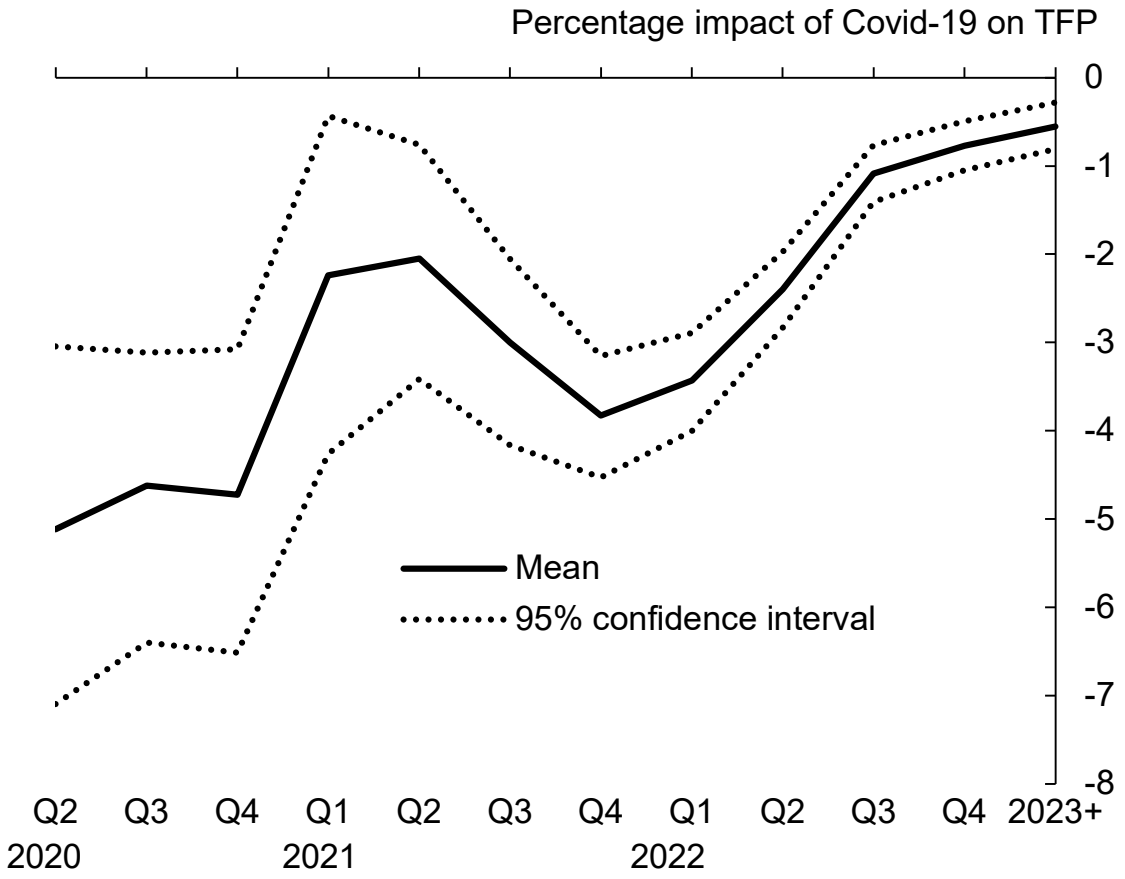
Notes: These calculations use the data shown in panel A and assume that excess firm entry/exit remains at its 2022 Q1 level before returning to zero thereafter. Based on the regressions in Table A3, firms who enter are assumed to be 30% less productive than average in their first year and 10% less productive in their second and third years, whilst firms who exit are assumed to be 25% less productive than average.

Figure A13: Confidence intervals around estimated productivity impacts

Panel A: Labour productivity per hour



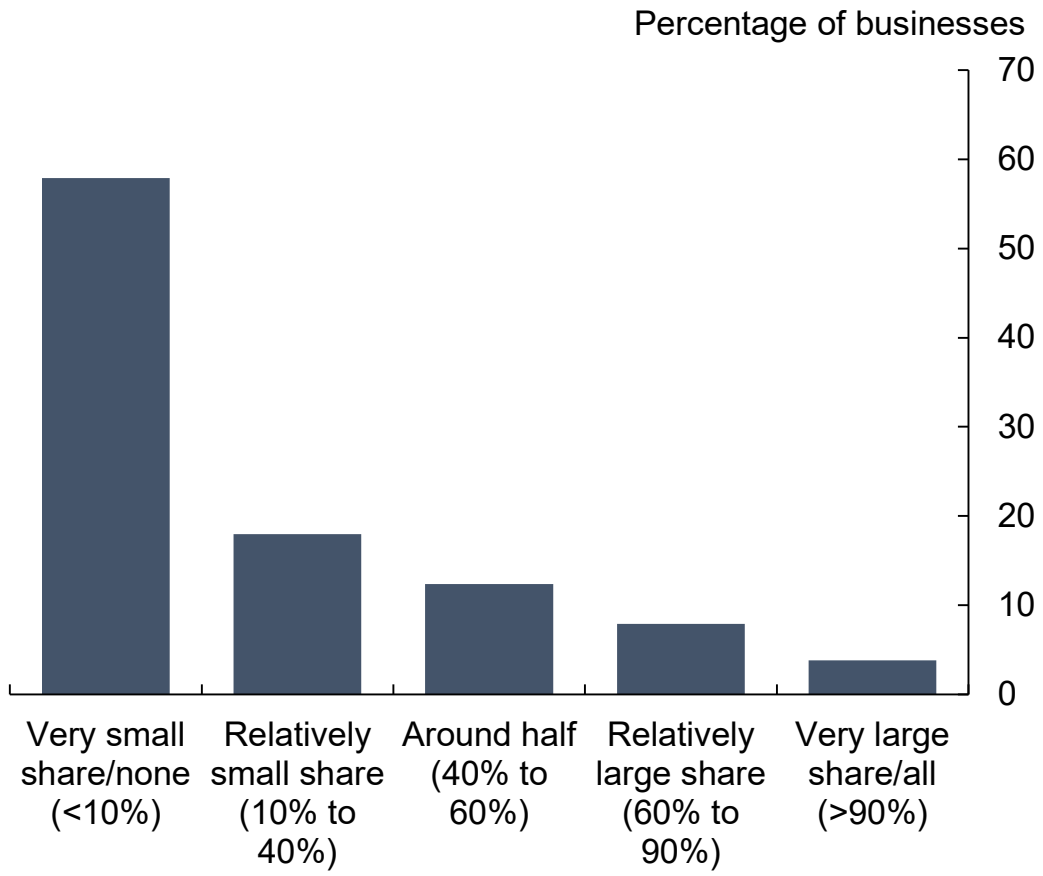
Panel B: TFP



Notes: See notes to Figure 4 for further details on how the impact of Covid-19 on productivity is calculated. Confidence intervals are estimated from a bootstrapping exercise that draws 1000 different samples with replacement.

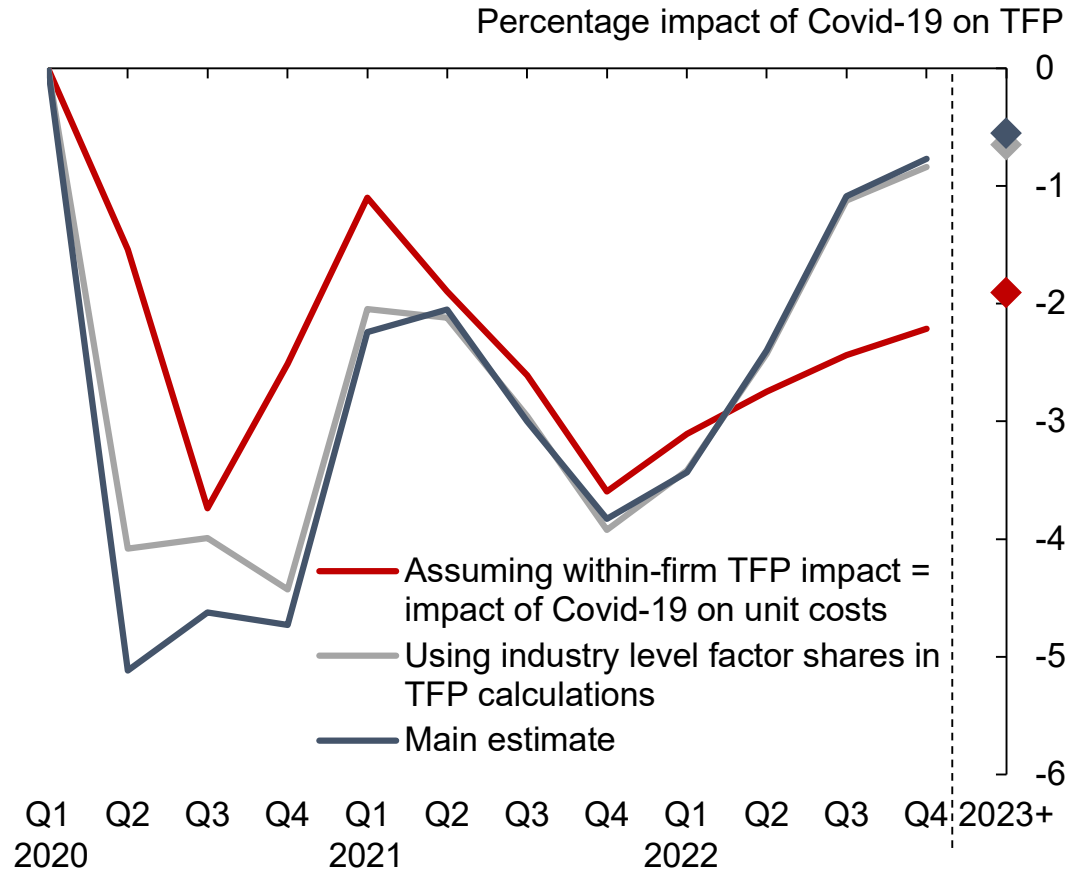
Figure A14: TFP impacts sensitivity analysis

Panel A: Percentage of additional unit costs accounted for by capacity constraints (2021 Q4 data)



Notes: Based on the question: 'Approximately how much of the Covid-related increase in your unit costs in 2021 Q4 is due to reductions in your capacity?'. Data were collected between November 2021 and January 2022.

Panel B: Impact of Covid-19 on TFP



Notes: In the alternative scenario, the impact of Covid-19 on TFP within firms is assumed to be equal to the impact of Covid-19 on unit costs reported by respondents (as shown in Figure 3). The impact of Covid-19 on TFP is otherwise calculated as shown in the notes to Figure 4.

Table A1: Linear probability models for propensity to respond to the DMP

Sample period	Mar 20 - Apr 22	Jan 19 - Apr 22	
	(1)	(2)	(3)
Industry impact of Covid on sales (2020 Q2 to 2022 Q1 average)	0.0001		
	(0.0001)		
Ln(Pre-Covid labor productivity)			0.0039***
			(0.0015)
Industry impact of Covid on sales (2020 Q2 to 2022 Q1 average) interacted with Covid period dummy variable		-0.0001	
		(0.0001)	
Ln(Pre-Covid labor productivity) interacted with Covid period dummy variable			-0.0003
			(0.0010)
Survey wave dummies	Yes	Yes	Yes
3 digit industry dummies	No	Yes	Yes
Observations	1,254,110	1,568,760	1,568,760
R-squared	0.006	0.015	0.015

Notes: Linear probability model for whether a firm in the sampling frame responds to the DMP survey in each month between January 2019 and April 2022 (1=responded to DMP, 0=Not responded). Firm characteristics are averages of 2017 to 2019 accounts data from Bureau Van Dijk FAME database. Labor productivity is defined as real value-added (operating profits plus total labor costs divided by the aggregate GDP deflator) per employee using accounting data. Industry impacts of Covid on sales are at the 1 digit industry level. Regressions only includes firms who were part of the sampling frame in January 2019. Equations 2 and 3 are restricted to firms who have productivity data available from company accounts. Covid period dummy variable takes the value of one for March 2020 to April 2022. All equations are estimated by OLS. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table A2: Summary of estimated impact of Covid-19 on productivity

	2020 Q2	2020 Q3	2020 Q4	2021 Q1	2021 Q2	2021 Q3	2021 Q4	2022 Q1	2022 Q2	2022 Q3	2022 Q4	2023+
Labor Productivity per hour												
Within Firms	-0.4	-1.2	-3.4	-2.2	-2.1	-2.6	-3.7	-2.9	-2.3	-1.3	-1.2	-1.2
Between Continuing Firms	10.5	4.8	4.3	6.6	2.5	1.0	0.4	0.7	0.4	0.3	0.2	0.1
o/w inter industry effects	*6.2*	*2.9*	*2.8*	*3.4*	*1.5*	*0.5*	*0.3*	*0.5*	*0.3*	*0.2*	*0.2*	*0.1*
o/w intra industry effects	*4.3*	*1.9*	*1.6*	*3.2*	*1.0*	*0.6*	*0.1*	*0.2*	*0.1*	*0.1*	*0.0*	*0.0*
Firm entry and exit	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0
o/w entry	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
o/w exit	*-0.1*	*-0.1*	*-0.1*	*-0.1*	*-0.2*	*-0.1*	*-0.1*	*-0.1*	*-0.1*	*-0.1*	*0.0*	*0.0*
Total	10.1	3.6	0.9	4.4	0.4	-1.6	-3.3	-2.1	-1.9	-1.0	-1.0	-1.1
Total Factor Productivity												
Within Firms	-10.4	-5.9	-6.4	-5.4	-3.8	-3.6	-4.2	-4.0	-2.7	-1.4	-1.0	-0.8
Between Continuing Firms	5.3	1.3	1.6	3.2	1.7	0.6	0.4	0.5	0.3	0.3	0.2	0.2
o/w inter industry effects	*3.1*	*1.6*	*1.4*	*1.9*	*1.0*	*0.3*	*0.2*	*0.3*	*0.2*	*0.2*	*0.1*	*0.1*
o/w intra industry effects	*2.2*	*-0.3*	*0.2*	*1.3*	*0.8*	*0.3*	*0.1*	*0.3*	*0.2*	*0.1*	*0.1*	*0.1*
Firm entry and exit	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0
o/w entry	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
o/w exit	*-0.1*	*-0.1*	*-0.1*	*-0.1*	*-0.2*	*-0.1*	*-0.1*	*-0.1*	*-0.1*	*-0.1*	*0.0*	*0.0*
Total	-5.1	-4.6	-4.7	-2.2	-2.0	-3.0	-3.8	-3.4	-2.4	-1.1	-0.8	-0.5

Notes: See notes to Figure 4 for further details on how the impact of Covid-19 on productivity is calculated. Inter and intra industry effects are for 1 digit industries.

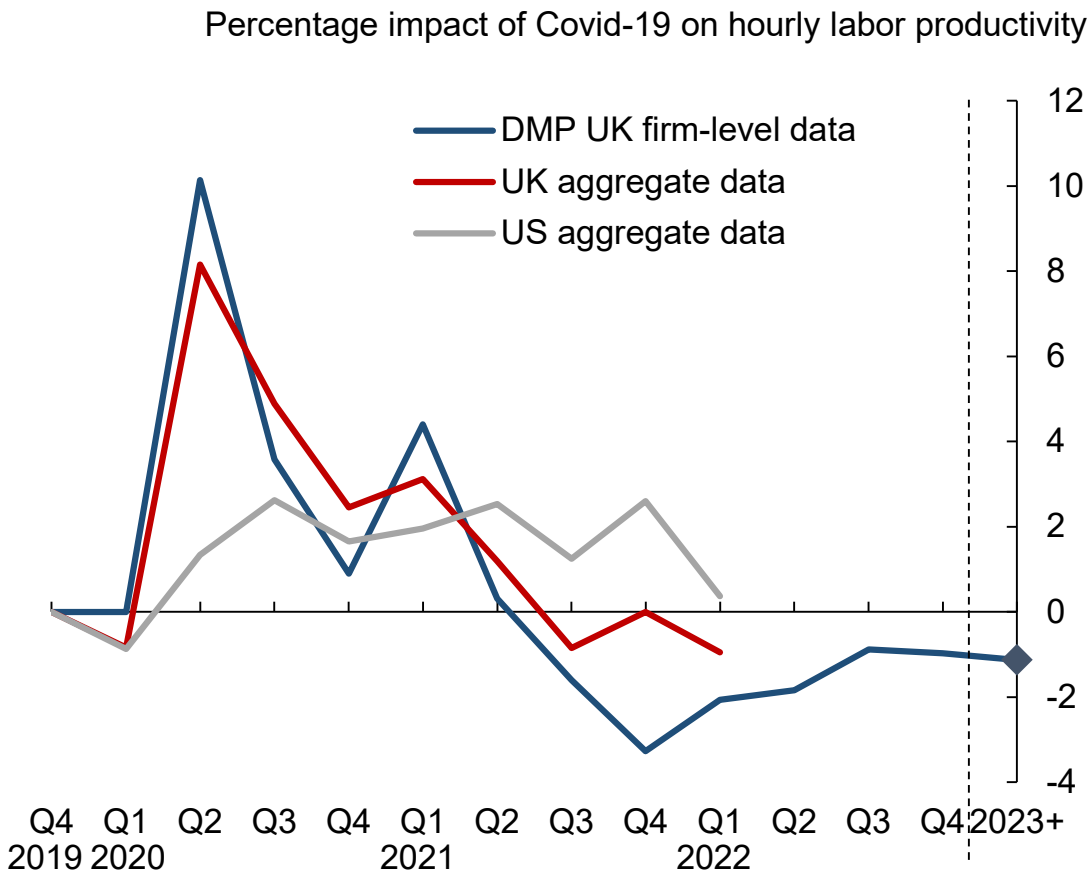
Table A3: Firm entry/exit and productivity

Dependent variable: Log labor productivity All equations estimated from 2016 to 2021	(1)	(2)	(3)	(4)
New firm in 1st year	-0.321***	-0.324***		
	(0.022)	(0.023)		
New firm in 2nd year		-0.114***		
		(0.020)		
New firm in 3rd year		-0.114***		
		(0.021)		
Firm in last year before failure			-0.251***	
			(0.026)	
Firm in last year before failure: failed pre-pandemic				-0.268***
				(0.030)
Firm in last year before failure: failed during pandemic				-0.181***
				(0.054)
Year fixed effects	Yes	Yes	Yes	Yes
Test coefficient is the same pre/during pandemic (p value)	-	-	-	0.16
Observations	184,090	184,090	184,090	184,090

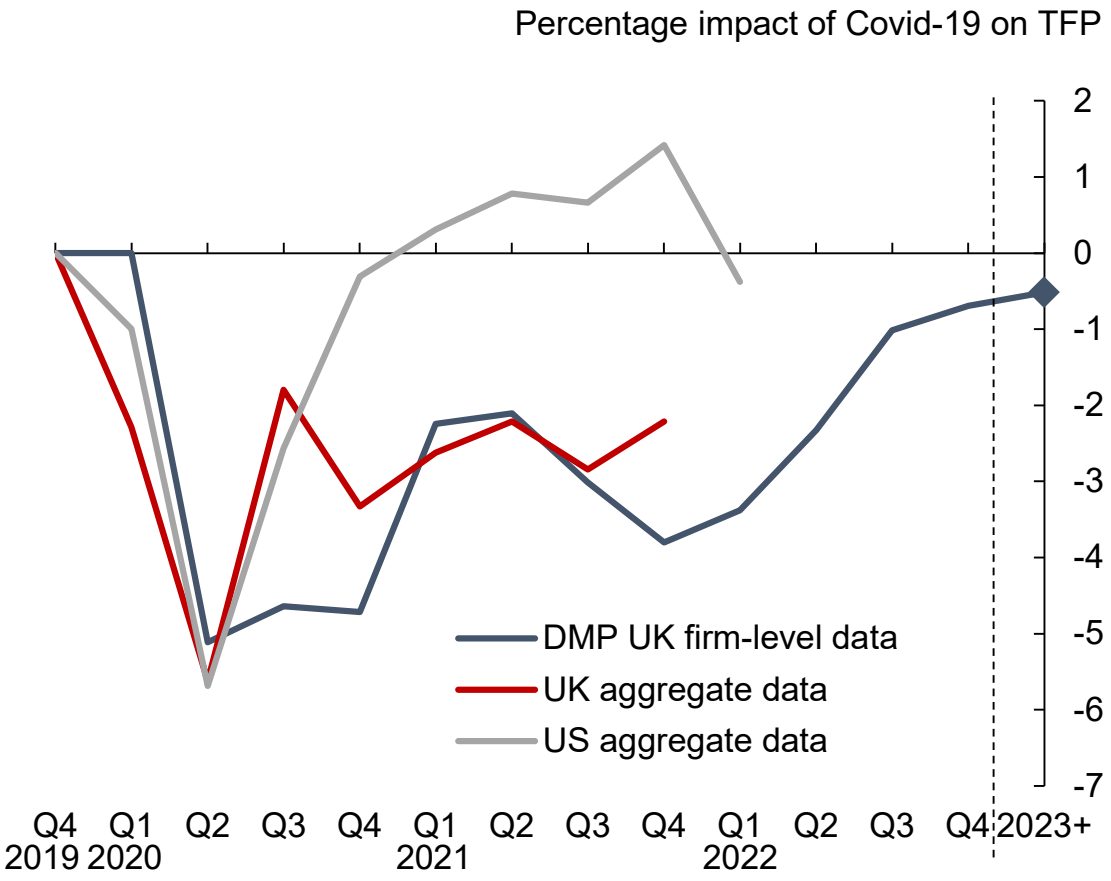
Notes: All regressions are weighted using employment data. Labor productivity is defined as real value-added (operating profits plus total labor costs divided by the aggregate GDP deflator) per employee using accounting data from Bureau Van Dijk FAME database. New firms entering are mostly firms who where incorporated before the start of the Covid pandemic. There was insufficient data available at the time of writing to test whether firms who entered during the pandemic had higher or lower productivity than those who entered before it.

Figure 1: Estimates of the impact of Covid-19 on productivity

Panel A: Labour productivity per hour

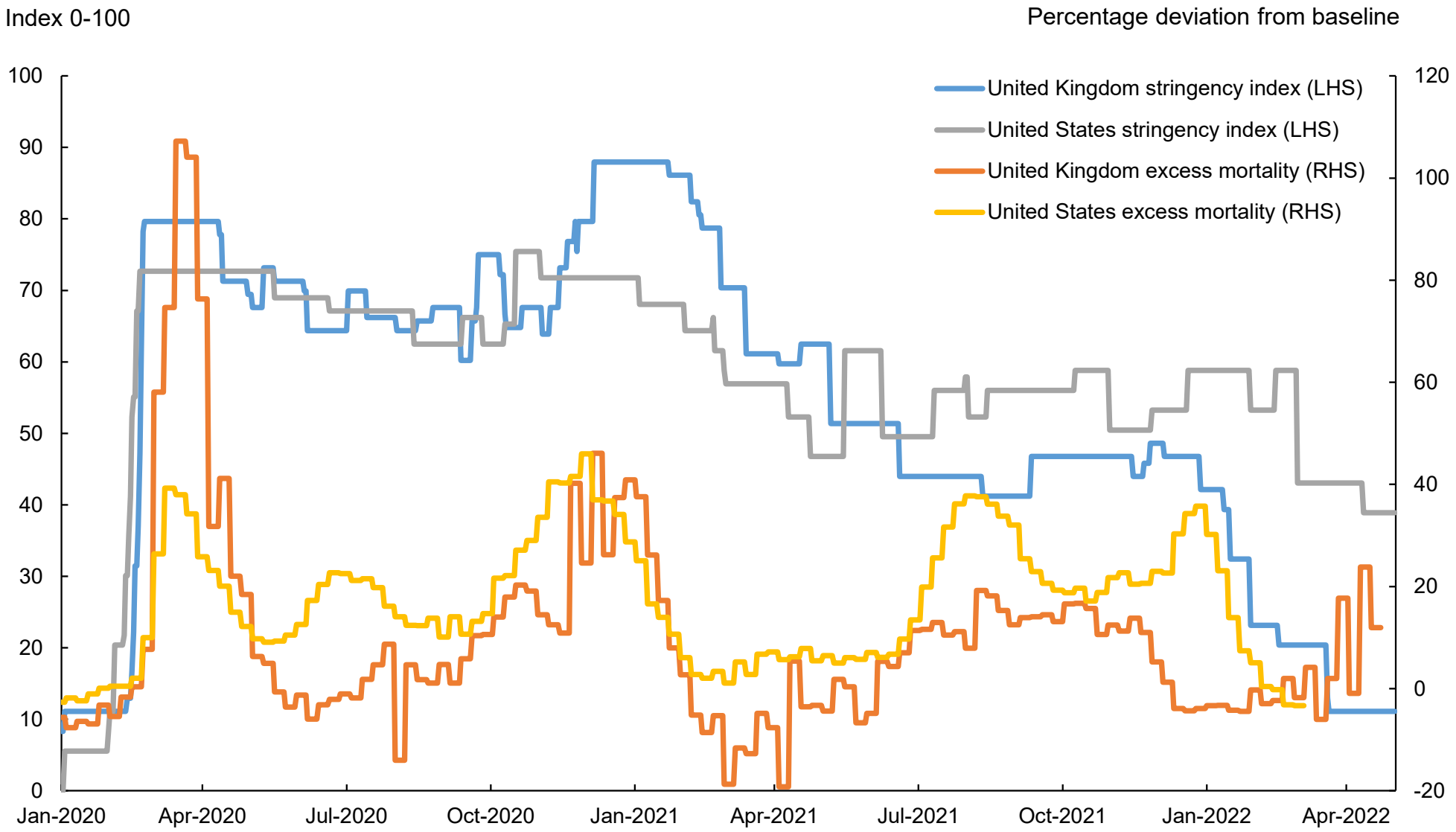


Panel B: TFP



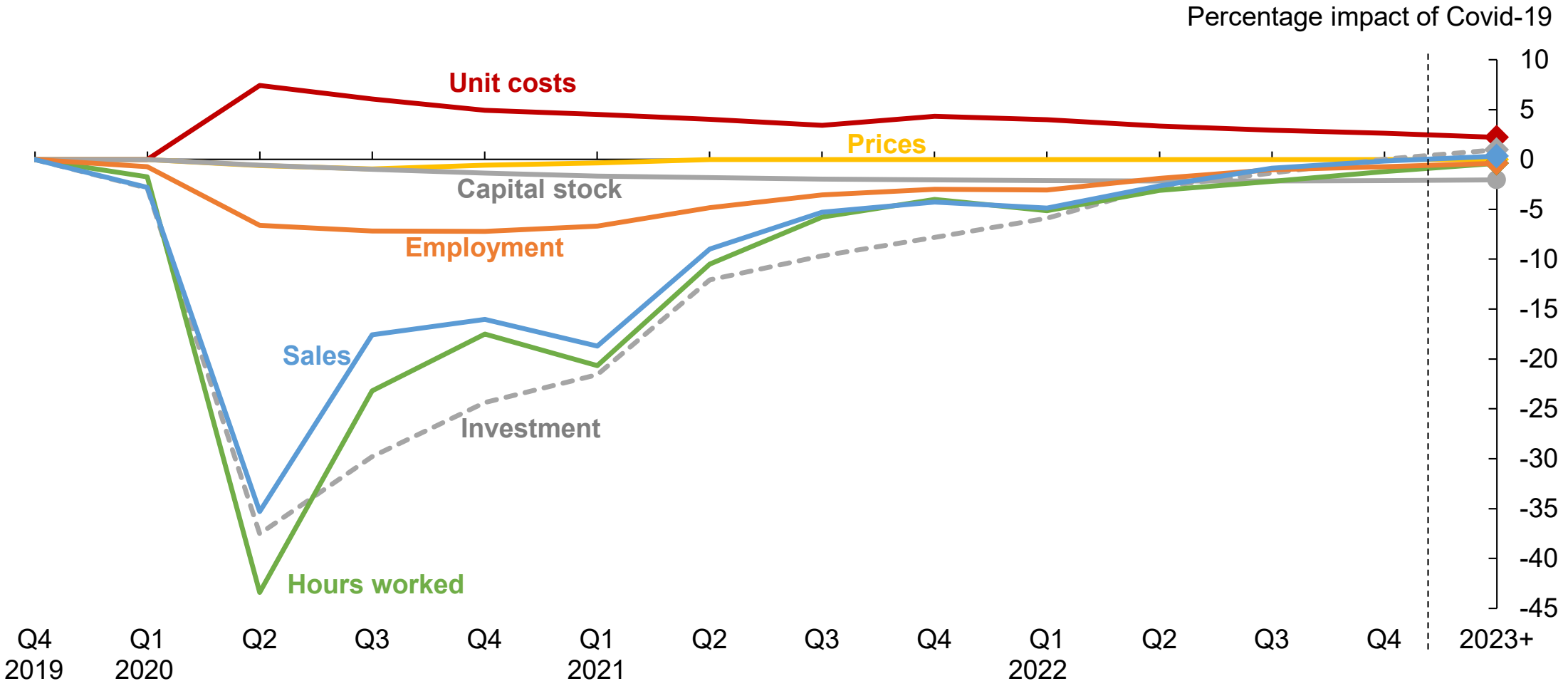
Notes: UK aggregate data are from the Office for National Statistics and are for the market sector. They are adjusted for an experimental series for hours worked (see Figure A1 in the Appendix for more details on this). US labor productivity data are from the Bureau of Labor Statistics and are for the non-farm business sector. US TFP data are from John Fernald and are for the business sector. TFP data are not adjusted for capacity utilisation. The impact of Covid-19 for UK and US aggregate data is estimated as the deviation of productivity from a 1% trend growth rate from 2020 Q1 onwards. The impact of Covid-19 in the DMP data is estimated directly from survey responses. See the notes to Figure 4 for more details on how this is calculated.

Figure 2: Measures of lockdown stringency and mortality



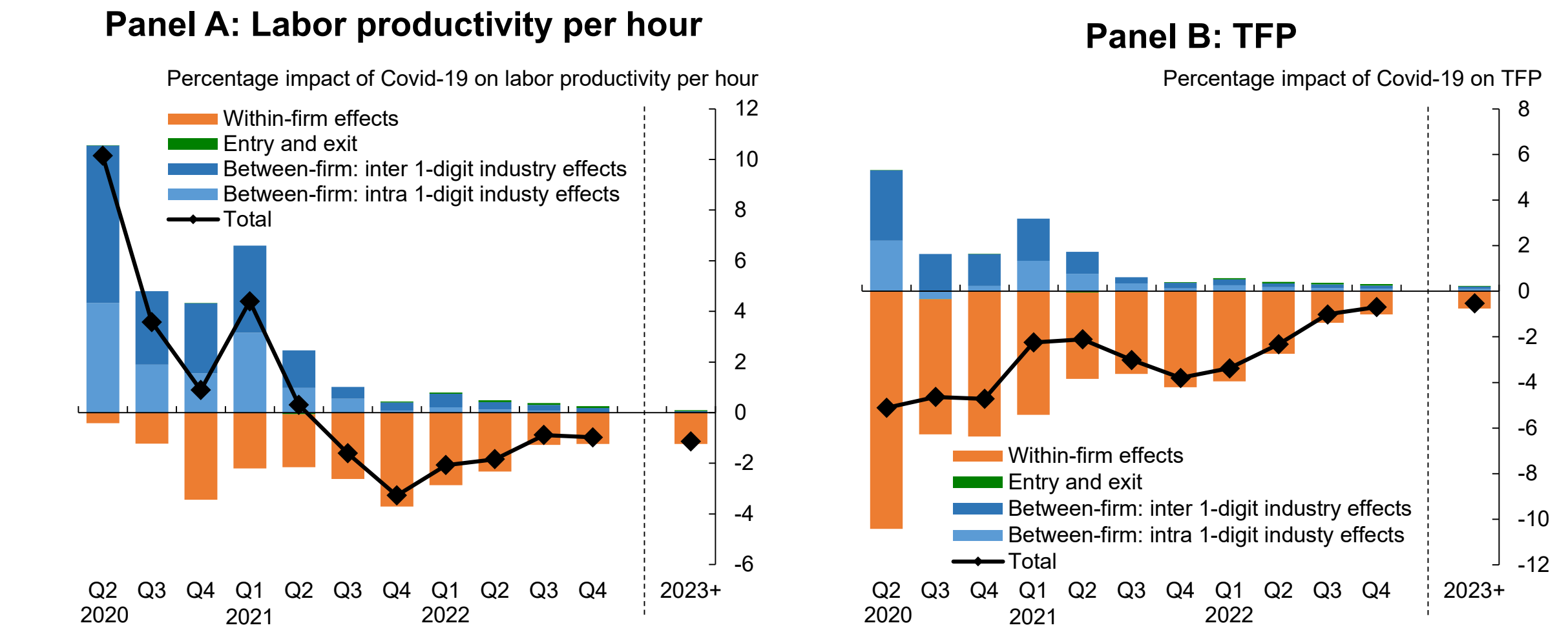
Notes: Lockdown stringency data are from the Oxford Covid-19 Government Response Tracker. Excess mortality data are from the Human Mortality Database and World Mortality Dataset.

Figure 3: Impact of Covid-19 on businesses



Notes: The results are based on the questions: 'Relative to what would otherwise have happened, what is your best estimate for the impact of the spread of Covid-19 on the sales/employment/average hours worked per active employee/capital expenditure of your business in each of the following periods?'; 'Relative to what would otherwise have happened, what is your best estimate for the impact of measures to contain coronavirus (social distancing, hand washing, masks and other measures) on the average unit costs of your business in each of the following periods?'; and 'Approximately what percentage of your employees fall into the following categories in each of the following periods? (i) Still employed but not required to work any hours (eg 'on furlough'), (ii) Unable to work (eg due to sickness, self-isolation, childcare etc.), (iii) Continuing to work on business premises, (iv) Continuing to work from home'. Data are the most recent observation per firm for each period collected between July 2020 and April 2022. Data on the impact of Covid-19 in 2020 Q1 have not been collected in the DMP. Data shown for 2020 Q1 are absolute changes in aggregate ONS data for private sector output, business investment, private sector employment and hours worked between 2019 Q4 and 2020 Q1. The impact on unit costs is assumed to be zero in 2020 Q1. Effects on the capital stock are estimated using by cumulating the investment impacts. The effects on the price level are estimated using data from DMP questions on actual price inflation and expected year-ahead price inflation: the impact of Covid-19 is estimated as the difference relative to 2019 at the 1-digit industry level.

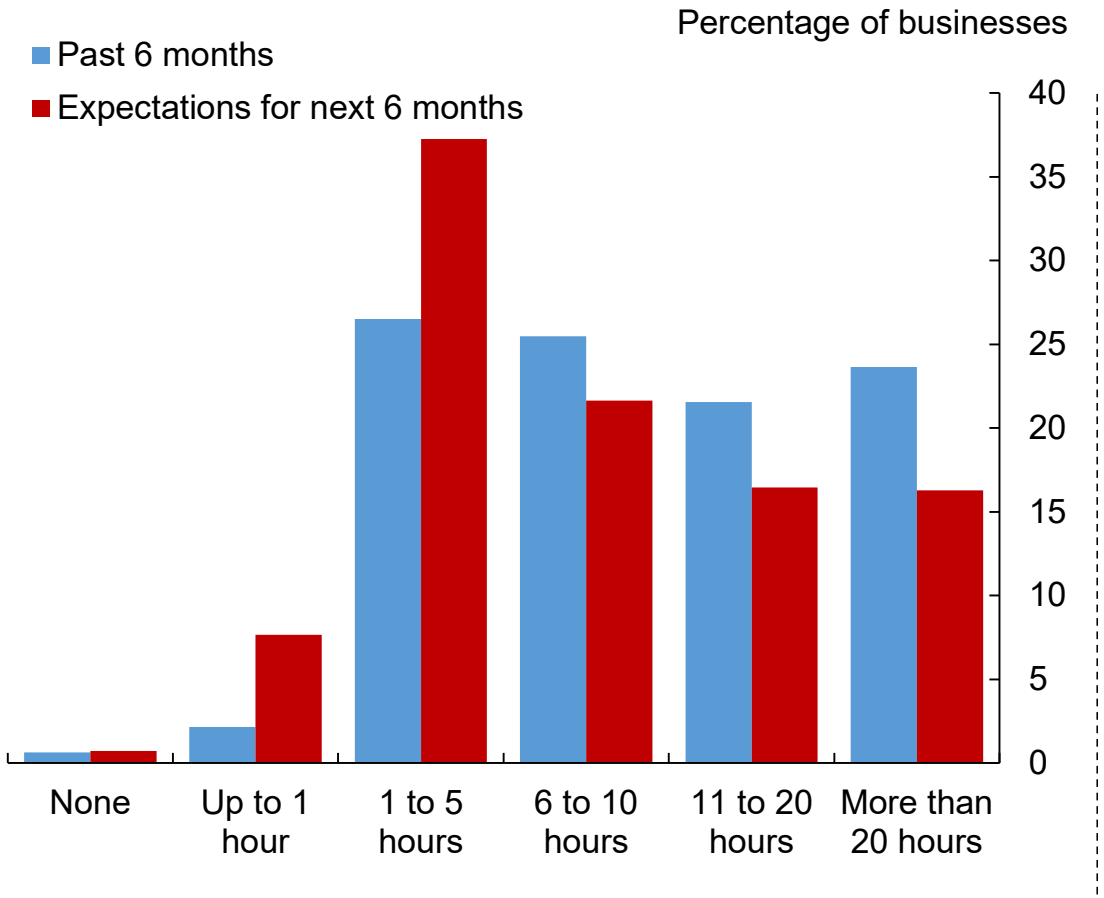
Figure 4: Within and between-firm contributions to Covid-19 productivity impact



Notes: Impacts on productivity for surviving firms are estimated as $\Delta\Pi_t = \sum_{i\in Surv} \bar{\varphi}_i \Delta\pi_{i,t} + \sum_{i\in Surv} \Delta\varphi_{i,t}(\overline{\pi_t} - \overline{\Pi})$ where $\pi_{i,t}$ is productivity in firm i at time t, Π_t is productivity at time t, $\varphi_{i,t}$ is the labor input share of firm i at time t and a bar over a variable indicates the average of the variables across times t-1 and t. Changes between t and t-1 are changes due to Covid-19 only. The first term represents the within-firm effects. The second term represents between-firm effects. The impact of Covid-19 on labor productivity for each firm is calculated as $\frac{dLP}{LP} = \frac{dY}{Y} - \frac{dP}{P} - \frac{dL}{L} - \frac{dM}{M}$ $where \frac{dM}{M} = \frac{M}{Y-M}\frac{dM^U}{M^U}$. The impact of Covid-19 on TFP for each firm is calculated as $\frac{dTFP}{TFP} = \frac{dY}{Y} - \frac{dP}{P} - \beta\frac{dL}{L} - \alpha\frac{dK}{K} - \frac{dM}{M}$. LP is labor productivity, TFP is total factor productivity, Y is nominal sales, P is the price level, L is labor input, M are non-labor intermediate costs, M^U are intermediate unit costs and K is capital input. Between-firm impacts are decomposed into intra and inter industry effects using the formula: $\sum_{i\in Surv} \Delta\varphi_{i,t}(\overline{\pi_t} - \overline{\Pi}) = \sum_{J\in Sectors} \sum_{i\in Surv} D_i^J \bar{\rho}_J \Delta\bar{\theta}_{i,t}(\overline{\pi_i} - \overline{\pi_J}) + \sum_{J\in Sectors} \Delta\rho_{J,t}(\overline{\pi_i} - \overline{\Pi})$ where, in addition to the above notation, $\rho_{J,t}$ is sector J's share of labor input at time t, $\theta_{i,t}$ is the share of firm i's labor input among surviving firms in its sector at time t, $\pi_{J,t}$ is productivity of firms in sector J at time t, D_i^J is a dummy variable that takes the value of 1 when firm i is located in sector J. The first term on the right hand side represents reallocation effects within industries – intra industry effects. The second term on the right hand side represents reallocation effects between industries – inter industry effects.

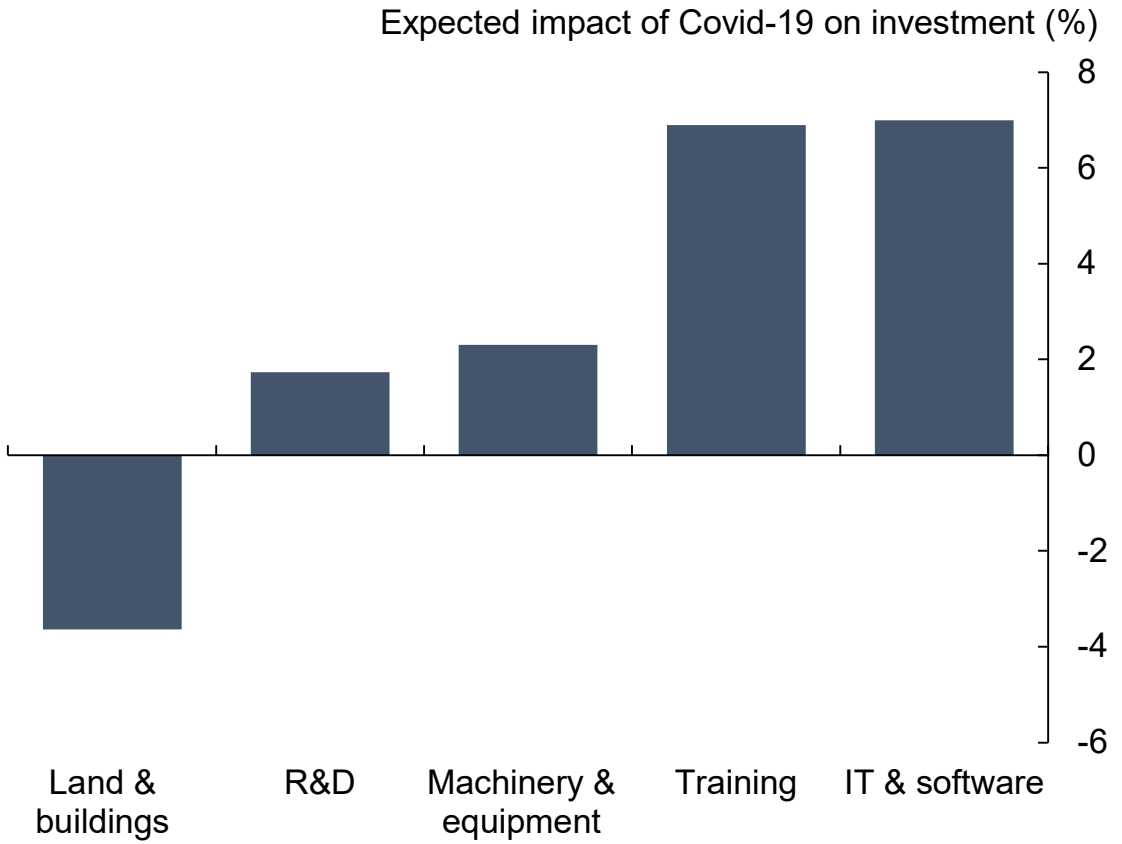
Figure 5: Covid-related influences on longer-term productivity

Panel A: Average hours per week spent by CEOs managing effects of Covid-19



Notes: Based on the question 'Approximately how many hours a week has the CEO of your business spent managing the effects of Covid-19 on your business over the past six months? And how many hours a week do you expect them to spend on this over the next six months?'. Data were collected between November 2020 and January 2021.

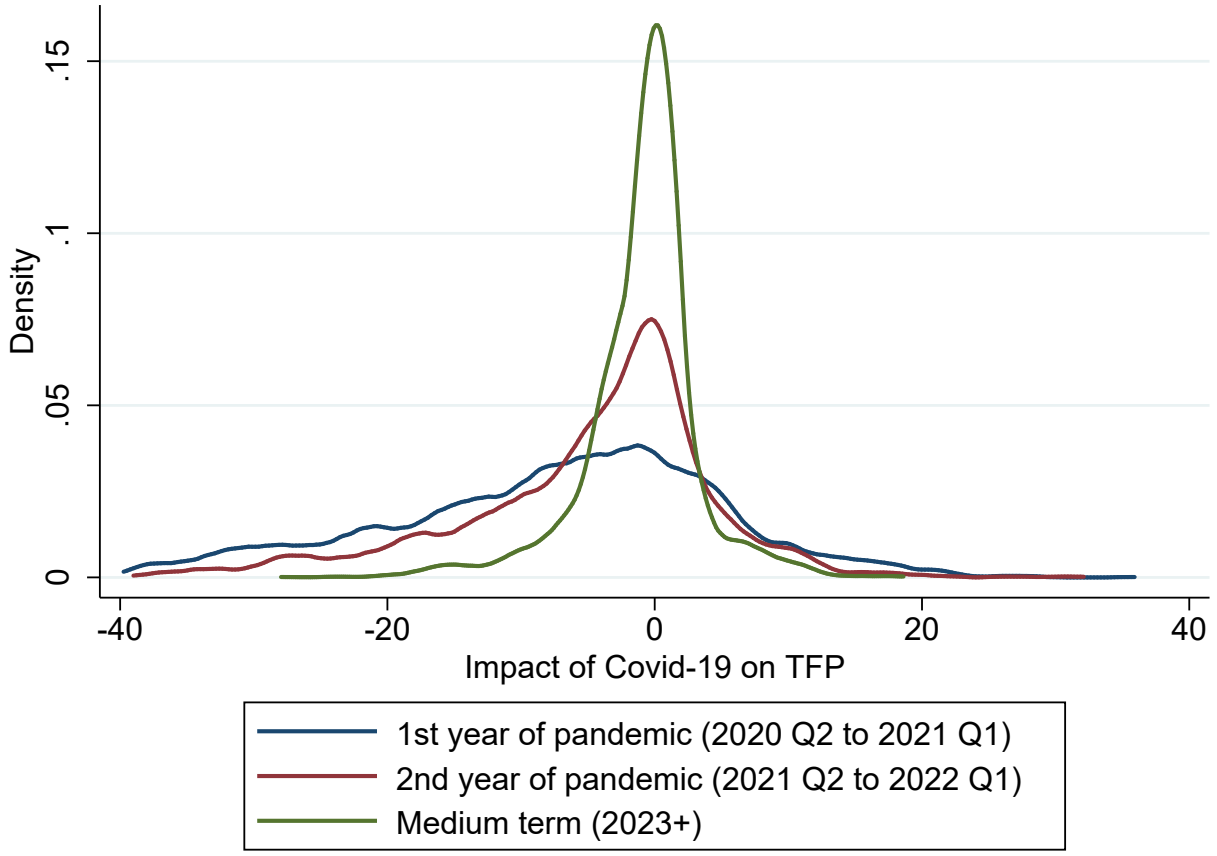
Panel B: Impact of Covid-19 on different types of investment



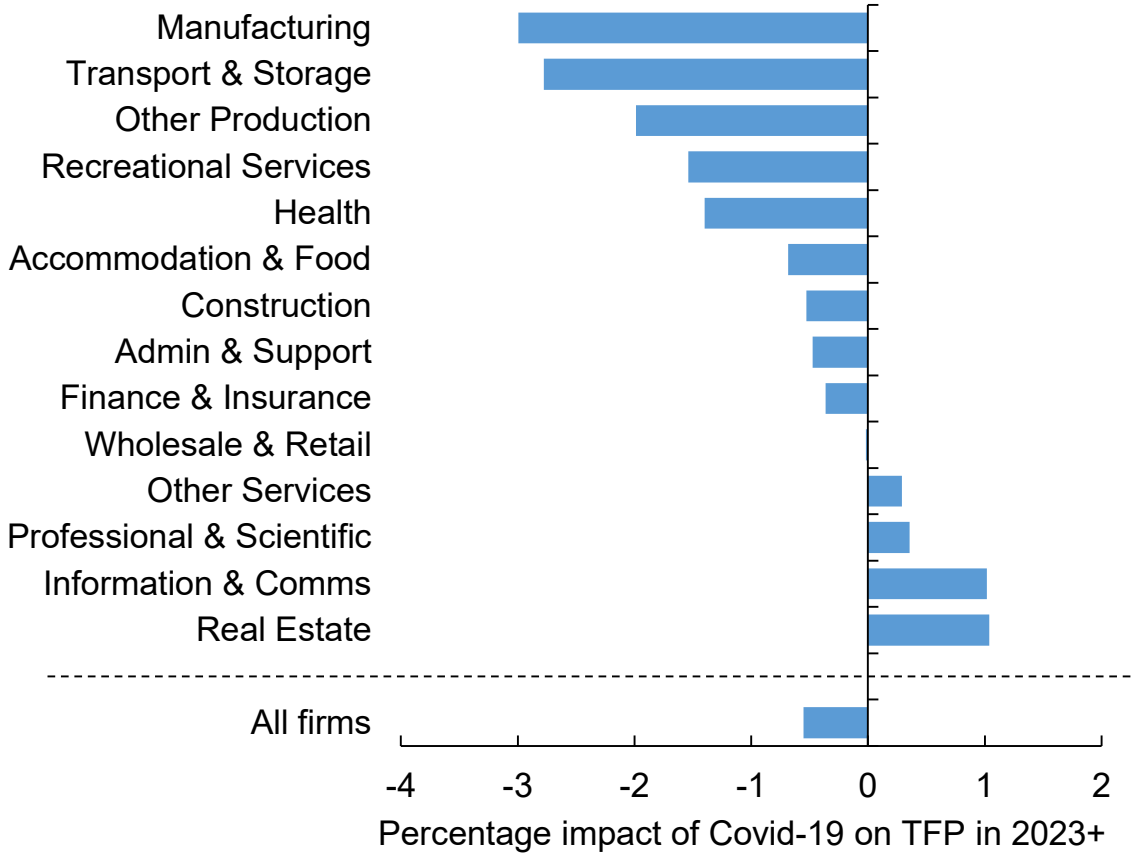
Notes: Based on the question 'In 2022+, how do you expect the Covid-19 pandemic to affect the following types of expenditure made by your business, relative to what have otherwise happened?'.
Data were collected between July and September 2021.

Figure 6: Heterogeneity of impacts on TFP

Panel A: Distribution of within-firm impacts on TFP across firms

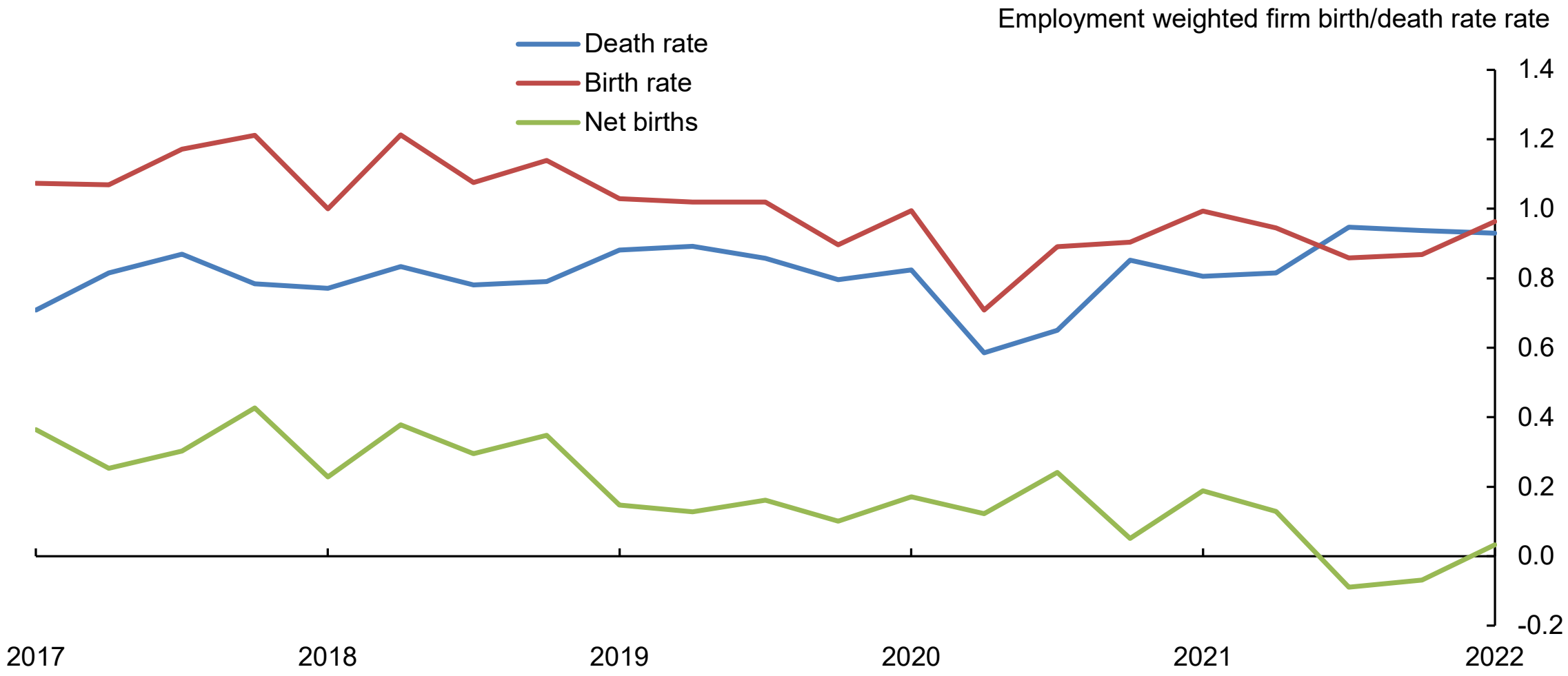


Panel B: Medium term impact of Covid-19 on TFP by industry



Notes: See notes to Figure 4 for details on how impact of Covid-19 on TFP is calculated.

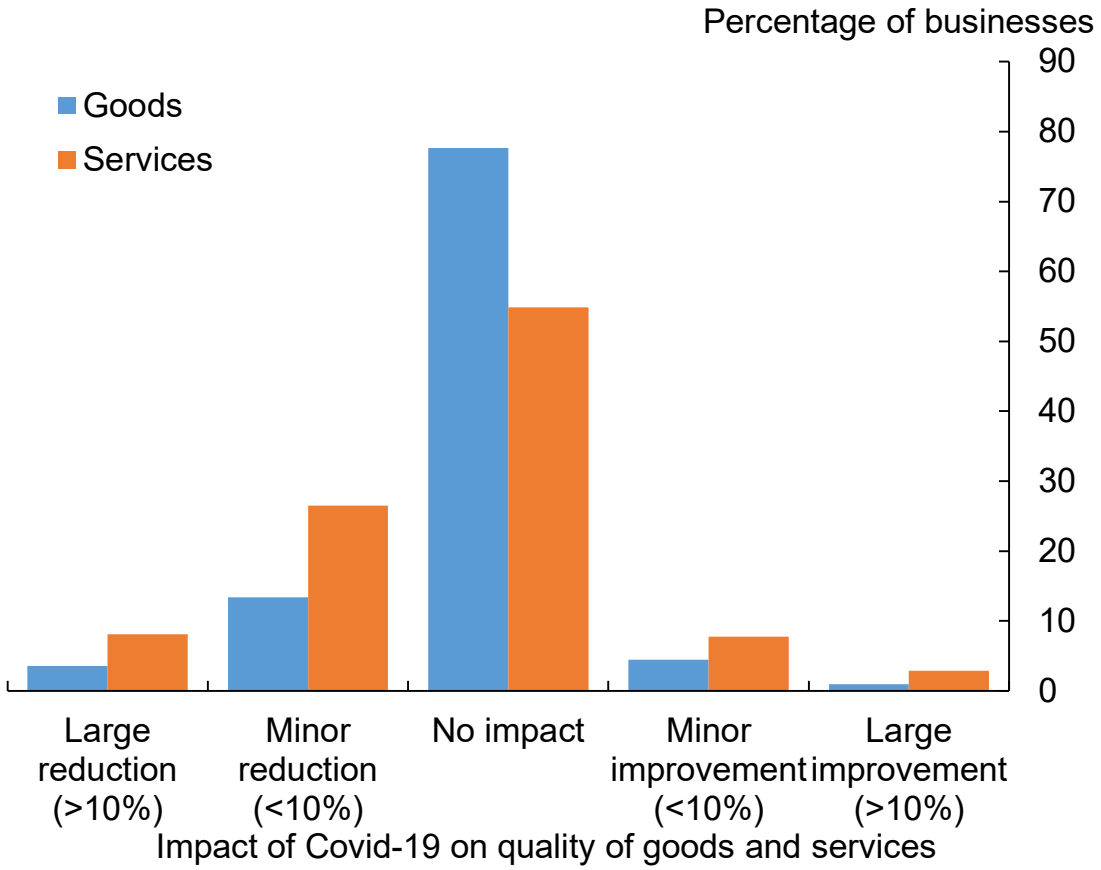
Figure 7: Firm entry and exit



Notes: Firm birth and death rate data are from the Office for National Statistics. These data have been seasonally adjusted by the authors.

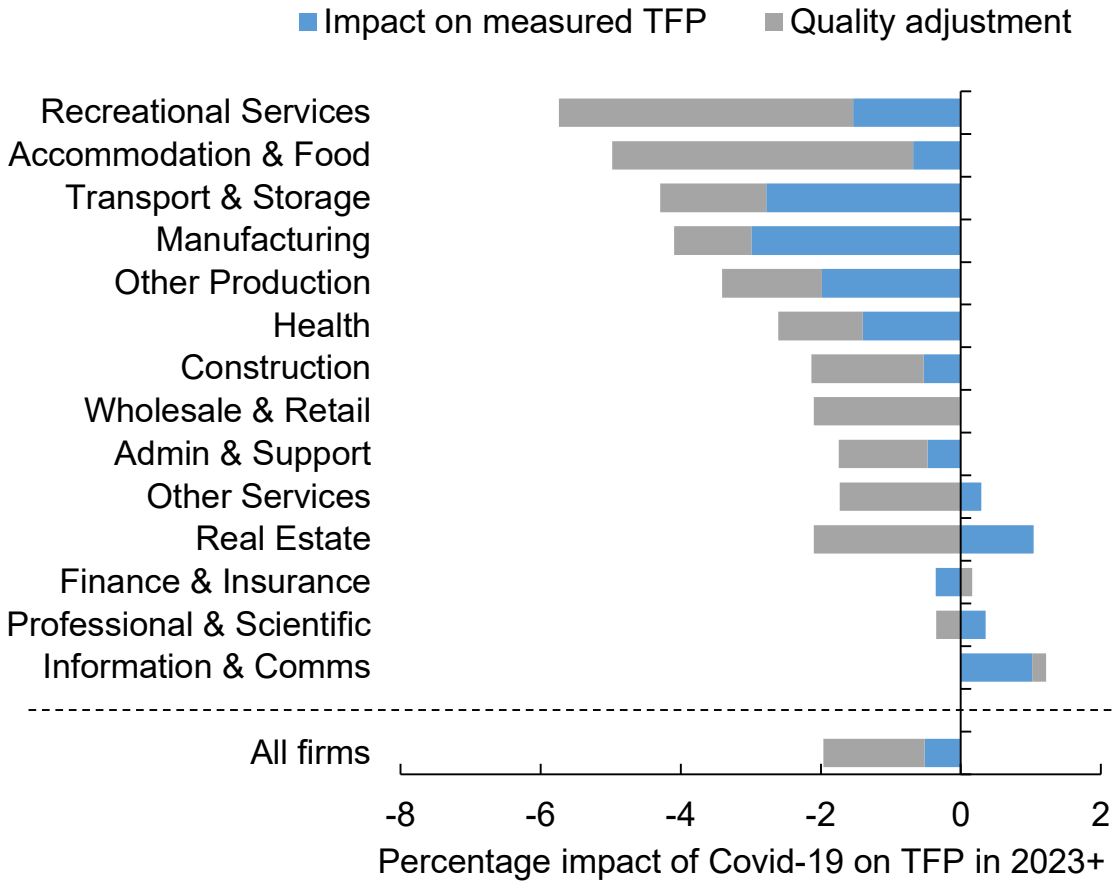
Figure 8: Potential impact of Covid-related quality changes on TFP

Panel A: Impact of Covid-19 on quality of goods and services



Notes: Based on the question: 'Has the Covid pandemic affected the average quality of the goods and/or services that your business produces in a way that is not reflected in the price?'. Data were collected between November 2021 and January 2022.

Panel B: Medium term impact of Covid-19 on TFP by industry



Notes: Quality adjustments to within-firm TFP are calculated using the data shown in panel A. The adjustment is applied to both inputs and output. The impact of Covid-19 on TFP is otherwise calculated as shown in the notes to Figure 4.

Table 1: Covid-19 impacts and Covid exposure measures

Dependent variable:	Impact of Covid-19 on TFP			Impact of Covid-19 on hours worked		
Time period	2020Q2 to 2021Q1	2021Q2 to 2022Q1	2023+	2020Q2 to 2021Q1	2021Q2 to 2022Q1	2023+
	(1)	(2)	(3)	(4)	(5)	(6)
Percentage of jobs that can be done from home$_J$	0.056***	0.035***	0.028***	0.099***	0.019***	0.009***
	(0.011)	(0.007)	(0.003)	(0.015)	(0.006)	(0.002)
Percentage of sales in 2019 that involved face-to-face contact$_i$	-0.030***	-0.019***	0.003	-0.081***	-0.016***	0.002
	(0.009)	(0.005)	(0.002)	(0.013)	(0.005)	(0.002)
Pre-Covid average wage per employee$_i$	0.337	1.383***	0.282**	11.649***	2.243***	0.021
	(0.550)	(0.361)	(0.137)	(0.778)	(0.297)	(0.106)
Observations	2,877	2,877	2,877	2,877	2,877	2,877
R-squared	0.019	0.023	0.033	0.138	0.039	0.007

Notes: This is a cross-sectional firm-level regression. Data on the percentage of jobs that can be done from home for firms in 1 digit industry *J* are taken from Dingel and Neiman (2020). Data on the percentage of sales in 2019 that involved face-to-face contact for each firm, *i*, are taken from a question in the DMP: 'What percentage of your sales in 2019 involved face-to-face contact with customers?'. Pre-Covid average wage per employee for each firm, *i*, are calculated using accounting data from Bureau Van Dijk FAME database (2017-2019 average). Regressions also include dummy variables for having missing exposure data. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Impact of Covid-19 on hours worked and pre-Covid productivity

Dependent variable: Impact of Covid-19 on total hours worked	2020Q2 to 2021Q1		2021Q2 to 2022Q1		2020Q2 to 2021Q1		2021Q2 to 2022Q1	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log labor productivity per job (2017-2019 average)	11.154***	6.141***	2.378***	0.928***				
	(0.592)	(0.597)	(0.231)	(0.253)				
Log TFP (2017-2019 average)					5.773***	2.066***	1.836***	0.790***
					(0.675)	(0.619)	(0.254)	(0.258)
Constant	-67.810***	-49.110***	-15.228***	-9.816***	-27.939***	-26.822***	-6.908***	-6.593***
	(2.245)	(2.254)	(0.877)	(0.955)	(0.464)	(0.400)	(0.175)	(0.167)
1 digit industry dummies	No	Yes	No	Yes	No	Yes	No	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,877	2,877	2,877	2,877	2,877	2,877	2,877	2,877
R-squared	0.110	0.327	0.035	0.142	0.025	0.304	0.018	0.140

Memo: Explanatory variable means: Log labor productivity per job = 3.73 , Log TFP = 0.30
Explanatory variable standard deviations: Log labor productivity per job = 0.67, Log TFP = 0.62

Notes: All regressions are weighted using employment data. Labor productivity is defined as real value-added (operating profits plus total labor costs divided by the aggregate GDP deflator) per employee using accounting data from Bureau Van Dijk FAME database. TFP is calculated as the residual from a production function $\ln(Y_{it}) = 0.63\ln(L_{it})+0.37\ln(K_{it})$ where Y_{it} is real value-added of firm i in year t, L is labor input (total real labor costs) and K is capital (total real fixed assets), nominal values from accounting data are deflated using the GDP deflator. *** p<0.01, ** p<0.05, * p<0.1.

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